“BIM IMPLEMENTATION STRATEGY FRAMEWORK FOR SMALL ARCHITECTURAL PRACTICES”

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Abbreviation

ACA	Association of Consultant Architects
ADDIE	Analysis, Design, Development, Implementation, and Evaluation
AEC	Architecture Engineering and Construction
AECOO	Architecture Engineering Construction Owner and Operation
AIA	American Institute of Architects
APCC	Australasian Procurement and Construction Council Inc.
ARMA	Association of Record Administrators
BCIS	Building Cost Information Service
BEIIC	Built Environment and Innovation Council
BEP	BIM Execution Plan
BI	Business Intelligence
BIM	Building Information Modeling
BIS	Department for Business Innovation and Skills
BRE	Building Research Establishment
BREEAM	BRE Environmental Assessment Method
BPD	Building Performance Database
BPR	Business Process Reengineering
BRIC	Brazil, Russia, India and China,
BRM	Benefit Realization Management
C2C	Cradle to Cradle
CABE	Commission for Architecture and the Built Environment
CAD	Computer Aided Design or Computer Aided Drafting
CAFM	Computer Aided Facilities Management
CAPEX	Capital expenditures
CBA	Choosing by Advantages
CBR	Case Based Reasoning
CDM	Construction Design and Management Regulations
CE	Concurrent Engineering
CIFE	Centre for Integrated Facility Engineering
CIS/2	CIMSteel Integration Standards
CITE	Construction Industry Trading Electronically
CMAA	Construction Management Association of America
CMMI	Capability Maturity Model Integration
CNC	Computer numerical control
CO2	Carbon Dioxide
COBIT	Control Objects for Information and related Technology
COBie	Construction Operations Building Information Exchange
CONCOPS	Concept of Operations
CORENET	Construction and Real Estate Network
COTS	Commercial of the shelf software
CPD	Continued Professional Development
CPIC	Construction Project Information Committee
CURT	Construction Users Roundtable
CRC	Cooperative Research Centre
CSCMM	Construction Supply Chain Maturity Model
DECC	Department of Energy and Climate Change

DDA	Disability Discrimination Act
DDD	Dimension Driven Design
DDS	Decision Support System
DfM	Design for Manufacture
DRUM	Distributed Transactional Building Information Management
EIS	Executive Information System
ESF	European Social Fund
ER	Exchange Requirement
FAST	Functional Analysis System Technique
FMie	Facilities Management Information Exchange
GUID	Globally Unique Identifier
GPS	Global Positioning System
GSA	General Services Administration
GSL	Government Soft Landings
HOK	Hellmuth, Obata + Kassabaum
IBDM	Integrated BIM and Document Management
ICIM	Interoperable Carbon Information Modelling
I-CMM	Interactive Capability Maturity Model
ICT	Information Communication and Technology
IDM	Information delivery manual
IES	Integrated Environmental Solutions
ISO	International Standards Organization
IAI	Industry Alliance for Interoperability
ICT	Information Communication and Technology
IDM	Informational delivery manual
IFC	Industrial Foundation Class
IFD	International framework for dictionaries
IIBA	International Institute of Business Analysis
ILM	Institute of Leadership and Management
InfoVis	Information Visualization
IPD	Integrated Project Delivery
ISD	Information system development
IT	Information Technology
JMA	John McCall Architects
JOC	Job Order Contracting
KIBS	Knowledge Intensive Business Services
KKD	Knowledge discovery and data mining
KPI	Key Performance Indicator
KTP	Knowledge Transfer Partnership
LESAT	Lean Enterprise Self-Assessment Tool
LOD	Level of Detail
MCS	Modelling Collaborative Systems
MPS	Model Progression Specification
MoSCoW	Must, Should, Could, Won’t
MVD	Model View Definition
NASA	National Aeronautics and Space Administration
NBS	National Building Specification
NCE	New Civil Engineer
NIEP	National improvement and efficiency partnership
NIESR	National Institute of economic and social research

NIST	National Institute of Standards and Technology
NPT	Non Productive Time
OAS	Office Automation System
OD	Organizational Development
OGC	Office of Government Commerce
ONS	Office of National statistics
OPEX	Operational expenditure
NBIMS	National Building Information Modeling Standard (USA)
NBS	National Building Specification
NIST	National Institute of Standards and Technology
P3M3	Portfolio, Programme and Project Management Maturity Model
PC	Personal Computer
P-CMM®	People Capability Maturity Model
PESTLE	Political, Economic, Legislative, Social, Technological, Environmental
PLIM	Project Lifecycle Information Management
PLM	Project Lifecycle Management
$(PM)^2$	Project Management Process Maturity Model
PPC2000	Project Partnering Contract 2000
PPR	Post Project Review
PRINCE 2	Projects in Controlled Environments
PSets	Property Sets
RAIC	Royal Architectural Institute Canada
R & D	Research and Development
RFI	Request for information
RFID	Radio Frequency Identification
RIBA	Royal Institute of British Architects
RICS	Royal Institution of Chartered Surveyors
ROHSEI	Return on Health, Safety and Environmental Investments
ROI	Return on Investment
RUCAPS	Really Universal computer aided production system
RUP	The Rational Unified Process (RUP) is an iterative software development process framework created by the Rational Software Corporation
SAP	Standard Assessment Procedure
SBS	Sick building syndrome
SIC	Standard Industrial Classification
SME	Small to Medium Sized Enterprise
SMM	Standard Method of Measurement
SPIE	Specifier Property Information Exchange
SPICE	Standardized Process Improvement for Construction Enterprises
STEP	Standard for the Exchange of Product model data
STL	Standard Tessellation Language
SUDS	Sustainable urban drainage system
SWOT	Strengths, Weaknesses, Opportunities and Threats
TRADA	Timber Research and Development Association
TQM	Total Quality Management
TVD	Target Value Design
UI	User Interface
UK	United Kingdom
UML	Unified Modeling Language

USACE	United States Corps of Engineers
USCG	United States Coastguard
USGBC	U.S. Green Building Council
VA	Value Analysis
VBA	Visual Basic for Applications
VBE	Virtual Building Environments
VDC	Virtual Design and Construction
VR	Virtual Reality
VPN	Virtual Private Network
WIMP	Window, icon, mouse, pointer
XML	Extensible Markup Language

Acknowledgement

This thesis reflects the generosity of many people who have offered technical advice, professional expertise and enthusiasm over the period this thesis has been developed.

Firstly I would like to express my deepest appreciation to Doctor Yusuf Arayici, my supervisor and advisor. He has generously provided his invaluable insights, inspiring ideas, constant guidance, and warm encouragement. At various points within the development of this thesis Dr. Arayici provided critical guidance and advice.

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The basis of this thesis was developed through action research at John McCall Architects. Particular thanks must be given to Colin Usher (director) and Karen O'Reilly (architect and KTP supervisor) at John McCall Architects and the many staff who contributed. With their advice and direction was possible to gain an understanding of the problems and issues faced by small architectural organizations.

I would also like to thank those at the University of Salford and the numerous conferences I have attended who have provided wisdom and insight into the area of my research.

I would also like to thank Gary Hope managing director of Infra Projects for his insight and vision of how to effectively integrate BIM into a project focused environment.

Thanks is also be given to the KTP staff and advisor and the Technology Strategy board which funded the Knowledge Transfer Partnership. The KTP provided the forum for the main bulk of research at John McCall Architects.

Acknowledgement should also be given to those members of Building Smart UK and software vendors that provided advice and technical guidance on issues investigated in this research.

Declaration

I certify that this thesis is my own original work. It does not contain any material previously published or written by another person without due reference in the text.

All the research has been conducted by the PhD candidate and no portion of the research referred to in this thesis has been submitted in support of an application for another degree or qualification at this or any other university or other institute of learning.

The various parts of associated research work have been published in international journals, conference proceedings and technical reports, and discussed amongst the wider research community through doctoral workshops and industrial talks where appropriate. The PhD candidate has taken the lead in the dissemination and integration of knowledge to attain the impact of this research.

Abstract

BIM (Building Information Modeling) is a new radically different emerging approach to design, construction and facilities management. BIM promises to better facilitate the building development, construction and building operation. In this thesis the domain of small architectural practices is considered and how BIM can be implemented to address the problems both of operational and product efficiency and effectiveness.

Research has indicated that guidance on how small architectural practices should implement BIM is lacking (Jung et al 2010). This lack of guidance is one of the reasons why small architectural practices are disinclined to adopt BIM. There is a growing need for more knowledge on how BIM technology and processes can be and should be adopted and what happens when BIM technologies and processes are implemented and used in the practice of architecture.

The aim of this thesis is to develop a BIM implementation strategy framework for small architectural practices.

To identify of the problems and issues of BIM implementation in a small architectural practice, a two years of case study using action research was undertaken. This involved instigating, participating and observing the implementation of BIM within a small architectural practice. Both the internal and external benefits to the architectural practice were considered. The findings of this BIM implementation research were then recorded and reviewed providing a structured approach to BIM implementation. From this process of review and reflection a revised improved framework and suggested methods for BIM adoption was developed and documented. At each stage of the BIM implementation recommendations are made.

The research was undertaken as part of a Knowledge Transfer Partnership between the University of Salford, John McCall Architects (a small architectural practice) and the researcher and author of this thesis. Though being actively involved in the BIM implementation it was possible to understand the issues and document the actions that were taken as part of the BIM adoption. The major limitation of this research is the focus on a single company as the source of evidence and research.

This enhanced BIM implementation framework and the suggested working methods represents the primary contribution to knowledge made by this thesis. This framework should be of value to other small architectural practices embarking on BIM implementation.

Chapter 1

Chapter 1: This chapter makes an introduction to the thesis explains the backgrounds, rationale for research, the research question, the aims and objectives of the research. It also gives a brief of the research methodology, the scope and the limitations of the research.

CHAPTER 1 Introduction

1.1 1ntroduction

An NBS survey (2013) indicates that the uptake of building information modelling (BIM) in the UK is on the increase. Using BIM represents a significant change to the practice of architecture (Birx, 2006). This change has been described as the perfect storm (FMI/CMAA 2007). That is the culmination of many influences and factors that simultaneously come into play resulting in changes of unusual magnitude (see figure 1.01).

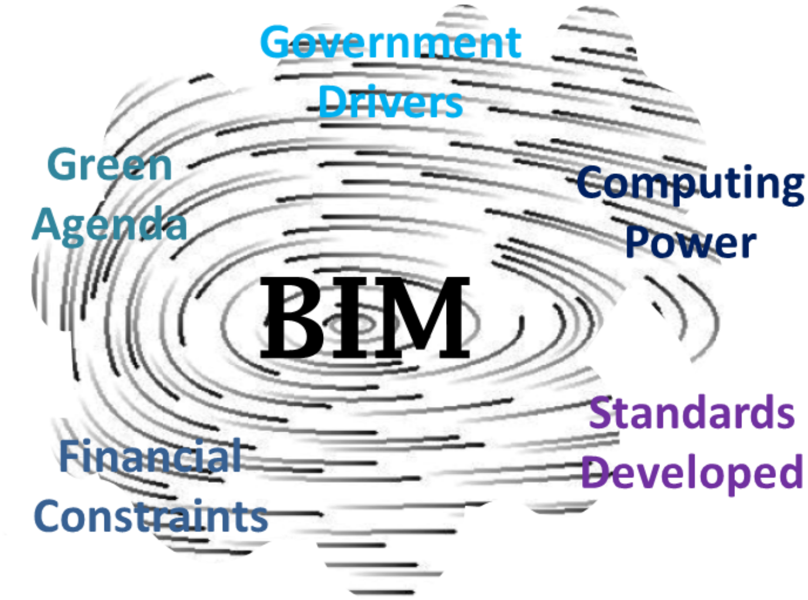


Figure 1.01: BIM at the heart of the storm

The future vision for the AECOO (Architecture, Engineering, Contracting, Owning and Occupying) industries is described by Broshaw (2006).

‘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 a 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 responsive. This is the future of integrated Practice’.

Using data rich BIM models allows decisions to be made on a more knowledgeable and scientific basis. Behaviours and properties can be programmed into BIM models where attributes are quantified and measurable (Harty 2012).

According to the Built Environmental Industry and Innovation Council (BEIIC) in Australia (2011),

“BIM has macroeconomic significance, that its accelerated widespread adoption would make a significant difference to national economic performance and that there is a compelling economic case for encouraging greater use of BIM in Australia."

The initial estimated savings to UK construction and its clients is £2bn per annum through the widespread adoption of BIM and is therefore a significant tool for Government to reach its targets. The UK construction industry is being asked to achieve 33 % cost reduction in construction and lifecycle costs and deliver the project 50% faster producing 50% less greenhouse gases before 2025 (HM Government 2013).

To gain and maximise the benefits from BIM, the changes they need to be understood, managed and coordinated in an appropriate way to ensure that it impacts positively, on the business and the industry. Hammer and Champy (2001) identified that implementation of new or redesigned processes fail in 50% to 70% of Business Process Reengineering (BPR) initiatives. Only 50% of architects adopting BIM say it has had a positive impact on their business (McGraw Hill Construction 2008). Providing an understanding and a framework for managing BIM adoption to achieve the benefits of BIM is the focus of this research.

Two forces are driving the adoption of BIM. External push factors such as the UK Government and industry drivers responding to economic and environmental concerns are external influences encouraging and demanding BIM adoption. The internal efficiencies the pull factors that can be achieved by adopting BIM are the secondary factors encouraging BIM adoption (see figure 1.02).

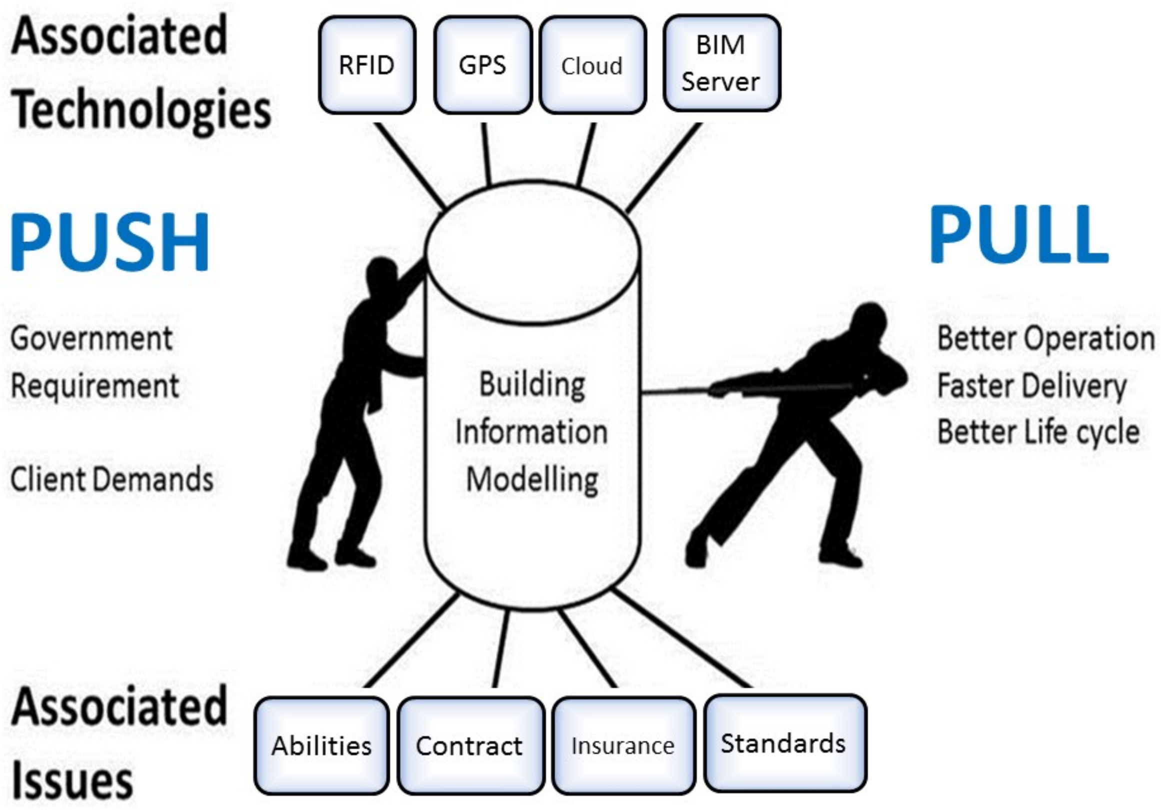


Figure 1.02: Internal and external factors effecting the adoption of BIM

The external factors are:

- Government requirements (Cabinet Office 2011)
- Client Demands
- Better Life Cycle management (Sabol 2008)

The internal factors are:

- Better Operation
- Faster Delivery (Finau 2011)

The relevance of these specific factors depends on the organization adopting BIM and the projects or building type involved. Associated technologies such as RFID, GPS, cloud computing and BIM servers will also enhance the benefits of BIM.

The green building sector will also drive the adoption of BIM software, according to a new SmartMarket Report from McGraw-Hill Construction (see figure 1.03). The report is called “Green BIM: How Building Information Modelling is contributing to Green Design and Construction”.

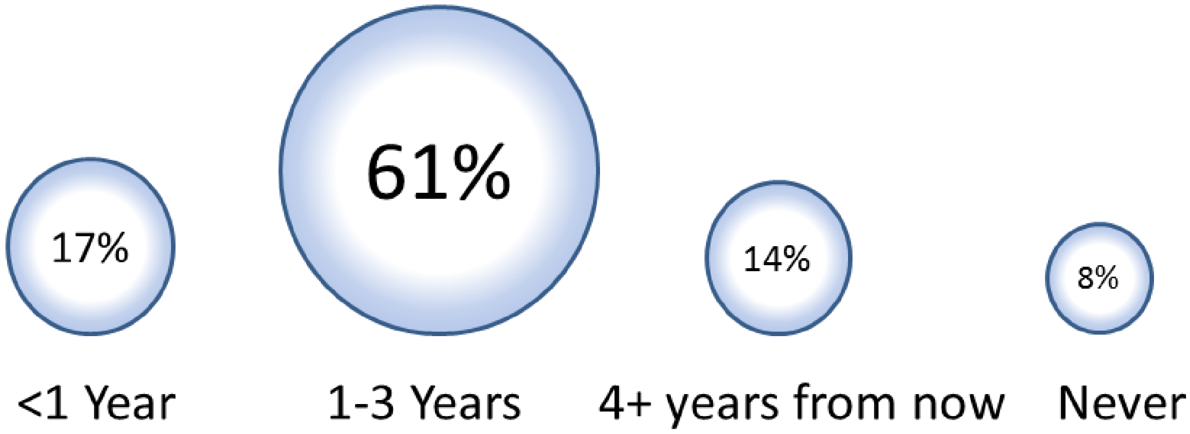


Figure 1.03: Timing expected to Green BIM Market Penetration (according to non-green BIM companies) (McGraw Hill Construction 2010)

BIM tools demand higher performance hardware and operating system platforms to work effectively. The hardware and software platforms now available have also played there role in making BIM an economically viable method of process improvement. All of the growth in the last 30 years will be completely dwarfed by the rapidly escalating pace of growth in computing power from 2010 to 2020 (see figure 1.04).

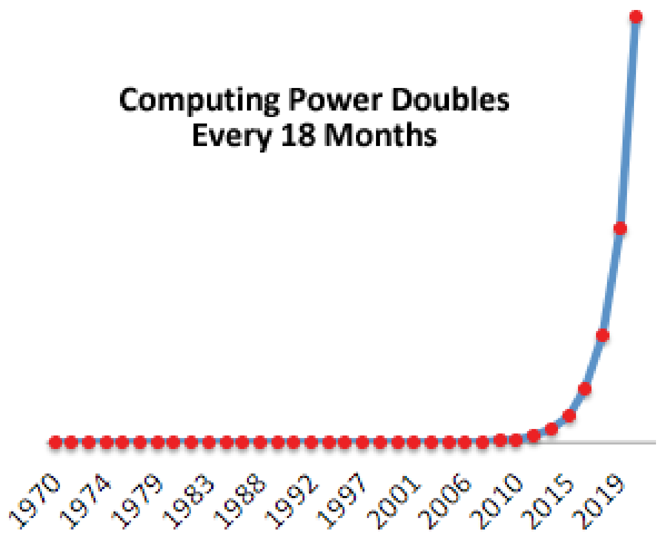


Figure 1.04: Chart showing how computer power has and is predicted to double every 18 months (Carrier 2012)

This change in computing power must also be seen related to the changes it makes possible (see figure 1.05). These changes will impact construction and the whole supply chain of the building industries.

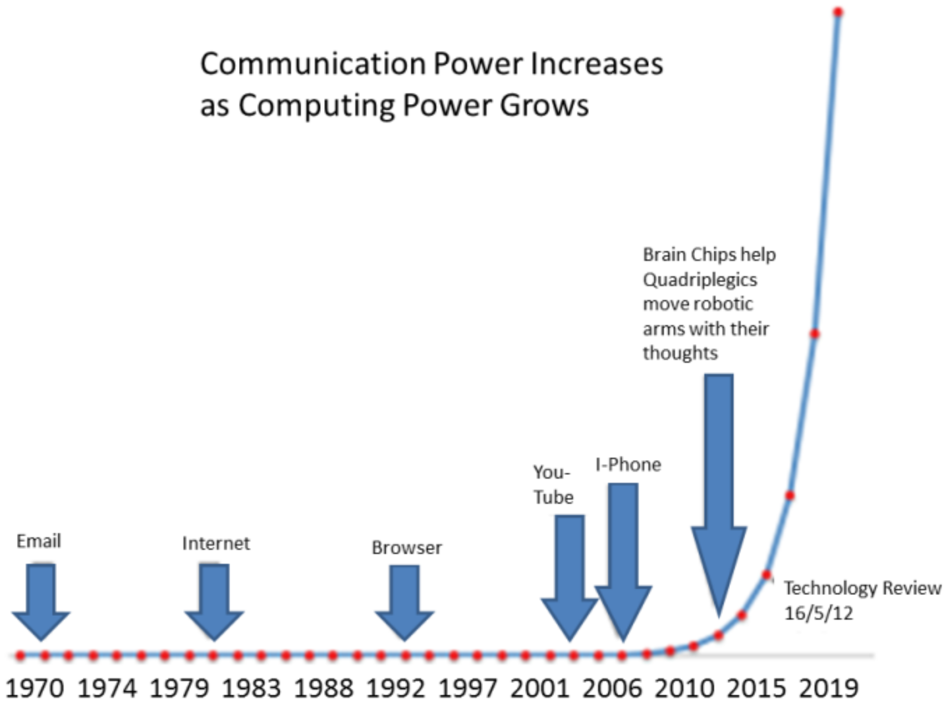


Figure 1.05: How methods of communication have changed as computing power has grown (Carrier 2012)

User expectation is also facilitating BIM adoption (Buildingsmart, 2009). A UK survey projects a 50% increase in BIM usage in 2011 and the majority of the industry using BIM within 5 years (NBS BIM survey 2010). It has been suggested that the four main elements influencing the spread of a new idea are: the innovation, channels of communication, time and the social system (Rogers 1962). The diffusion of innovation occurs through a five step process (see figure 1.06). In terms of Moore's model of market adoption (originally developed by Rogers (1962)) the chasm has been crossed and we are moving into the stage of the early majority (Ikerd 2009) (see figure 1.07).

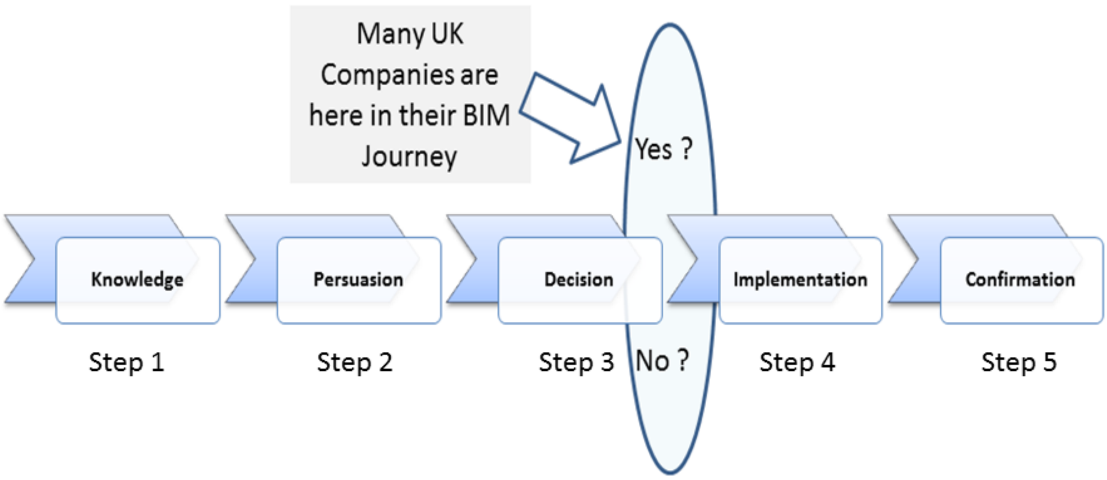


Figure 1.06 The Five stages in the decision innovation process (adapted from Rogers 1962)

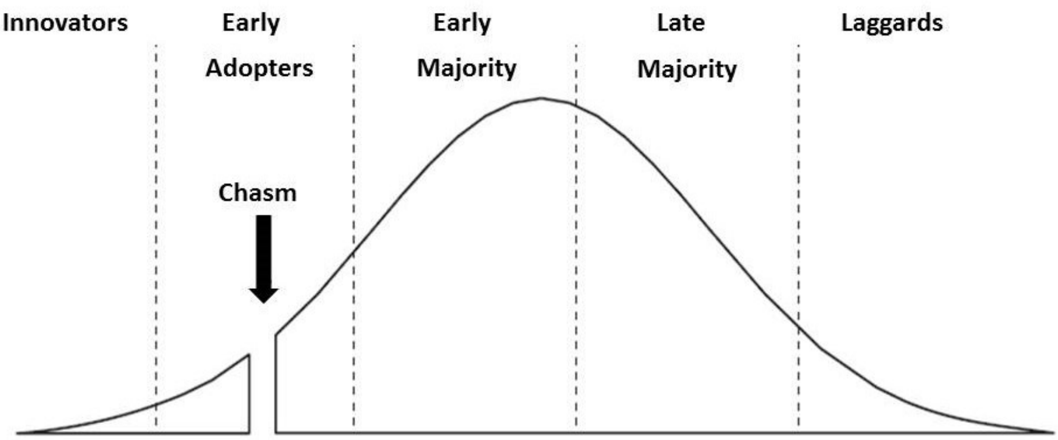


Figure 1.07: Market Adoption Model indicating the likely adoption of BIM over time (Moore, 1999)

The awareness of BIM is growing and the UK government is trying to persuade organisations to use BIM. Although small architectural practices only get 14% of their workload from the public sector (Roberson 2010). For many companies they are now at the point of transitioning between step three (taking the decision to implement) and step four (undertaking implementation).

A key element of this is the sophistication of BIM maturity that will be reached by a practice going through the process of BIM adoption. This relates to the capabilities of the users, the software and the systems that are put into place. Achieving appropriate and sustainable levels of BIM operation is central to the successful adoption of BIM.

BIM is the catalyst for multiple changes in the practice of architecture whether in a large or small practice. It is vital that practitioners understand the impact BIM is having on the practice of architecture and how to change their current modes of practice to incorporate BIM. This fundamental shift will impact on all issues and operations both inside and external to an architectural organisation.

Yet ultimately it must be remembered that what clients want is a better buildings not a better models. Better buildings are produced by making better informed decisions.

1.2 Observations

The rationale under which this research is conducted is based on several observations:

1.2.1 Observation 1: There has been a growing interest in BIM (see figure 1.08, 1.09). An increasing level of BIM adoption is predicted (see figure 1.10, 1.11). It seems that the widespread BIM adoption within small architectural practices is about to take place in the UK (Charlton, 2010). In some places that transition has already taken place (see figure 1.09). A UK survey predicts a 50% increase in BIM usage in 2011 and the majority of the industry using BIM within 5 years (NBS BIM survey 2010) (also see figure 1.08 and 1.12). With this widespread change predicted to be about to take place (Pike Research 2012) it is important that methods and guidance is in place to ease this transition.

Pike Research projects that the global market for BIM products and services will be about $1.8 billion in 2012 and almost $6.5 billion in 2020. The figures represent both BIM software revenue as well as sales from related services, such as training, support and project management (see figure 1.10 and 1.11) .

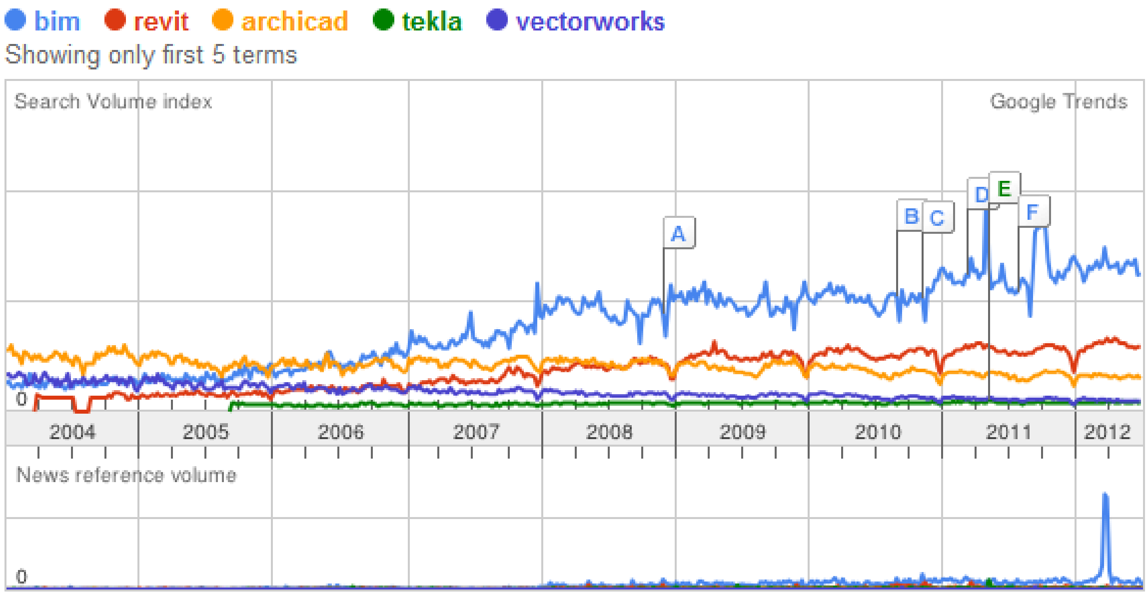


Figure 1.08: Trends showing searches for the term BIM (note the news reference volume in 2012) (Google Trends 30/6/2012)

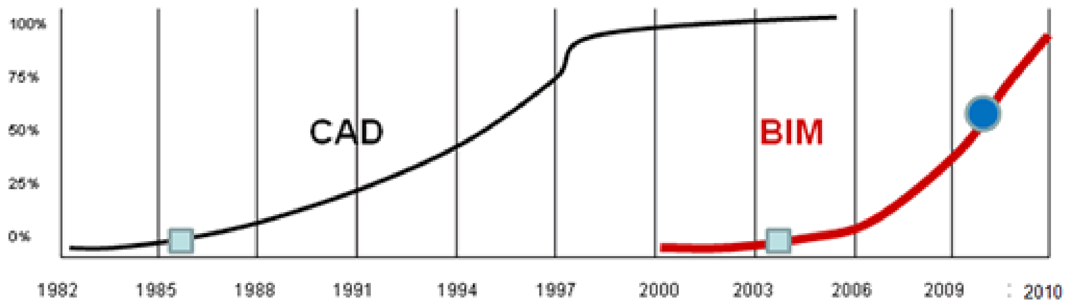


Figure 1.09: The change from CAD to BIM at Architectural Firm (20 staff) Neeley Lofrano San Francisco (Neeley 2010)

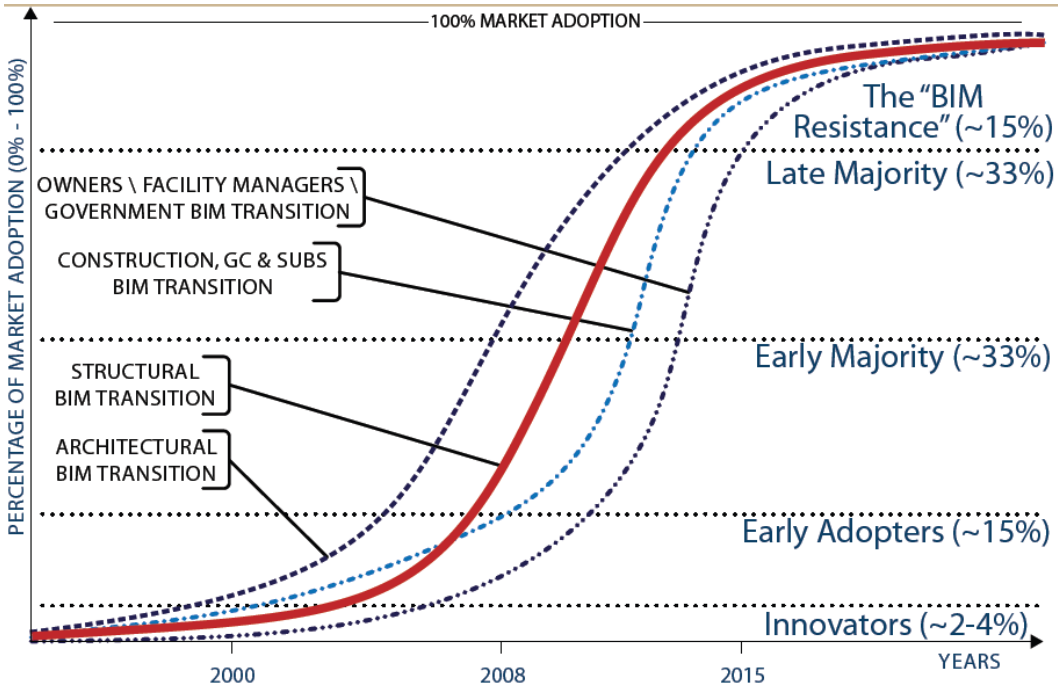


Figure 1.10: Projections of BIM technology adoption (Ikerd, 2008)

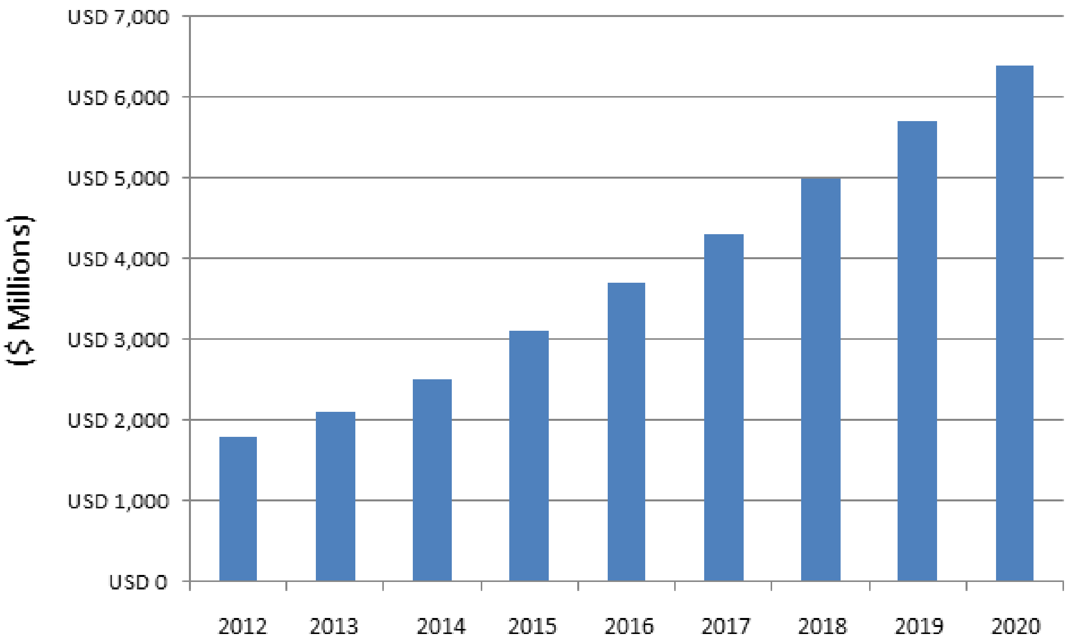


Figure 1.11: Building Information Modeling Revenue, World markets; 2012 -2020

(Machinchick 2012)

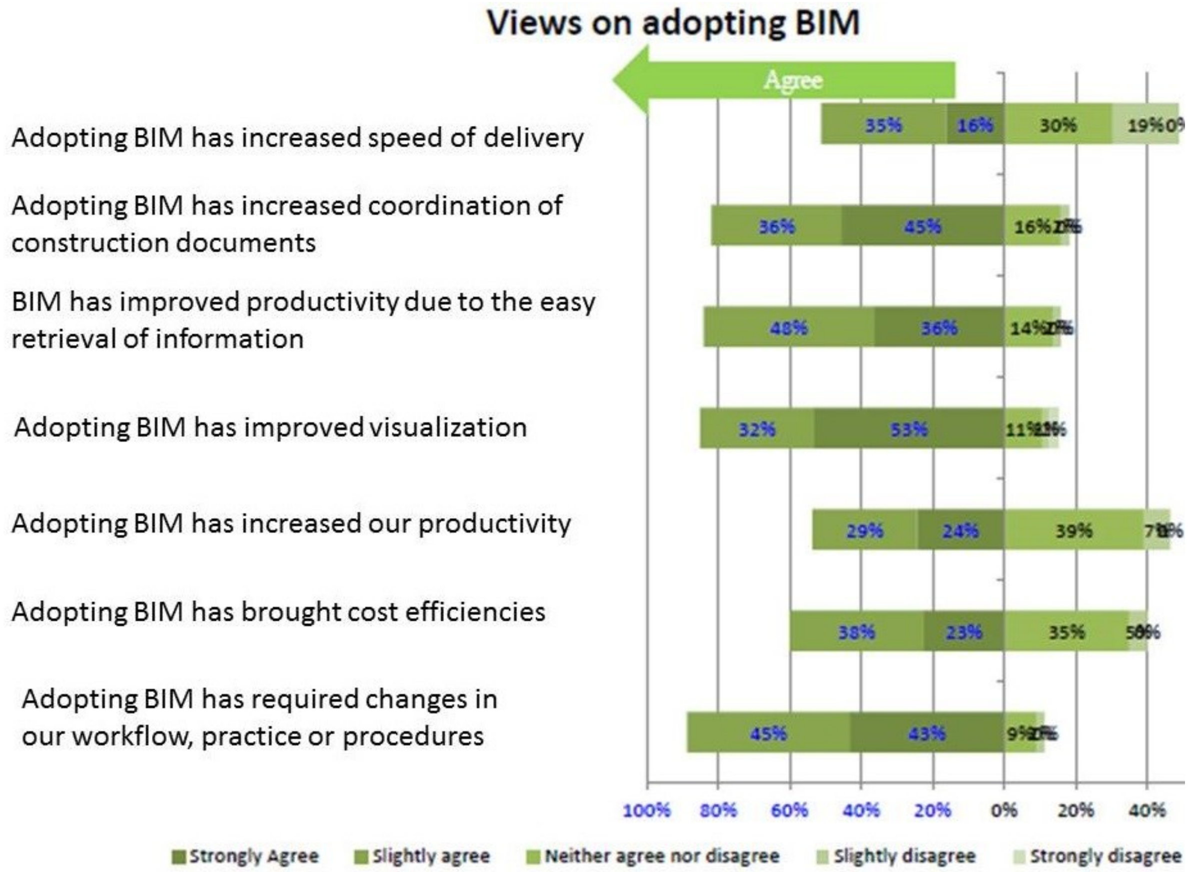


Figure 1.12: Views on adopting BIM adapted from NBS survey 2010 (Hamil, 2010)

1.2.2 Observation 2: Improvements in the construction industry are necessary and BIM offers a way to bring about improvements. New economic imperatives demand new more efficient and effective methods of working. Many previous studies have identified the problems that permeate the building industry (Egan 1998, Latham 1994) and other studies have indicated the potential benefits of adopting BIM (CIFE 2007). Data models for different systems are arbitrarily different. The result of this is that complex interfaces are required between systems that share data. These interfaces can account for between 25-70% of the cost of current system (West 1996). The problems of interoperability between engineering software systems have existed since the introduction of computer-aided design CAD in the 1970s (Pratt 1993).

1.2.3 Observation 3: There is a lack of research relating to BIM implementation and in relation to small architectural practices in particular (Jung et al, 2010; Hartmann et al, 2011) (See figure 1.13). The research by Jung (2010) indicates that no research has been done on BIM implementation strategy, policy, procedure or BIM manuals. According to an NBS (2013) survey produced mainly from architects 25 % of the respondents used 2D CAD (Computer Aided Design) only, while 36 % used no CAD at all.

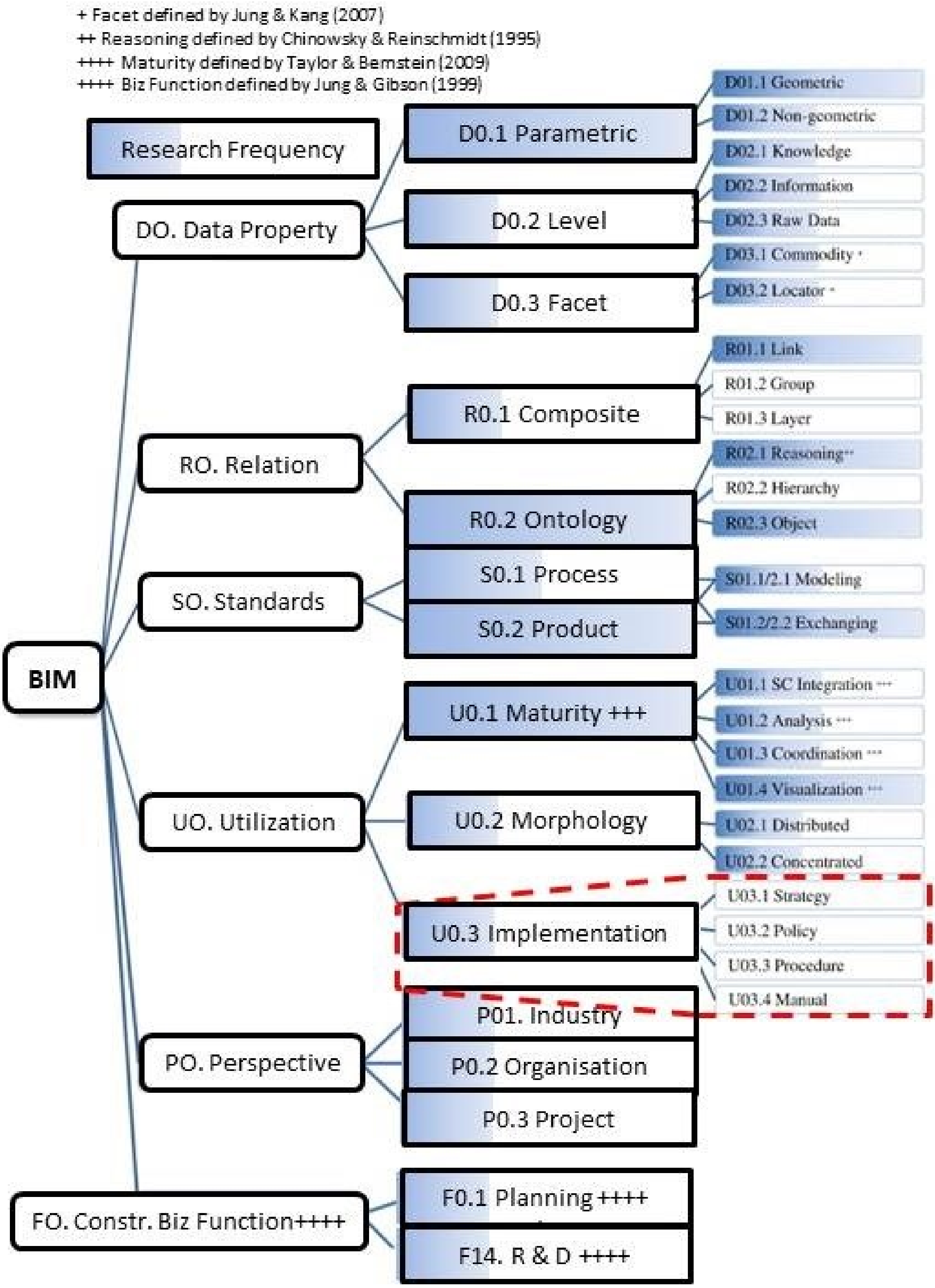


Figure 1.13: Building information modelling (BIM) framework for practical implementation showing frequency of research (Jung et al 2010)

1.3 Research Problem

The research problem is how to successfully implement BIM in a small architectural practice (see figure 1.14). It is a form of prescriptive research aimed at providing recommended actions or choices and giving directions to the effective implementation of BIM.

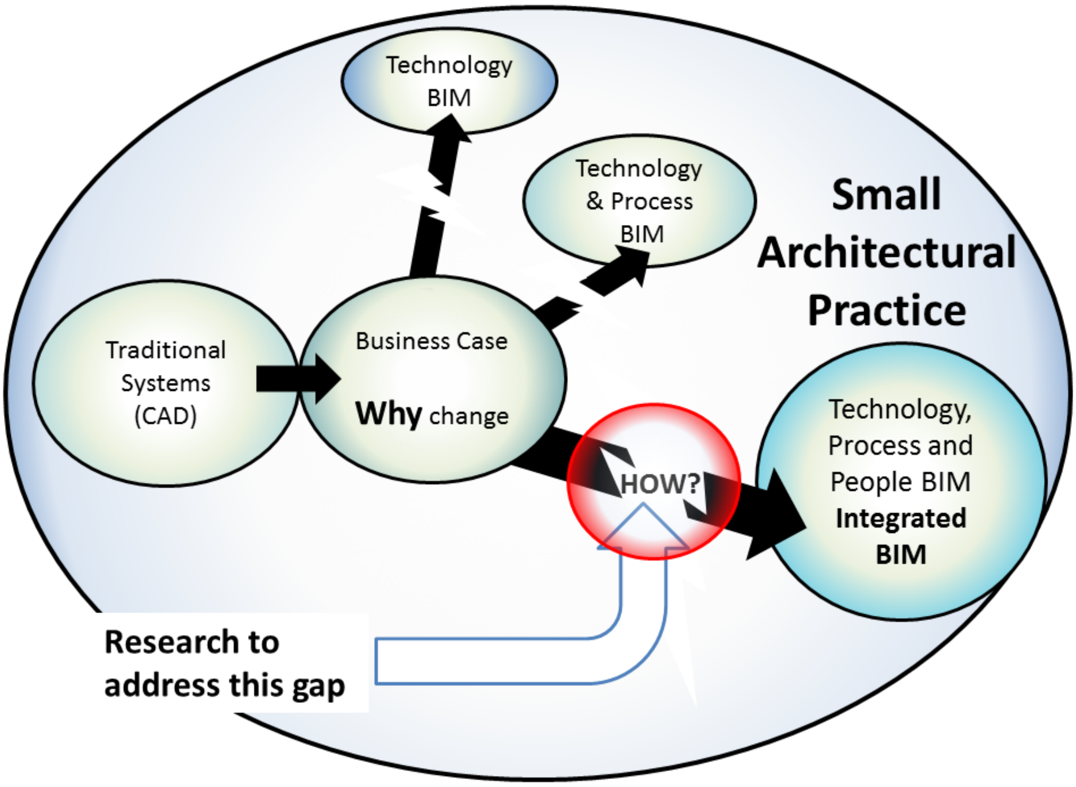


Figure 1.14: The gap this research is to address

The focus is on practices in the UK, but the lack of research in this area is a problem that is not just restricted to the UK. The problem is one of translational research which was identified by Wiezel (1999). Translational research bridges the gap from discovery to delivery (Conova 2005). The issue here is how to take 3D parametric modelling, interoperability and object intelligence and other benefits provided and implement them through the use of BIM and IFC compatible objects and utilize this in small architectural practices and the wider construction industry (see figure 1.15).

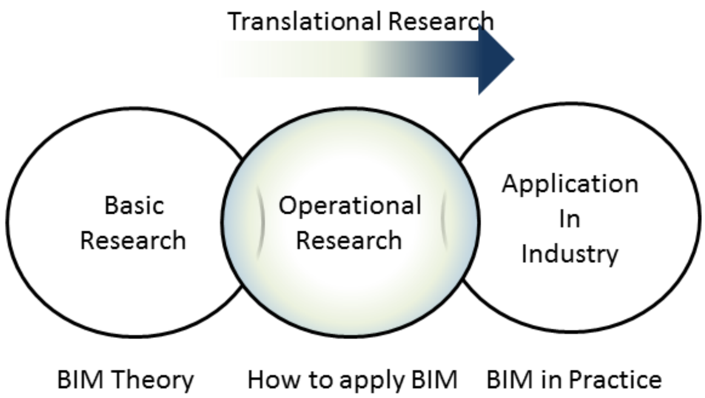


Figure 1.15: A diagram of transitional research

In relation to the technology readiness model (Mankins 1995) the research involves levels 7, 8 and 9 (see figure 1.16).

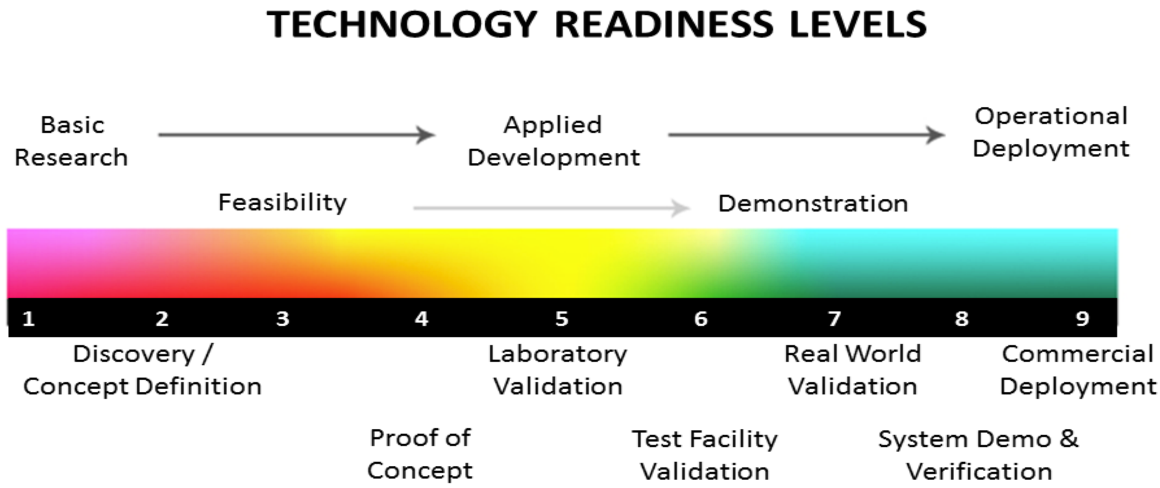


Figure 1.16: The Technology Readiness Model (Ocean energy industry 2013)

By adopting BIM the problems of informational fragmentation and duplication of work by multiple disciplines can to some extent be addressed. The impact of BIM is potentially to improve the process at every level and stage: eliminating the risk of calculation, misinterpretation of design, enabling rapid prototyping, increasing speed of delivery, enabling validation and visualization, improving communication, providing interoperability between stakeholders and, ensuring control and sharing of documentation (Coates et al 2010).

BIM has been utilised by large architectural practices and on large building projects e.g. London Underground, BIM is not widely used by small architectural practices. BIM application has the potential to give small architectural practices a competitive edge. Using BIM should enable the intelligent interrogation of designs; provide a quicker and cheaper design production; better co-ordination of documentation; more effective change control; less repetition of processes; a better quality constructed product; and improved communication (clients can be quite uninformed i.e. unable to read drawings) across the supply chain (Arayici, 2011).

This research will help small architectural practices to enhance and develop current and new services e.g. transfer of data to support whole life management of the building. The scope and quality of the enhanced services will lead to new clients and increase in the number of projects/frameworks with which the companies will be invited to partner.

1.4 Research Aim and Objectives

The overall aim of this thesis is to develop a BIM Implementation strategy framework for small architectural practices in the UK (see figure 1.17).

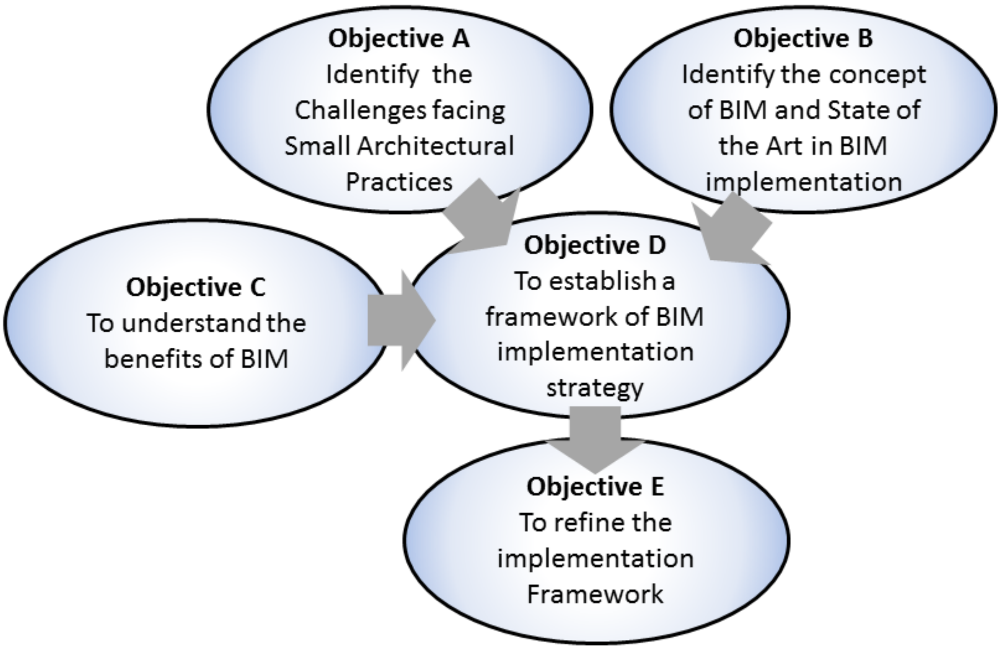


Figure 1.17: Research Objectives

The following objectives are set out to achieve this aim:

a) To explore the current practice and experience in small organisations in the construction Industry and particularly small architectural practices

b) To review literature related to BIM and the concepts behind BIM and BIM implementation

c) To review potential benefits of BIM

d) To establish a framework of BIM implementation strategy to enhance the practice of architecture.

e) To refine and enhance the initial BIM implementation framework by using the measures and results from the testing and experimentation on a real BIM implementation project

1.5 Research Questions

To enable the successful adoption of BIM, knowledge of how to achieve this outcome needs to be researched, formulated and presented in a format usable within the context of a small architectural practice. It is proposed that an enhanced BIM implementation strategy framework has the potential to achieve this objective. This results in the research question as stated below.

As a result of justification of the research, the question is “what is an appropriate strategy framework for the implementation of BIM in a small architectural practice.”

The research for this thesis was undertaken in the context of the UK so the findings have a UK bias. This having been said many of the finding are relevant to organisations adopting BIM irrespective of size, location or discipline.

By answering such questions it is hoped that small architectural practices adopting BIM can avoid the “J” curve of productivity loss when adopting BIM (see figure 1.18).

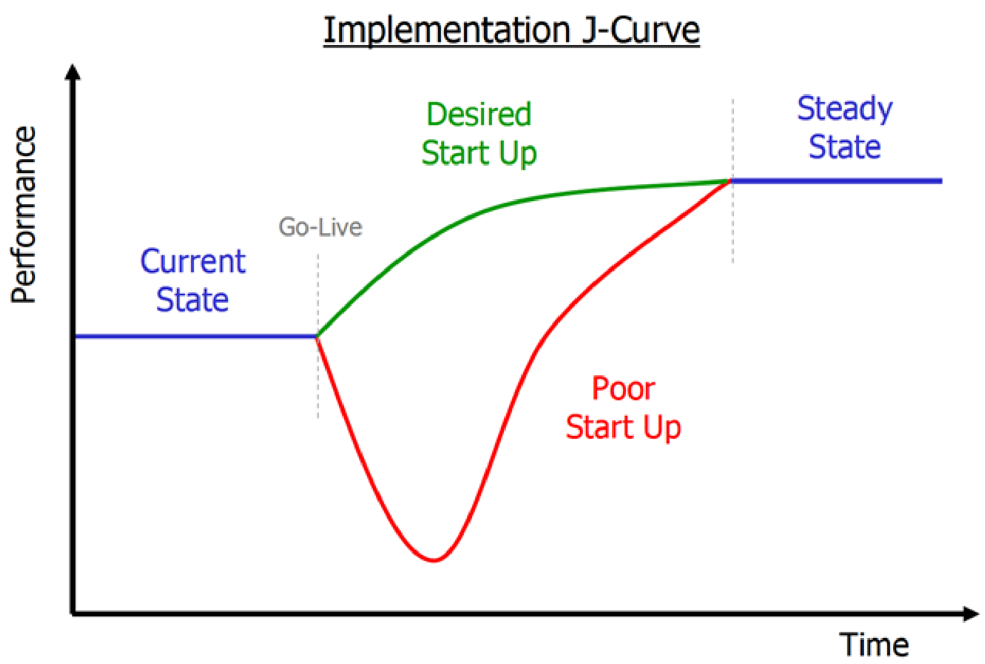


Figure 1.18: Graph of performance against time when implementing new business practices (ANGL 2012)

1.6 Research Methodology

The research methodology followed the CIFE “Horseshoe” Method (Kunz 2007) for transitional research (see figure 1.19).

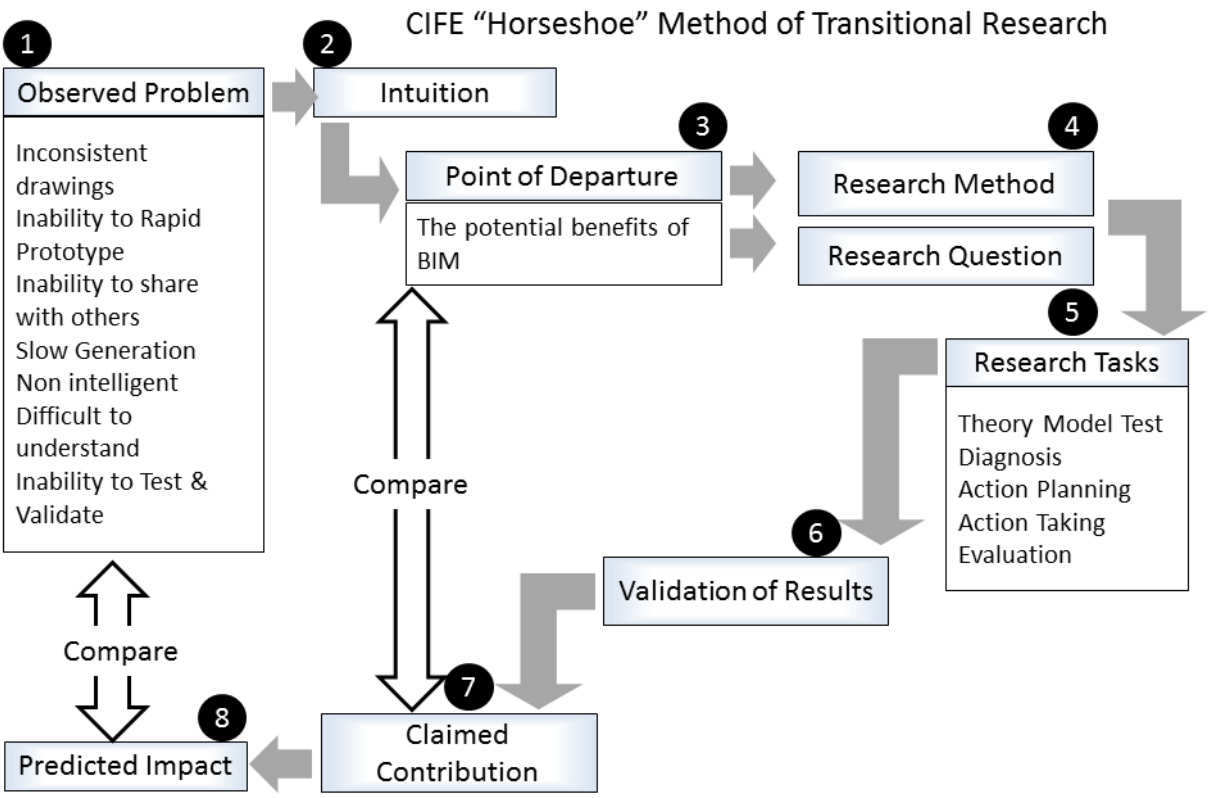


Figure 1.19: The CIFE Horseshoe method of Transitional

The problem was observed and through intuition a point of departure was determined. It this case the point of departure was that BIM would bring benefits to the practice or company adopting this approach. The research questions and the research methods were determined. The research approach adopted was decided to be action research. Action research enables the researcher to be actively involved and gain insights that are difficult to gain from external observation. The research tasks were then formulated. The research was validated as part of the evaluation stage of the action research cycle. The claimed contribution to knowledge and the predicted impacts are documented in the final chapter of this thesis.

1.7 Contribution to the Body of Knowledge

1.7.1 Synopsis of the Research Impact

The word “contribution” is intended to mean that the research conclusions are not already known. The word “knowledge” intends a limitation to what has been established in the academic discipline.

After a literature investigation within this field no research has been uncovered, within a similar organisation or using the research methodology used to address the research question posed. The primary knowledge gained will be a greater insight into the issues, methods and achievable objectives which a small architectural practice can expect to go through as part of a successful BIM adoption. Through this research new constructs were developed further explaining the issues and complexities in this area of endeavour. Many tasks necessary for the implementation of BIM were identified which previously have not been documented. The ideal sequences for these tasks were determined and then they were added to the new framework.

The particular significance of this research is its potential to assist small architectural practices facing the challenge of adopting BIM and thus making a step to a more efficient and effective construction industry.

It will therefore contribute to knowledge and practice to increase the effectiveness of future BIM implementations. It endeavours to explore implementation in practice and, through that, reveal the reasons why the espoused benefits of BIM are difficult to accomplish. In doing so, the lessons learnt can improve future BIM implementations in small architectural practices.

The novel contribution of this research is presented in terms of a better understanding of the implementation of BIM in real life setting. This better understanding aims at addressing the gap identified in the literature explaining the methods and approaches for successful adoption which may then allow the benefits of BIM to be realized in practice.

1.7.2 Scope and Limitations of the Work

The proposed research includes some limitations related to its approach. The action research adopted provided insight through a single case study. Taking one case study maybe atypical and without supporting substantiating study it is not possible to triangulate and establish the convergent or concurrent validity of the findings. Yin (2003) describes a rationale for using a single instrumental case study when a set of propositions have been defined where the case study is designed to “…confirm, challenge, or extend the theory.”

The scope of this thesis is the development and validation of a BIM implementation strategic framework. Although a major element of BIM is about inter-organisational integration this thesis is limited to the application of BIM within small architectural practices in the UK (see figure 1.20). A small architectural practice is regarded as a practice employing up to 15 architects and ancillary staff. By limiting the research to small architectural practices the research is not limited to small architectural projects. But it is usually the case smaller practices conduct smaller projects.

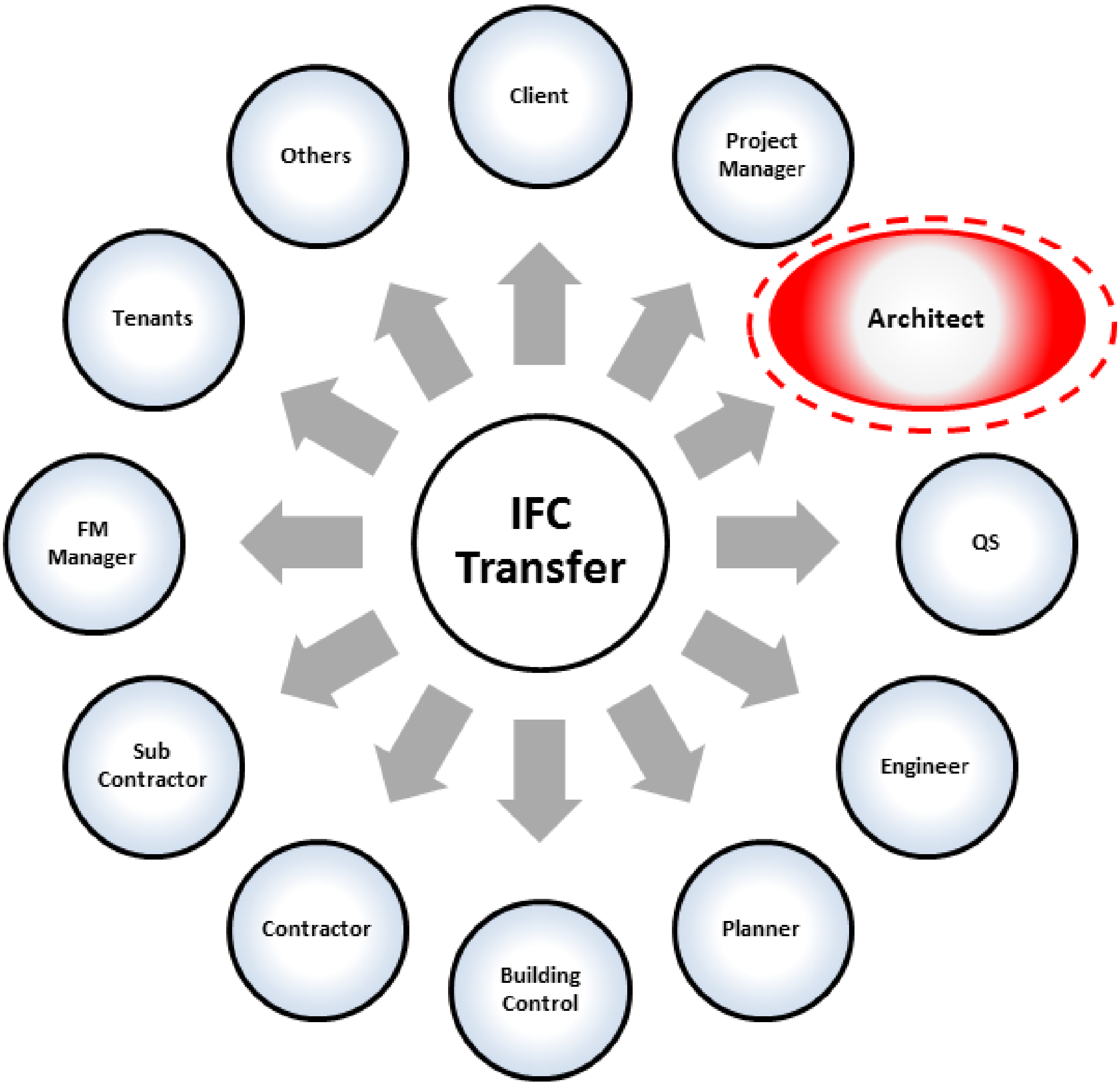


Figure 1.20: Showing area cover by this research

This research specifically looks at the issues related to BIM adoption in small architectural practices.

The limitations to the research are a result of the following factors:

a) Time available to undertake the primary research (2 years). The BIM implementation continued after the two year period at the case study company.

b) The complexity of the subject (the practice of architecture requires many skills and inputs). Only some of these complexities were addressed at the case study company.
c) The type of research adopted (Action Research). Action research by its nature is a result of the experiences of the researcher. How the researcher experiences matters is to some extend dependant on prior knowledge, skills and experiences.
d) The results of action research cannot necessarily be generalized for broad application, as action research seeks to find solutions that are “localized” for specific situations (Stringer 2007).

These limitations could be overcome in future by:

a) Undertaking case study research on a wider sample of practices or over a longer period of time
b) Undertaking research in multidisciplinary or larger architectural practices or organisations
c) Undertaking this area of research with different research methodologies

1.8 Structure of Thesis

This study was designed as a piece of action research followed by framework development and validation as part of the evaluation process. Action research is now used within a range of settings and has developed by drawing from pragmatic philosophy, critical thinking, and humanistic and transpersonal psychology, constructionist theory, systems thinking and complexity theory (Reason and Bradbury, 2006). An important element of action research is participation by 'informants' who engage in 'collective, self-reflective enquiry, in social situations in order improve the rationality and justice of their own social practices' (Kemmis and McTaggart 1988). The steps in the “AR” cycle (Action Research) and the corresponding chapters in this thesis are illustrated below (see figure 1.21). The knowledge generated through action research is not organised as in traditional research and the thesis reflects this.

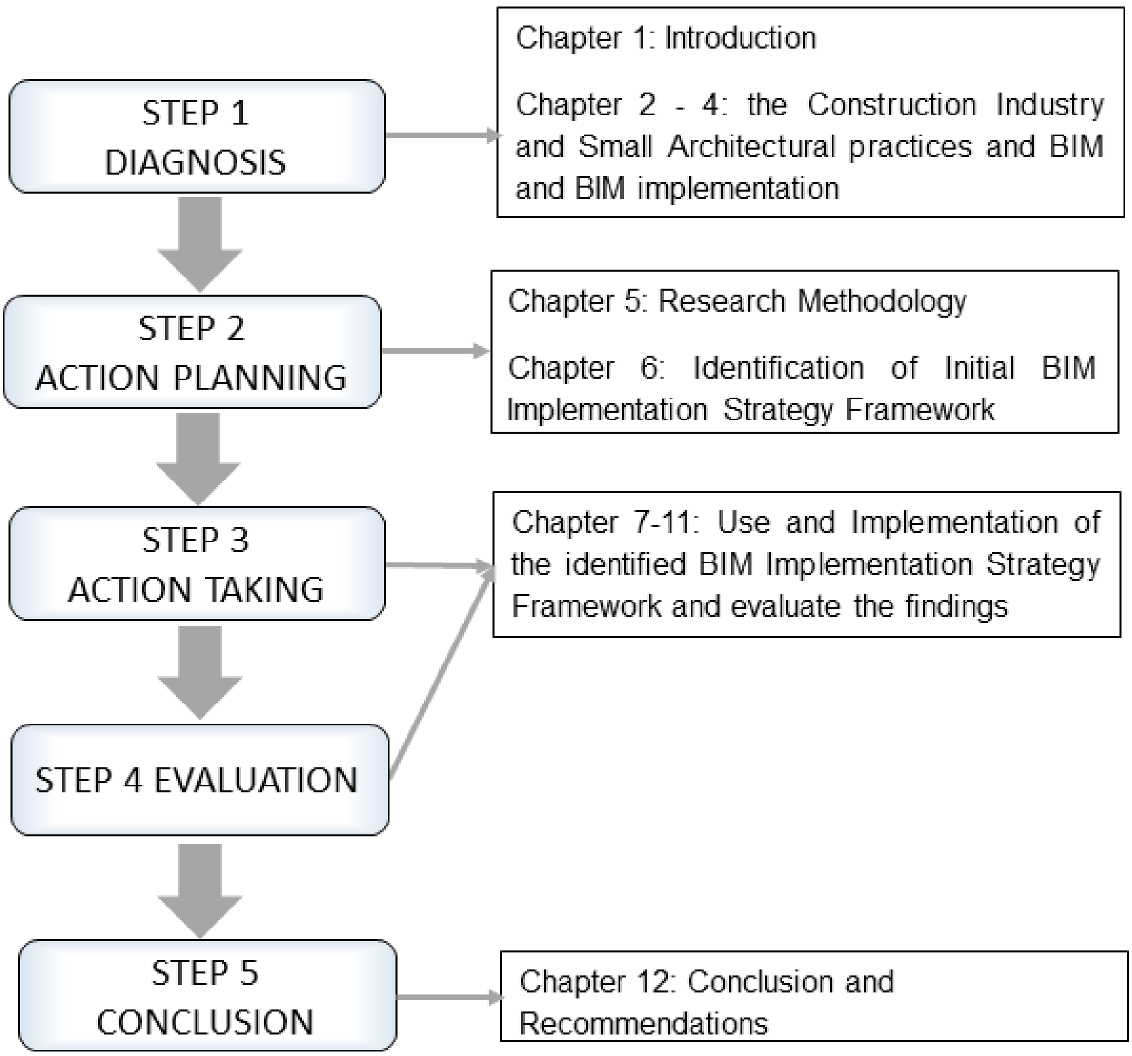


Figure 1.21: Structure of Thesis

Further details of the content of each chapter are also explained.

Chapter 1 makes an introduction to the thesis explains the backgrounds, rationale for research, the research question, the aims and objectives of the research, a brief of the research methodology, scope and the limitations of the research.

Chapter 2 critically elaborates the current practice of construction industry, issues, problems and challenges in the industry with a particular focus on small architectural practices.

Chapter 3 explains the BIM concept as a new way of working methodology for architectural companies and its current use and implementation in the sector and related challenges and issues in its implementation.

Chapter 4 explains the benefits of adopting BIM.

Chapter 5 explains the research methodology in detail and gives more information about the action research strategy used in the research. Detail is also provided about John McCall Architects the case study company.

Chapter 6 establishes an initial BIM implementation Strategy Framework that proposes strategies and approaches at strategic level such as action research led bottom up change management strategies, while it also provides well prescribed roadmap of BIM implementation at operational level from the current review of a company and business processing re-engineering to piloting and capacity building tasks. A description of the case study company where the action research was undertaken is also included.

Chapter 7 – 10 explains the use and implementation of the identified framework from chapter 5 through the BIM implementation and adoption project undertaken between the University of Salford and John McCall Architects in Liverpool. By action research strategy, these chapters details how the following tasks of the BIM implementation strategy framework is used and helped for the BIM adoption project between the university and John McCall Architects. These chapters also conduct an analysis and reflect on the experiential learning from the actual implementation of the BIM Implementation Strategy Framework in order to identify and refine the areas of improvement.

Chapter 11 Taking the lessons learn from the actual BIM implementation at John McCall Architects a new improved BIM implementation strategy framework is developed.

Chapter 12 draws up the conclusion, propose the refined BIM Implementation Strategy Framework for other small architectural practices and finally highlights the potential areas of research that are also recommended as the future studies from this PhD.

1.9 Summary of Chapter

This chapter introduced the research context and justified the motivation for the study. The subject of BIM implementation has been introduced with predictions of its adoption. The need and lack of research in this area has been highlighted and the research problem identified, which is how best to implement BIM in small architectural practices. The research objectives and questions have been documented along with the aims and limitations of this work. Finally the proposed structure for the thesis is documented.

Chapter 2

Chapter 2: This chapter focuses on Objective A as identified in chapter one. Through literature review the problems, issues, challenges, of the construction industry and particularly of small architectural practices are considered.

CHAPTER 2 Small Architectural Practices and their Challenges

2.1 Introduction

Small architectural practices face a range of challenges in order to achieve the required architectural solutions (see figure 2.01).

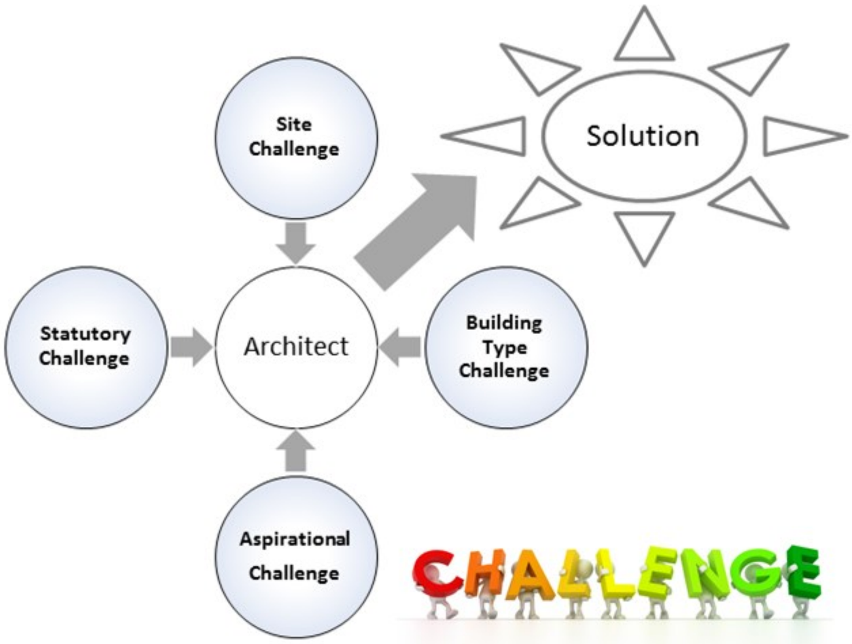


Figure 2.01: Challenges to be overcome by the architect

To understand the challenges to small architectural practices three approaches were taken. These approaches were:

- To review journals, reports (particularly those by Latham 1994 and Egan 1998) and more recent UK government reports indicating the challenges facing the construction industry.

- To undertaking a FAST Analysis as a method to provide an insight of how demands are to be achieved. Function Analysis System Technique builds upon value analysis by linking the simply expressed, verb-noun functions to describe complex systems.

- A review of the role and the standard interactions of an architectural practice were also undertaken.

2.2 The Construction Industry and its Challenges

In 2008 there were 53,500 registered contractors in the UK, only 283 of them employed 300 or more staff (Crotty 2012). Only 0.14% of the firms employ 24% of the workforce and generate 35% of the industries output (ONS 2009).

The projects that the construction industry tends to undertake are one-of-a-kind and involve the coordination of practitioners such as designers, engineers, suppliers and contractors. Building contracts may also vary in cost and the amount of work done over the period of the construction contract.

Construction is usually brought about by non-uniform autonomous agents where the output is non-linear (the output is not proportional to the input). Projects in construction should be considered as a complex dynamic system (Bertelsen 2002).

A typical construction project consists of a number of organisations and teams that are brought together for the duration of that particular project to form a so-called "virtual enterprise". As practitioners may only be brought together for a single project, the act of aligning how each party operates can be considered as an overhead on each project.

Defining characteristics of the construction industry have been identified as its inability to complete projects predictably (see figure 2.02) and its chronically low levels of profitability (see figure 2.03) (Crotty 2012) (CMAA 2007) (Construction Excellence 2011).

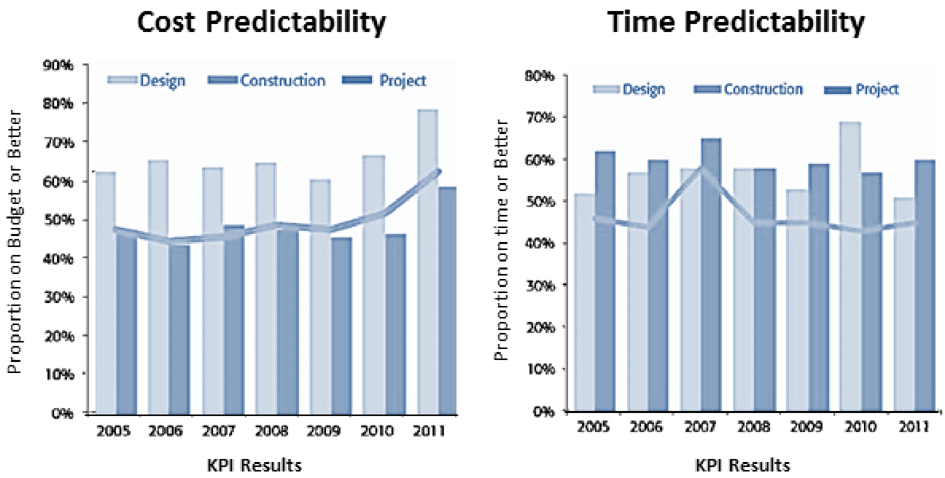


Figure 2.02: Cost and Time predictability of construction projects in the UK (2011 Industry Performance Report, Construction Excellence)

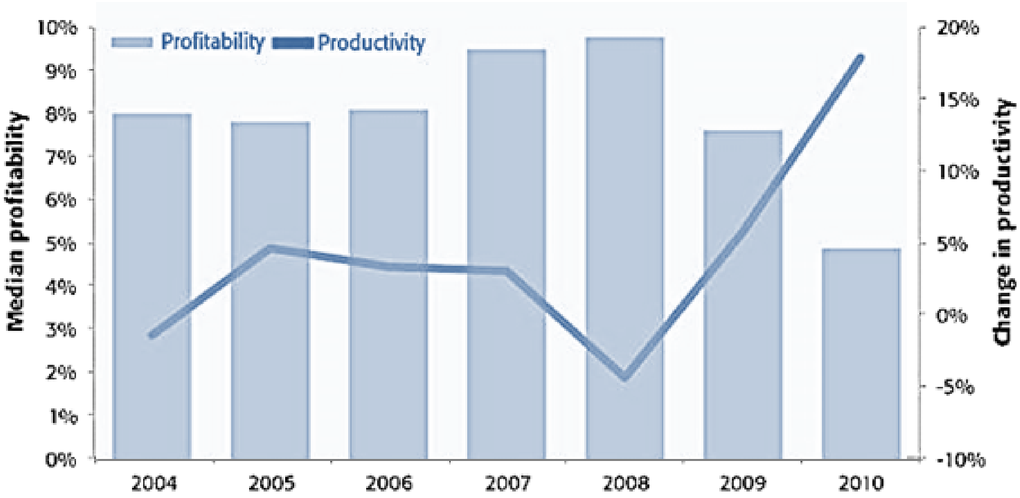


Figure 2.03: Profitability and Productivity on construction projects in the UK (2011 Industry Performance Report, Construction Excellence)

The main problems within the construction industries can be traced back to its method of operation (see figure 2.04).

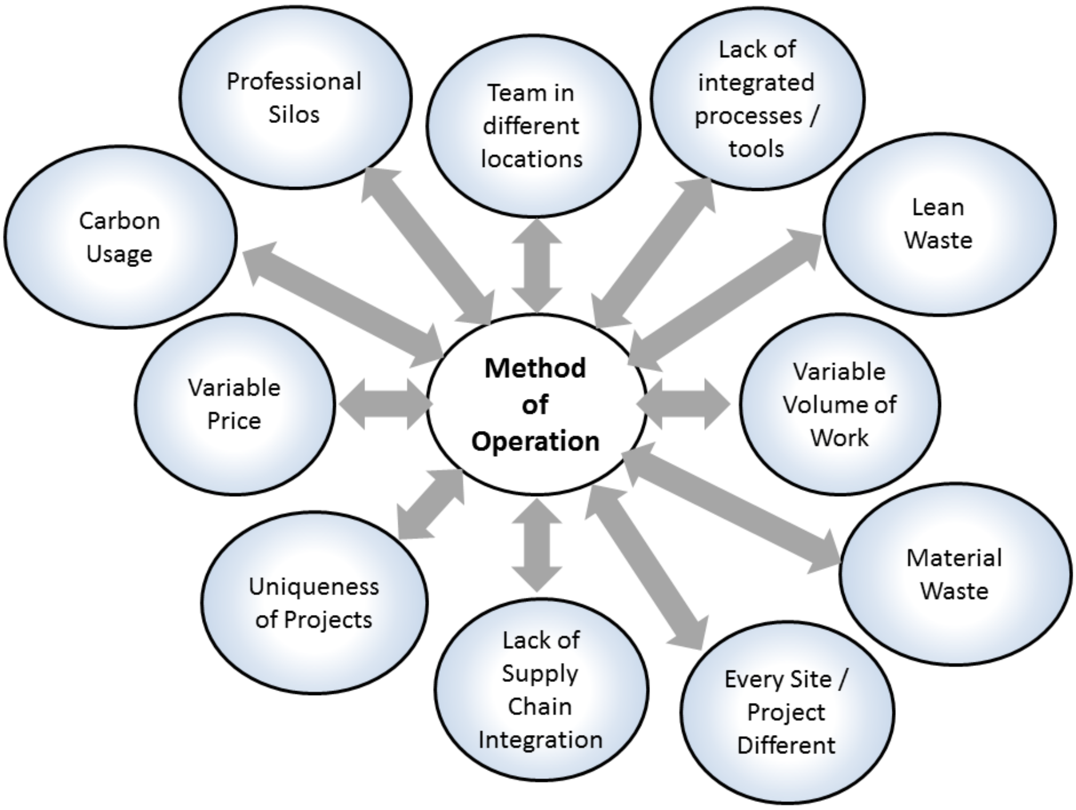


Figure 2.04: Issues and Problems within the Construction Industry

Figure 2.04 and the list below were generated in part through interviews undertaken with contractors subsequent to the main research.

The construction industry could benefit from the following:

- Effective and rapid development appraisal
- Integrated design and planning applications
- Effective and sustainable product selection
- Automated energy assessments
- FM Information capture prior to construction
- Proactive Maintenance
- Accurate Quantity take-offs
- Virtual pre construction
- Rapid revision control

Many of these factors represent untapped capabilities that can be provided by applications utilizing BIM.

2.3 The need for Construction Industry improvement as defined by the UK Government

There have been many reports on how to improve the construction industry in the UK (Latham 1994), (Egan 1998). After writing his report Rethinking Construction Egan (1998) set out seven targets for the construction industry (see figure 2.05).

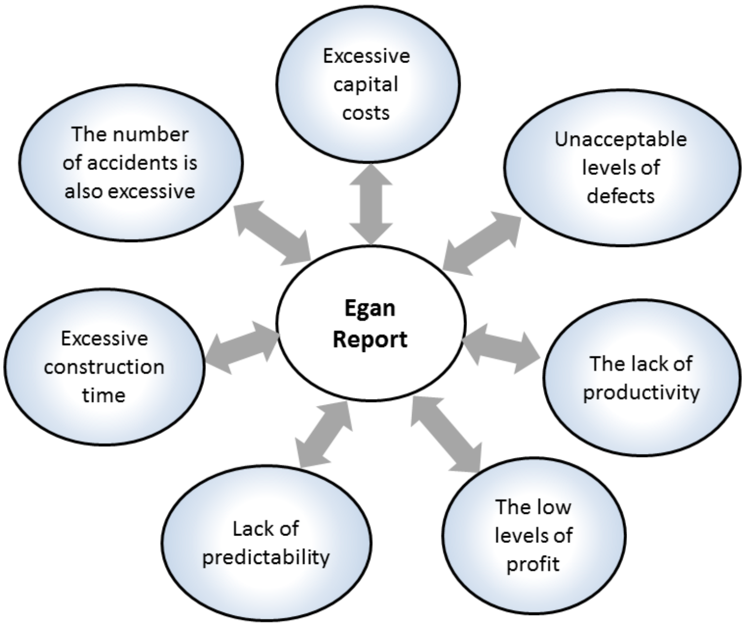


Figure 2.05: Findings of the Egan Report (1998)

These targets were later reviewed in the report “Never Waste a Good Crisis” Wolstenholme 2009 (see figure 2.06).

Figure 2.06: How have we done against Egan's targets? (Wolstenholme 2009)

What is clear from the findings is that the targets of reduced cost, reduced construction time and reduced predictability are not being achieved. While the targets of reduced defects and reduced accidents are only partially being met. BIM offers a new way of addressing all of these targets.

"Up to 30 per cent of construction is rework, labour is used at only 40-60 per cent of potential efficiency, accidents can account for 3-6 per cent of the total project costs, and at least 10 per cent of materials are wasted. These are probably conservative estimates…The message is clear – there is plenty of scope for improving efficiency and quality simply by taking waste out of construction."

Latham 1994

Most recently the Construction 2025 report (HM Government 2013) sets out new targets (see figure 2.07).

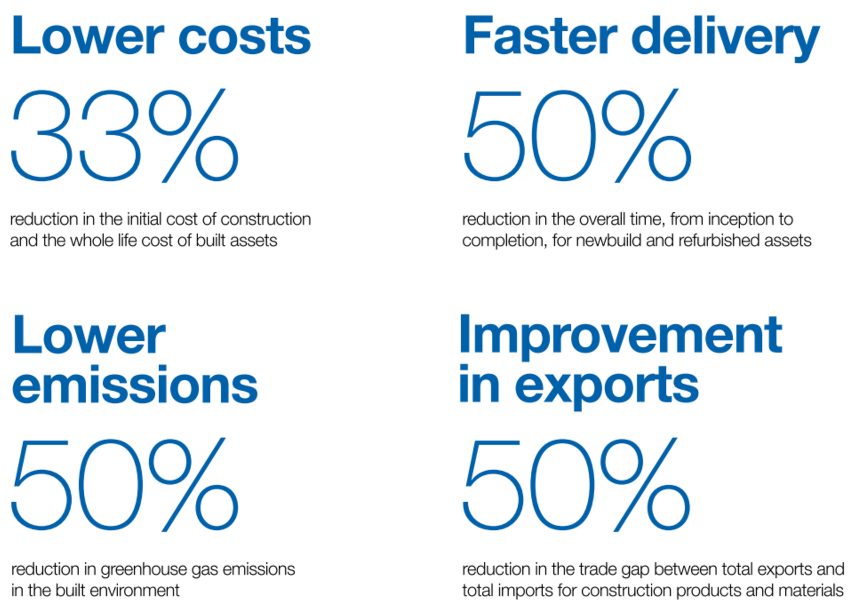


Figure 2.07: Targets set out by the Construction 2025 report (HM Government 2013)

2.4 FAST Analysis of how demands on the Construction Industry are to be achieved

To understand the operational needs of the construction industry a FAST (Function Analysis System Technique) analysis was undertaken.

Function Analysis System Technique is an evolution of the value analysis process created by Charles Bytheway (2007). FAST builds upon VA (value analysis) by linking the simply expressed, verb-noun functions to describe complex systems (see figure 2.08). This forms the basis for subsequent approaches and review. FAST asks three questions:

- What is the problem?
- Why is this a problem?
- Why is a solution necessary?

By undertaking a FAST analysis (see figure 2.09 Appendix A) it was possible to better understand the drivers for improvement related to the construction industry (see figure 2.10).

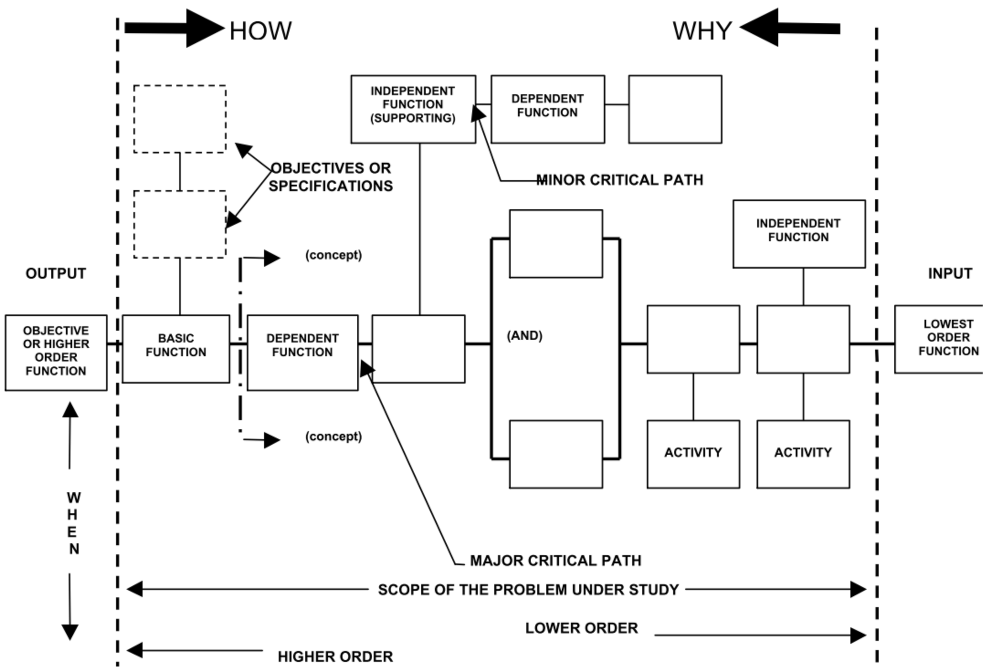


Figure 2.08: Concept of a FAST analysis (Wixson, J. 1999)

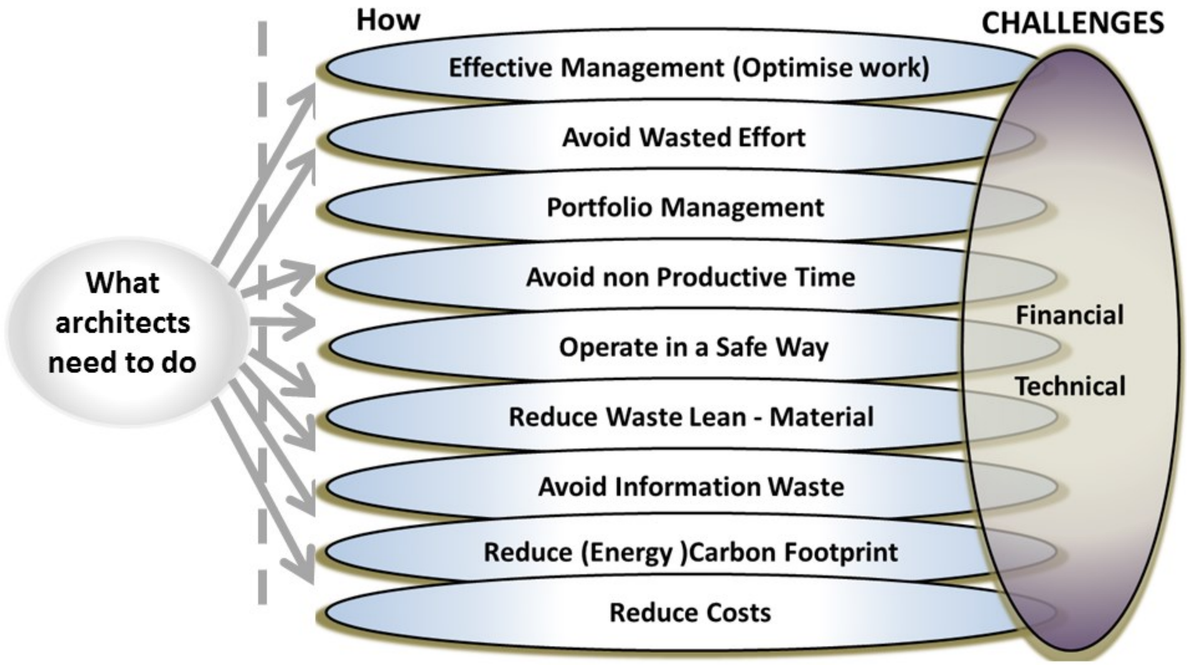


Figure 2.10: How to improve the construction industry generated by FAST analysis

2.5 Challenges facing the Construction Industry

2.5.1 The need for Effective Management

According to the Institute of Leadership and Management (ILM 2012) 93% in a survey said low management skill was impacting on their business. The construction process often involves many activities in many places by many parties this in many case requires advanced management techniques (Ong 2007). The activities usually involve people and the transformation or assembly of parts. The development of artefacts, approvals and certifications can also be an important element of such works. Sometimes where the tasks are sequentially dependant it is necessary for these activities to be prescribed by a critical path or sequence of operation.

Without the right knowledge being applied at the right time in the right way an inferior and potentially dangerous product maybe produced. Management of the complexities of parts, process, people and their application in systems of operation is required (see figure 2.11). Such systems are not necessarily computer based but they are becoming more so over time. With more and a wider provision of data projects can be more efficiently managed and a better product produced.

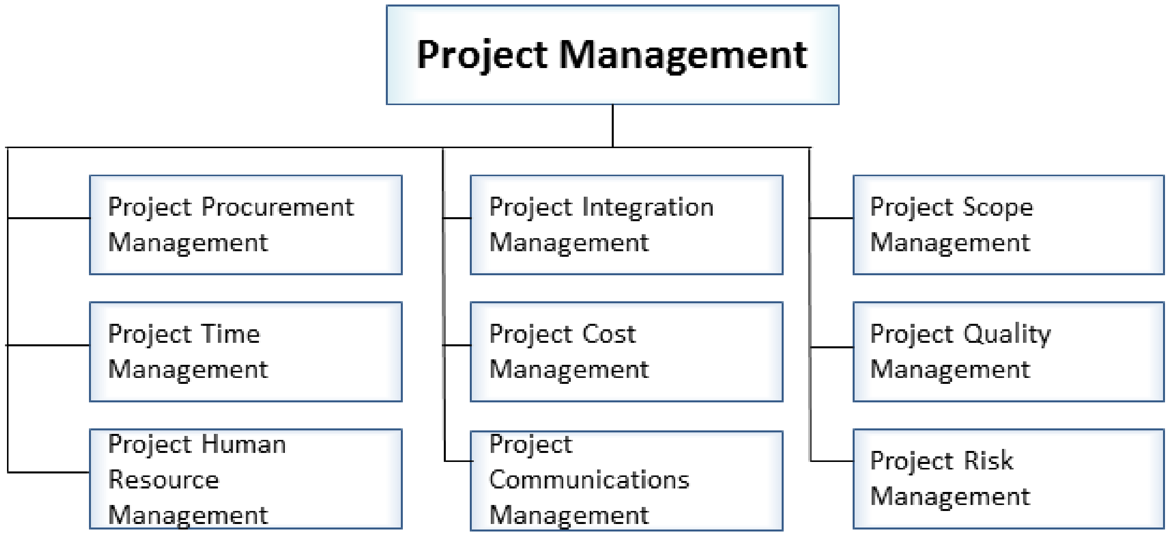


Figure 2.11: A Project Management Framework (PMI 2001)

2.5.2 The Need to Avoid Wasted Effort

Usually decision making is carried in architectural practice without the complete information (Reinertsen, 1997; Sanban et al, 2000; Herder et al.,2003; Koskela, 2004). This means that wasted effort can occur through abortive work based on insufficient information.

In 2004 the U.S. Construction Industry Institute estimated that 57% of money spent on construction is that was non-value adding (waste) (see figure 2.12). With the U.S. construction market estimated at US$1.288 trillion for 2008, at 57% waste, over $600 billion per year is being wasted (Eastman 2009).

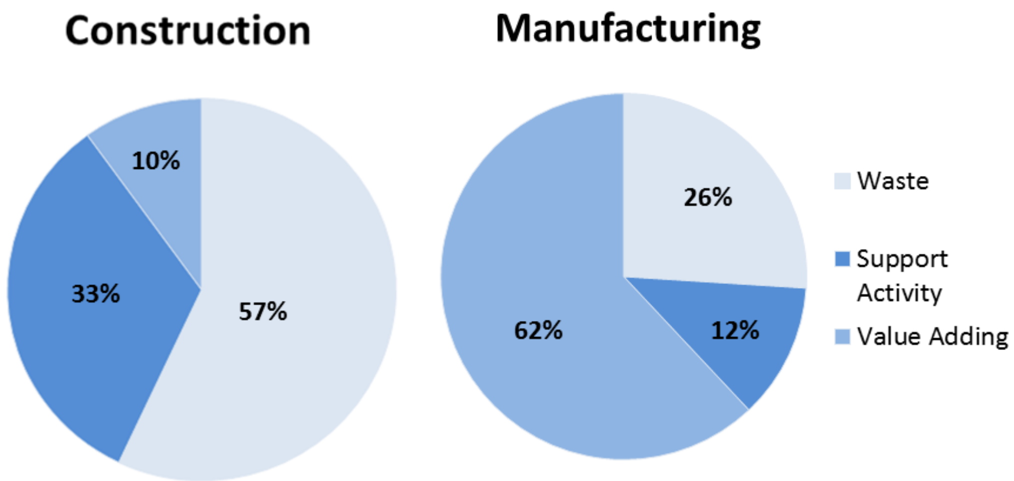


Figure 2.12: A large portion of the money spent in the construction industry is wasted, especially when compared to the manufacturing industry (Eastman et al 2008)

Rework represents a major problem in the building industry and the cost of rework can range from 3% to 23% of the contract value (Love 2004). The BRE (1981) found that 50% of the error had their origin in the design stage. So this is an issue which a change in architectural practice and the design for manufacture (DfM) approach may address.

Fayek et al. (2003) categorized the components of rework as:

- the standby time during which the rework scope is identified
- the time required to carry out the rework
- the time required to gear up to carry on with the original scope of the activity

The effects of rework can have many negative effects on the project team (see figure 2.13).

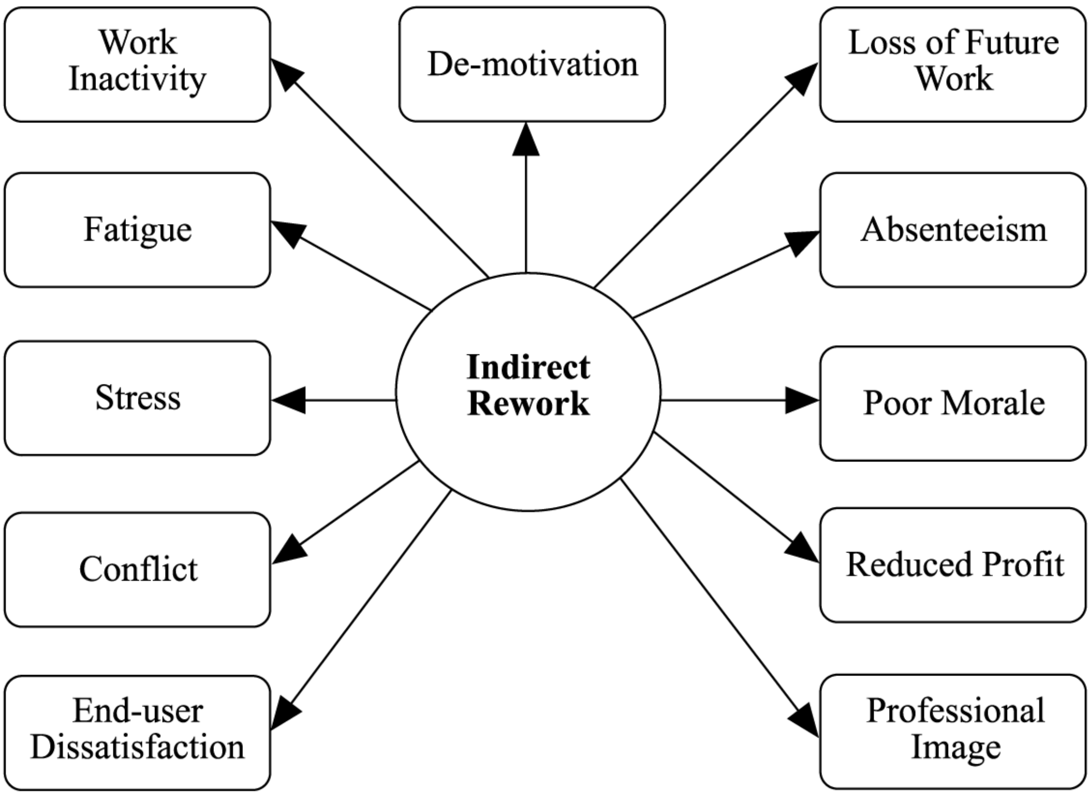


Figure 2.13: The consequences of rework on the project team (Love 2002)

The current shortage of construction contracts is reflected in the poor success rate of some contractors and architects when bidding for work. According to ConstructionLine 27.9% of contractors do not acquire over 10% of the contacts they bid for. Architects also chase a lot of work they do not win (see figure 2.14). Efforts made on contracts that are not won are wasted effort by the development team but this cost must be carried by the contracts won.

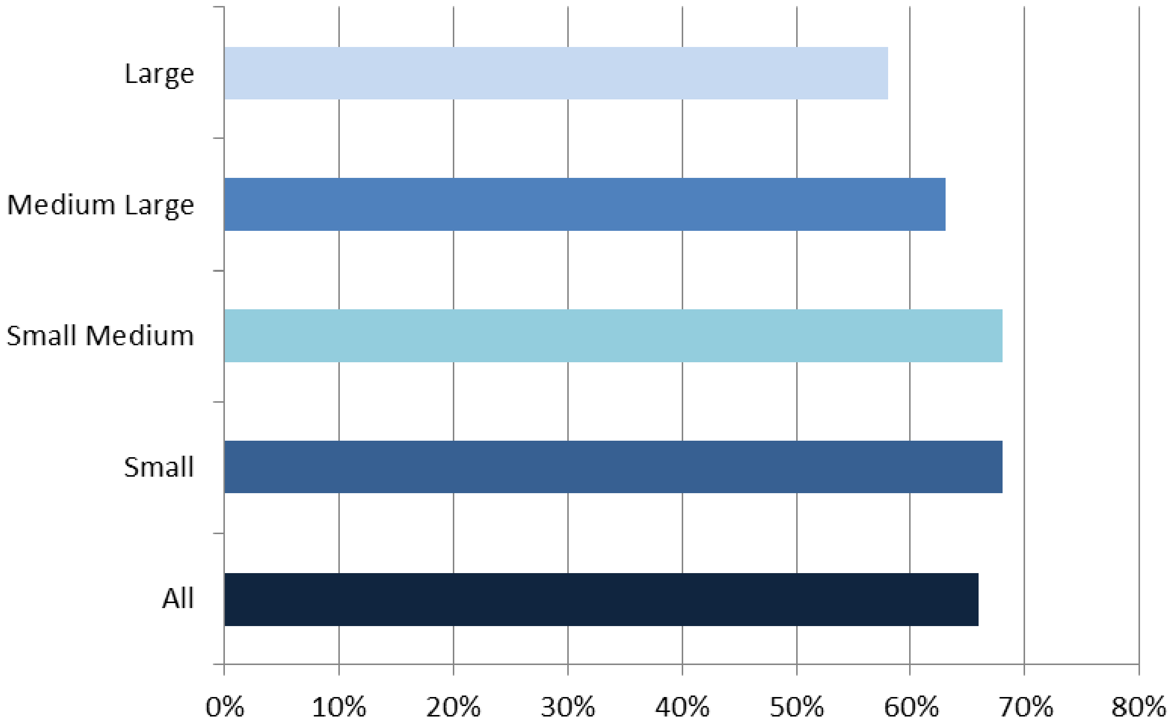


Figure 2.14: Jobs won as percentage of jobs chased (Collander 2012)

Wastes can also occur when buildings require unnecessary manpower resources during the construction, operation and decommissioning stages.

2.5.3 Portfolio Management

The activity of building often contains units that are in different physical locations, use different computer platforms. Yet there is a need to work collaboratively and to share the same project data (Faraj et al, 2000) (Engestrom et al 1999). The way disciplines interact with others is one of the challenges of the work undertaken.

An important element to realize is that companies operating in the construction sector may be undertaking multiple projects simultaneously. Therefore it is not appropriate to view projects in isolation. By coordinating activities and resources appropriately across multiple projects whether in design or construction leads to efficiencies and potential profit for organisations and practices. This requires a managed distribution of knowledge, skills and resources. To achieve this, organisations need to know what needs to take place on individual projects. But they also need to be able to extrapolate this into an organisation understanding and management system.

2.5.4 To Avoid Non-Productive Time

Many traditional methods of operation in architectural practice result in non-productive time (NPT) (see figure 2.15).

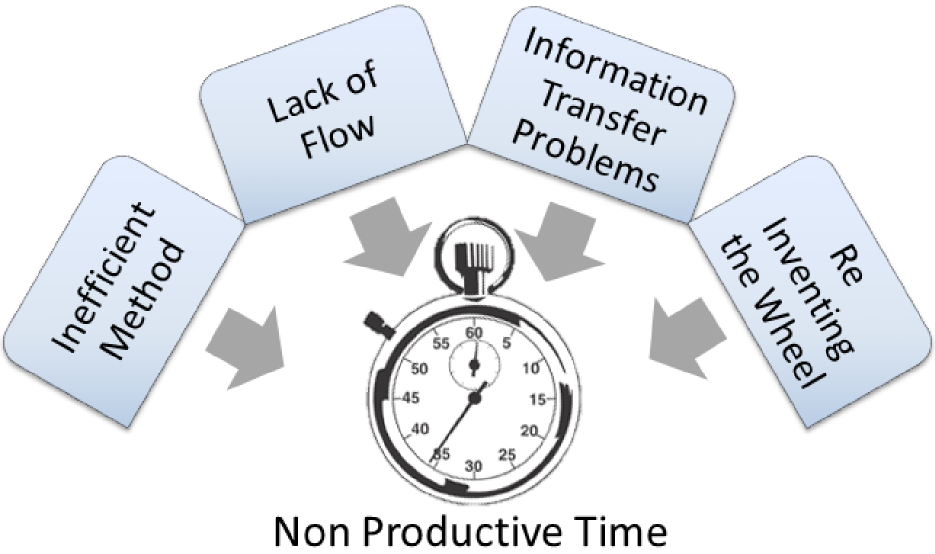


Figure 2.15: Types of non-productive time in an architectural office

Historically the architectural practices have been profligate in the use of paper. This is a costly, time consuming method and also raises sustainability issues. 35% of harvested trees are used for paper manufacture. The figures for the use of hardcopy in the construction industry in the US are shown (see figure 2.16). When considering non-productive time an area on which to focus is the reduction in the production of hardcopy (paper drawings, paper based reports).

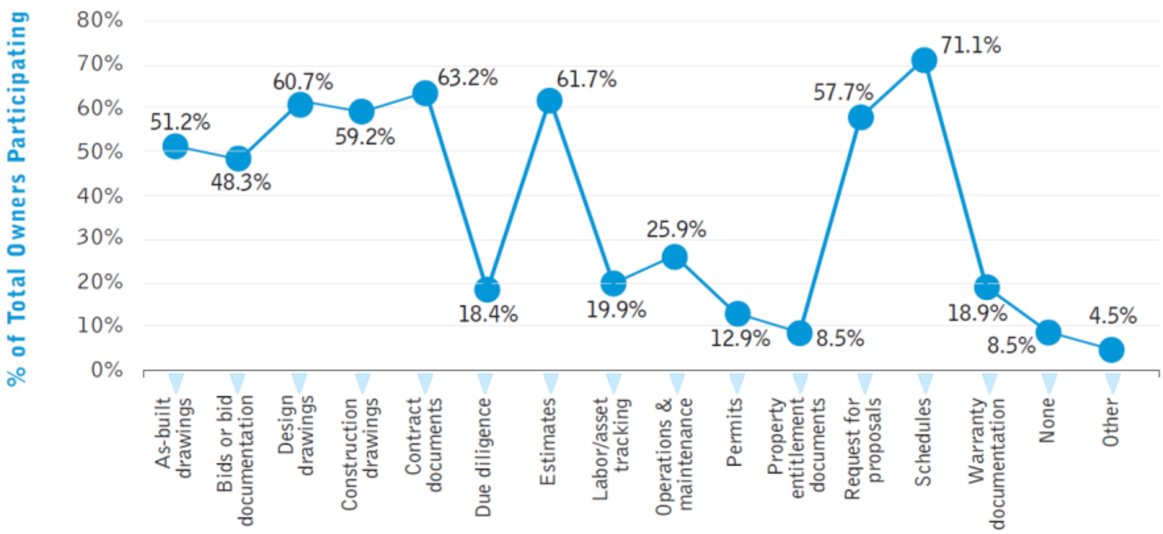


Figure 2.16: Electronic Document use in 2007 in US construction (FMI/CMAA 2007)

Electronic documentation has not been widely adopted in the construction industries and this represents an area of inefficient practice (see figure 2.17).

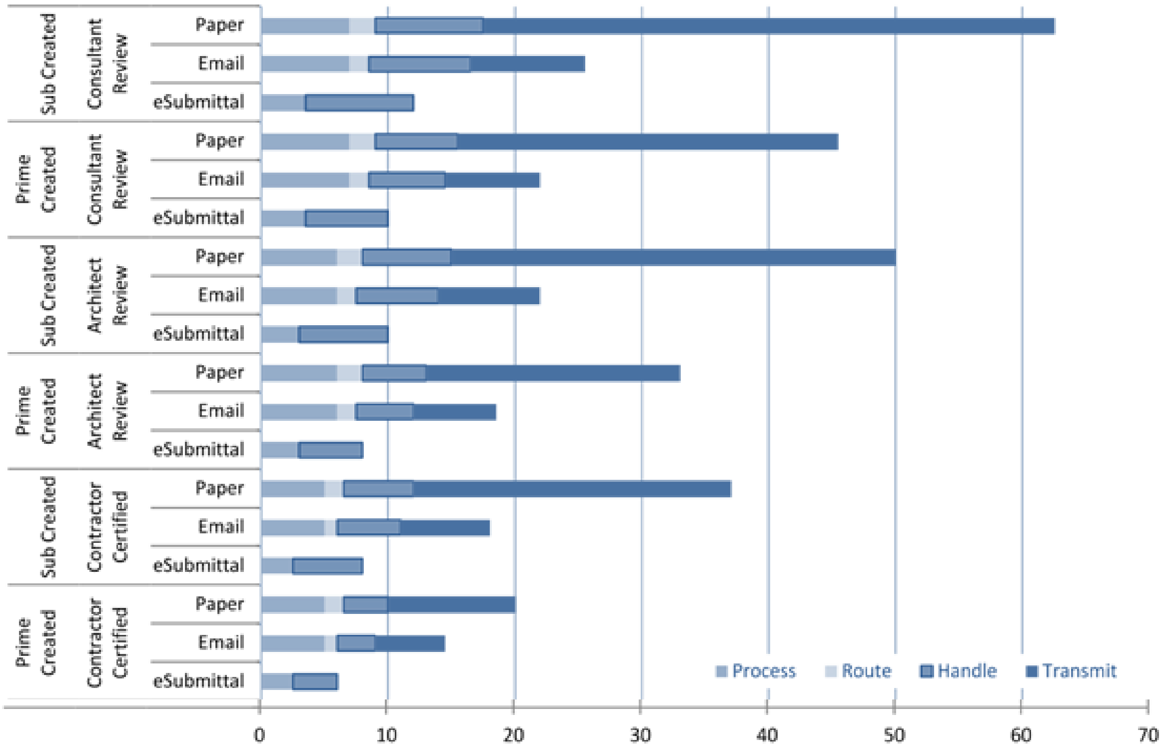


Figure 2.17: The Value Added Analysis of the Construction Submittal Process (East, Love 2011)

Paper based operation is inefficient in its method of transmission, it incurs and storage overhead and uses processed raw materials. Hardcopy leads to inconsistent information, difficulty in checking and validation, laborious tasks, duplication and versioning problems (Klancnick 2012).

According to Equisys (2006) one in six pages printed in the workplace is never used. Gartner Research has estimated that it cost £15 to file a piece of paper and £500 a year rental for a single filing cabinet. According to Gartner Research professionals spend 50 per cent of their time searching for information and it takes 18 minutes on average to locate each document. According to ARMA (the Association of Record Administrators) international companies misfile up to 20 per cent of their records, thus losing them for ever.

Waste occurs when a team is demobilized then remobilized. Information and the project momentum maybe lost in the process. This typical occurs during the planning or building control approval processes of a project. When it is possible to use the same staff over the life of a project the need for the waste of project staff induction is reduced.

2.5.5 To Operate in a Safe Way

The rate of accidents and ill-health is high in the construction industry and accounts for more than one third of fatal accidents for the whole UK workforce (HSE 2013) (see figure 2.18).

Main Industry SIC2007(Section)	Employees	Self Employed	Workers	Members of the Public	Total Fatal Injures
Agriculuture	14	22	36	5	41
Mining and Quarrying	6		6		6
Manufacturing	26	2	28	1	29
Gas, electricity and water supply, sewerage waste and recycling	8		9	3	11
of which waste and recycling (SIC38)	6		6	1	7
Construction	34	18	53	3	56
Services	41	10	50	380	431
All Industries	129	52	181	392	574

Figure 2.18: Number of fatal injuries by main industry, averaged from 2007/08 to 2011/12 (HSE 2013)

Architectural practices have an important role to play designing buildings and using materials that can be built, operated and decommissioned safely. Regulations are in place for this, the Construction (Design and Management) Regulations 2007 address these issues.

Buildings may fail for many reasons, structural failure, system failure, failure as a result of fire or deliberate damage. These raise health and safety issues and should be dealt with as part of the architectural design. New materials and new working practices also need to be tested and analysed to avoid failure in use.

2.5.6 To Reduce Waste

Material waste can occurred during the construction of a building or during its operation. Over 31% of materials used in the construction industry currently become waste (Economist 2002) (WRAP 2011). The use of raw materials has increased exponential in construction over the last century (see figure 2.19). The use of materials is one of the major facts related to sustainable issues.

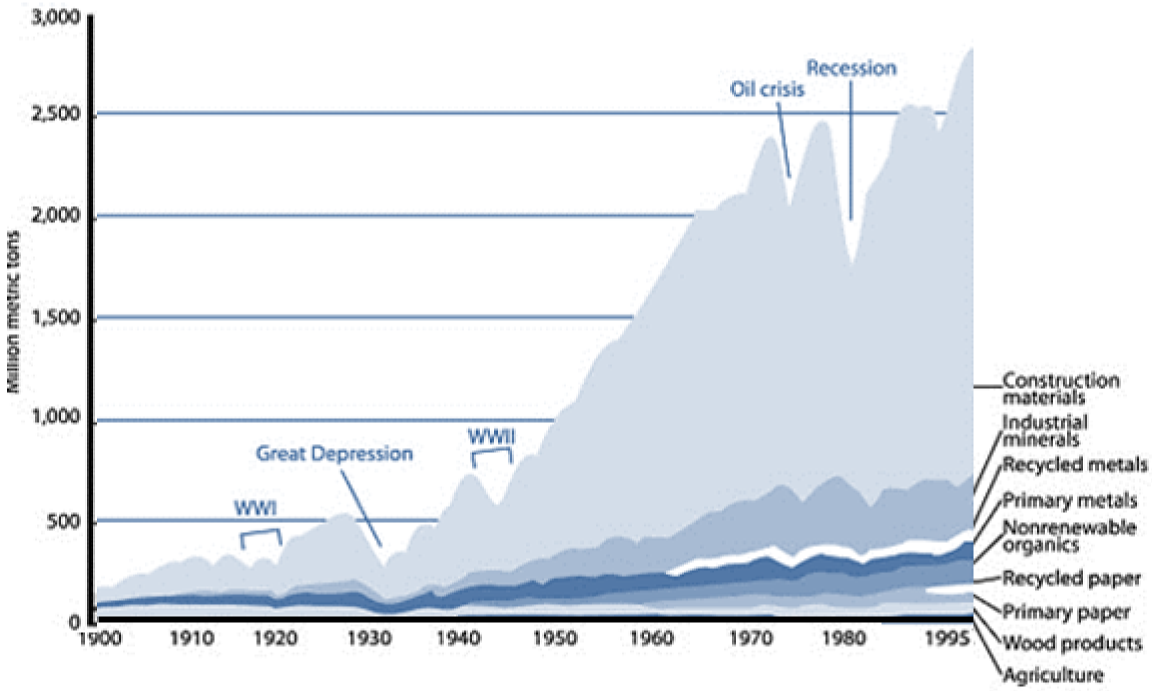


Figure 2.19: Use of raw materials curve, US, 1900 - 1995 (Matos 1998)

When considering scarce resources there are four major items. These are water, energy, construction materials and labour.

2.5.6.1 Material Waste

Waste may occur as part of design as a result of configuration and geometry. Unnecessary area may be taken by excessive circulation space or rooms that are larger than necessary. As part of the design process there needs to be a drive to eliminate such wastes which unless corrected represents an unnecessary overhead or drain over the whole building lifecycle. Buildings can also be wasteful in the materials they use. Construction waste represents 22% of the waste produced in the UK (see figure 2.20).

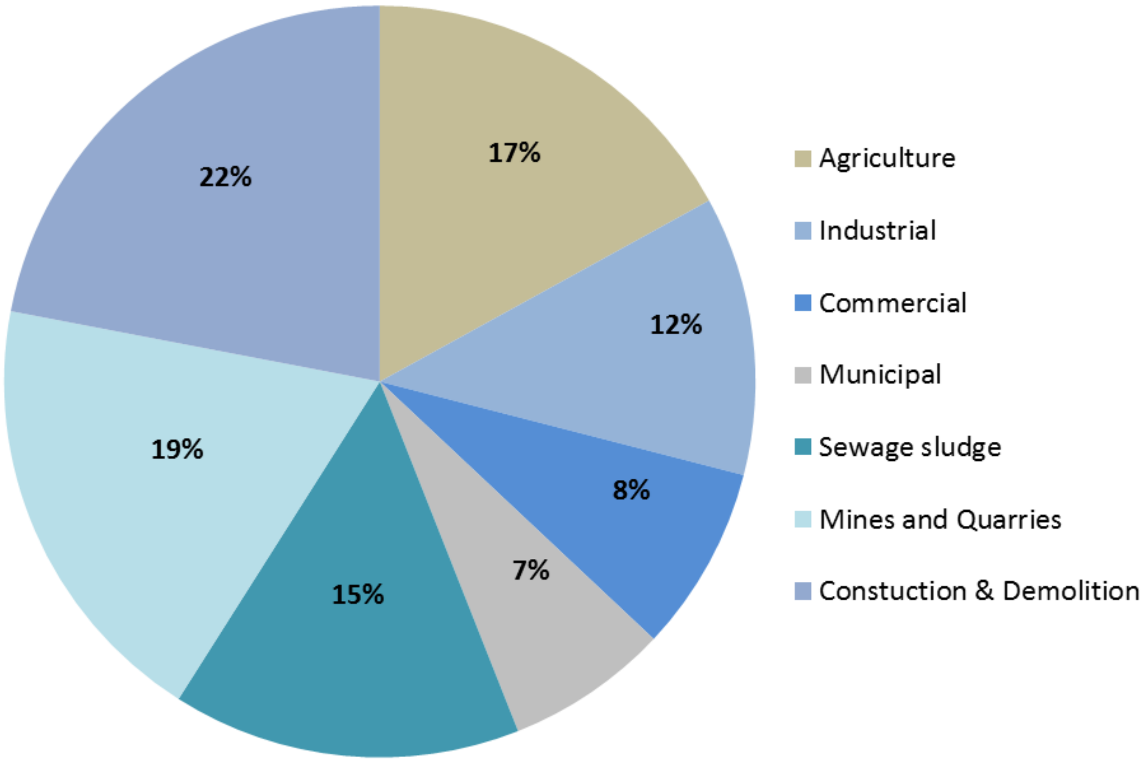


Figure 2.20: Types of waste generated by weight in the UK in 1999 (DETR, 2000)

If buildings are designed to material sizes for example 3.6 m the normal maximum size of a piece of 5mm float glass or modules of this size waste can be minimised.

The distance a material needs to travel before it is install can have a significant effect on its level of embedded carbon. Taking positive action at the design stage of a project can result in significant savings in costs, wastes and carbon throughout the lifecycle.

2.5.6.2 Water Usage and Waste

The UK has become the sixth largest importer of water in the world (Lawrence 2008). Only 38% of the UK's total water comes from its own resources. Each Briton uses 4,645 litres a day when hidden factors (water for food and clothes) are included. Compared with other countries the UK has a particularly high domestic and industrial water usage (see figure 2.21).

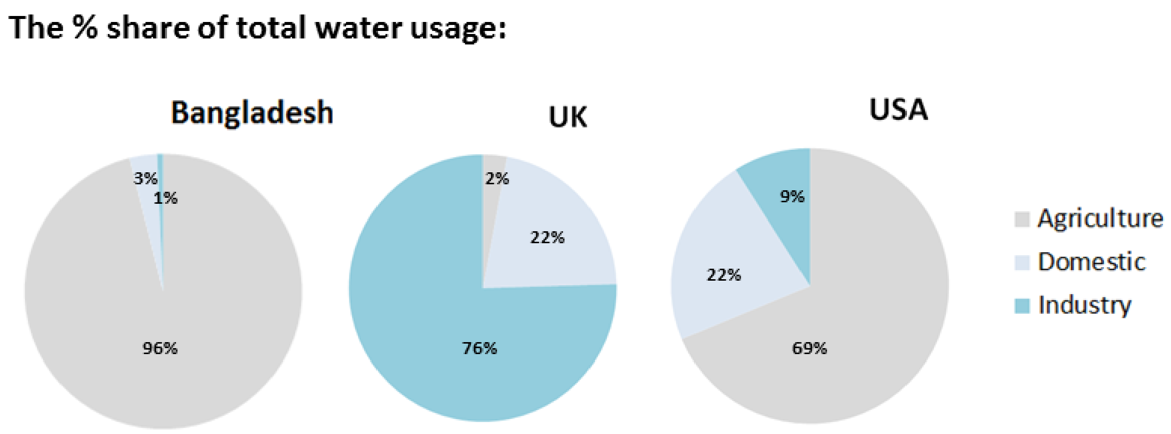


Figure 2.21: Showing the comparable water usages in Bangladesh, UK, Malawi and the USA (BBC 2012)

A considerable amount of water is also wasted through leaks and other factors (see figure 2.22).

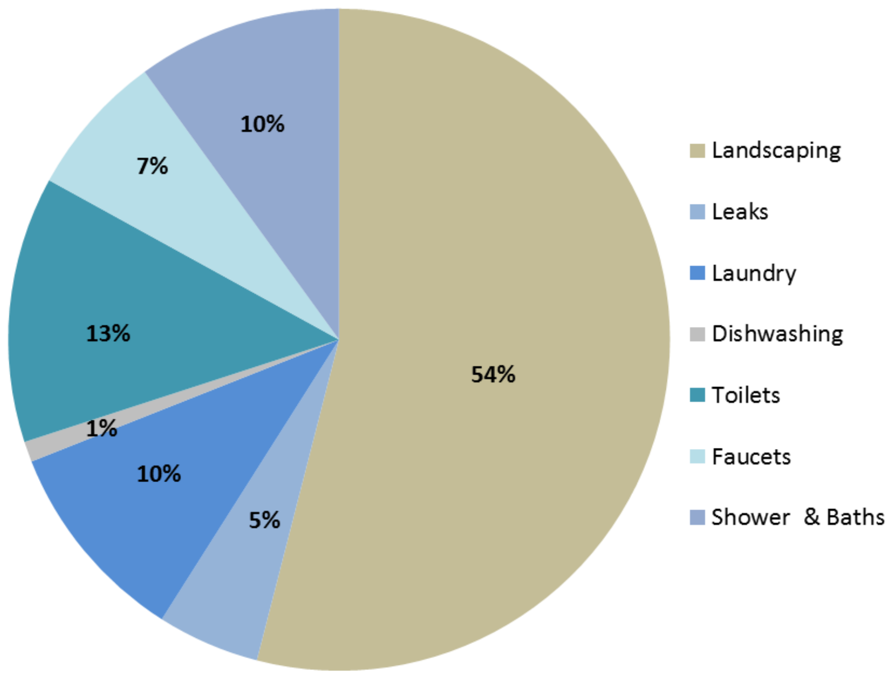


Figure 2.22: Average single family residential water use (USA) (Knight 2011)

2.5.6.3 To Avoid Informational Waste

"Project-based organization face substantial obstacles to be overcome in capturing knowledge and in the re-cycling of project-based learning that stem from the relatively self-contained, idiosyncratic and finite nature of project tasks"

(Bresnen et al. 2003)

The traditional process used within the construction industry has been described as one of data atrophy (Brandon 2011) (see figure 2.23).

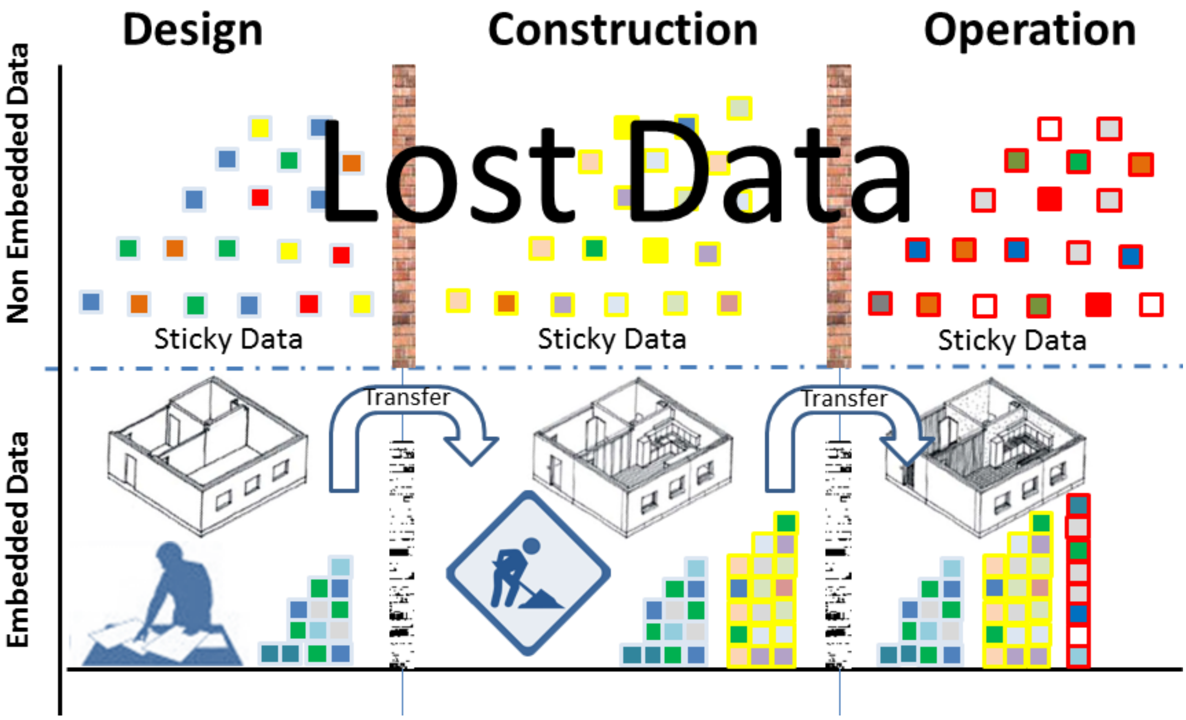


Figure 2.23: Data normally lost using traditional contracts and traditional methods

2.5.6.4 To Reduce Energy and Carbon Footprint

38% of carbon emissions are generated from buildings (USGBC 2007). Predictions of climate change are driving the need to reduce our energy usage and carbon emissions.

Climate change is the biggest problem that civilisation has had to face

Sir David King former Chief Scientific Advisor, UK

The average temperature and the average sea level has been rising and the snow cover in the northern hemisphere has been decreasing (see figure 2.24). Different scenarios and future estimates for continued global warming exist (see figure 2.25).

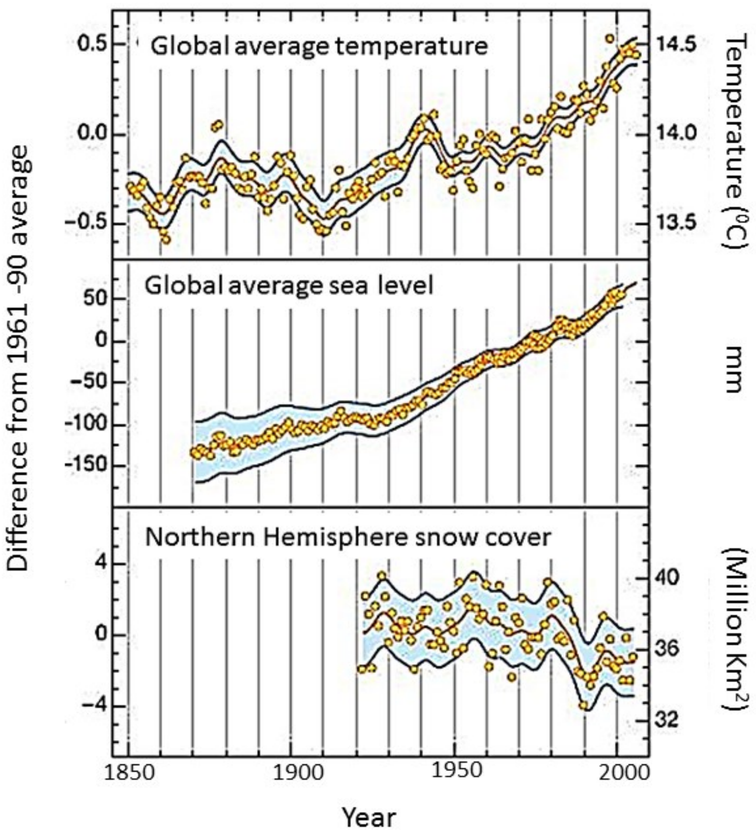


Figure 2.24: Changes in global average temperature, global average sea level and northern hemisphere snow cover (Soloman 2007)

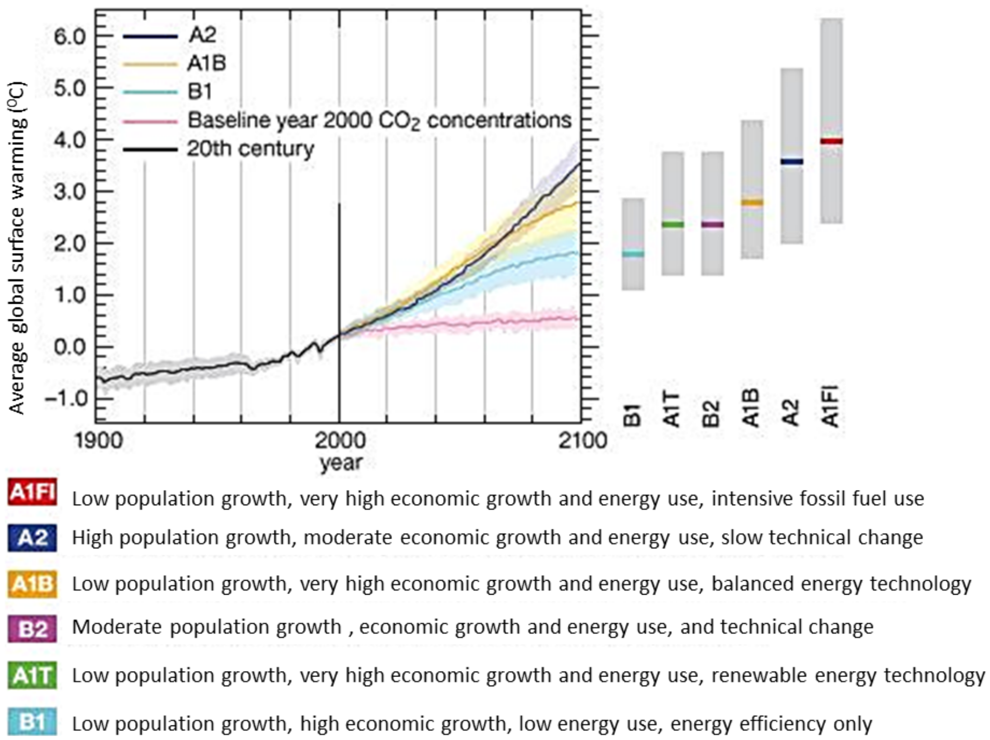


Figure 2.25: Global warming estimations of past and future global warming (Soloman 2007)

Sustainable development requires that the building does not cause unnecessary load or risk to the environment. The term “sustainable development” was introduced and defined in the Brundtland Report (WCED, 1987) as: “…development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” A green building approach could also be a way to address the problems of sick building syndrome (Deluca 2012).

The phrase, "people, planet, profit", was coined by Elkington (1997). This reflected in the triple bottom line view of sustainability embracing community, economy and environment (see figure 2.26).

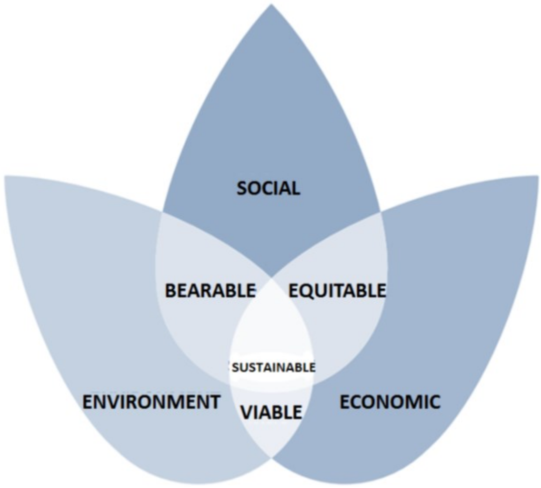


Figure 2.26: The three of areas sustainability illustrate interdependence of the elements (Adams 2006)

The sectorial CO_2 reductions necessary to reach an 80% emission reduction have been set out (see figure 2.27).

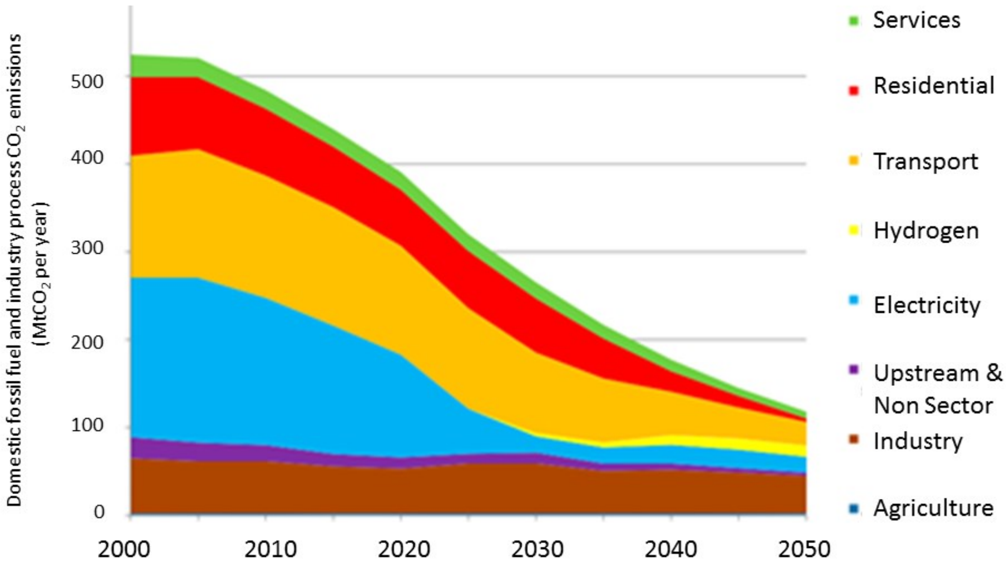


Figure 2.27: UK sectorial CO_2 emissions to 2050 on an 80% emission reduction path (Committee on Climate Change 2008)

To meet these new targets the range of criteria for successful buildings has increased (see figure 2.28).

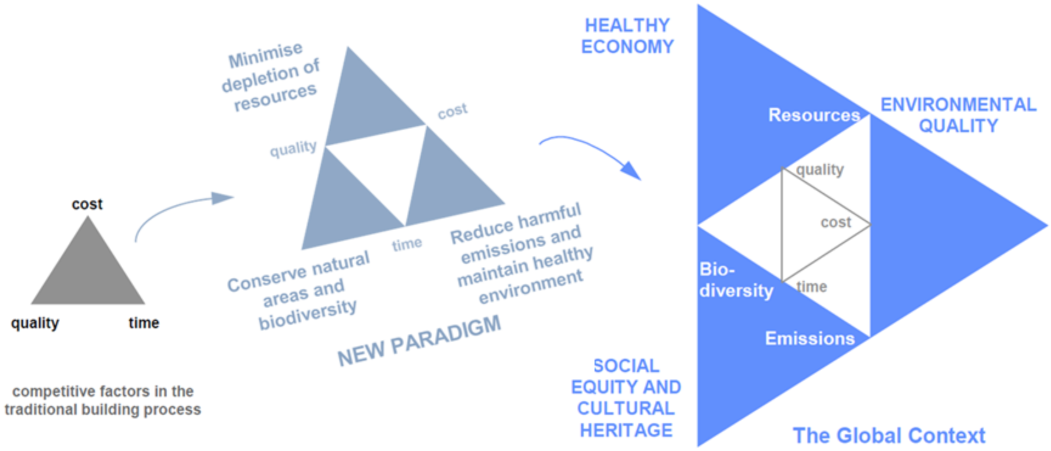


Figure 2.28: Challenges of sustainable construction in a global context (Huovila et al 1998)

The concept of low carbon incorporates several concepts (Department for Business Innovation and Skills 2010):

- Energy efficiency
- Renewable energy sources
- Low environment impact
- Zero Waste
- Sustainable materials
- Reuse
- Adaptability for the future

Increasing energy prices and climate change are driving the need to develop more sustainable buildings and infrastructure. The Government has set itself an ambitious target to cut the UK's carbon emissions (CO_2) by 80% by the year 2050 (HM Government 2011). How energy is used by the different sectors in the UK is shown (see figure 2.29). 27% of the UK's CO_2 emissions come from energy use in homes.

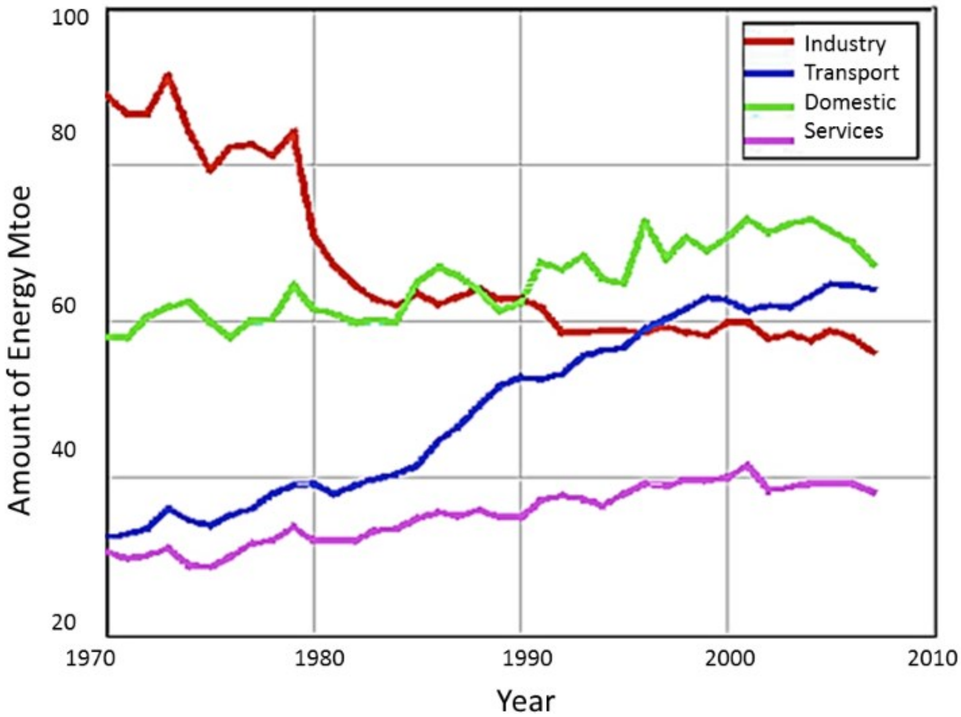


Figure 2.29: Total energy consumption per sector (MacArthur 2010)

The energy used comes from multiple sources (see figure 2.30). The major use of energy in a building comes during the operation phase of its lifecycle (see figure 2.31).

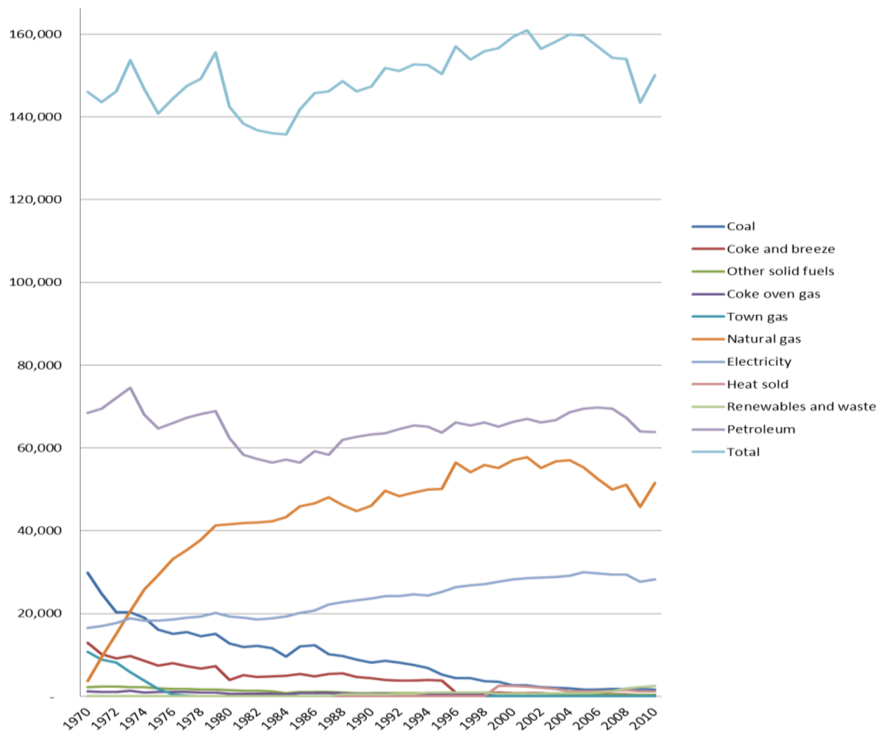


Figure 2.30: Final energy consumption by fuel 1970 to 2010 in the UK shown using thousand tonnes of oil equivalent (Source: Department of Energy and Climate Change - Digest of UK Energy Statistics Annex, Table 1.1.5)

Sub-Sector	Greenhouse Gas Emissions Mt CO2e	% of total Carbon Footprint
Design	< 0.1	< 1%
Manufacture	39.8	13%
Distribution	6.1	2%
Operations on-site	4.5	1%
In Use	255.9	84%
Carbon Footprint Total	306.3	100%

Figure 2.31: Estimate of carbon footprint of UK construction 2007 (Department of Business Innovation and Skill 2010)

Sustainability is not just related to the building construction methodology, it also relates to the location of the site, the transport needs of the users and the way in which the energy use of the building is kept to a minimum.

The Code for Sustainable homes has been developed to reduce carbon dioxide emissions. This is achieved by applying the different levels of the code for sustainable homes is shown (see figure 2.32 and 2.33). For non-domestic building types the BREEAM (BRE Environmental Assessment Method) regulations apply.

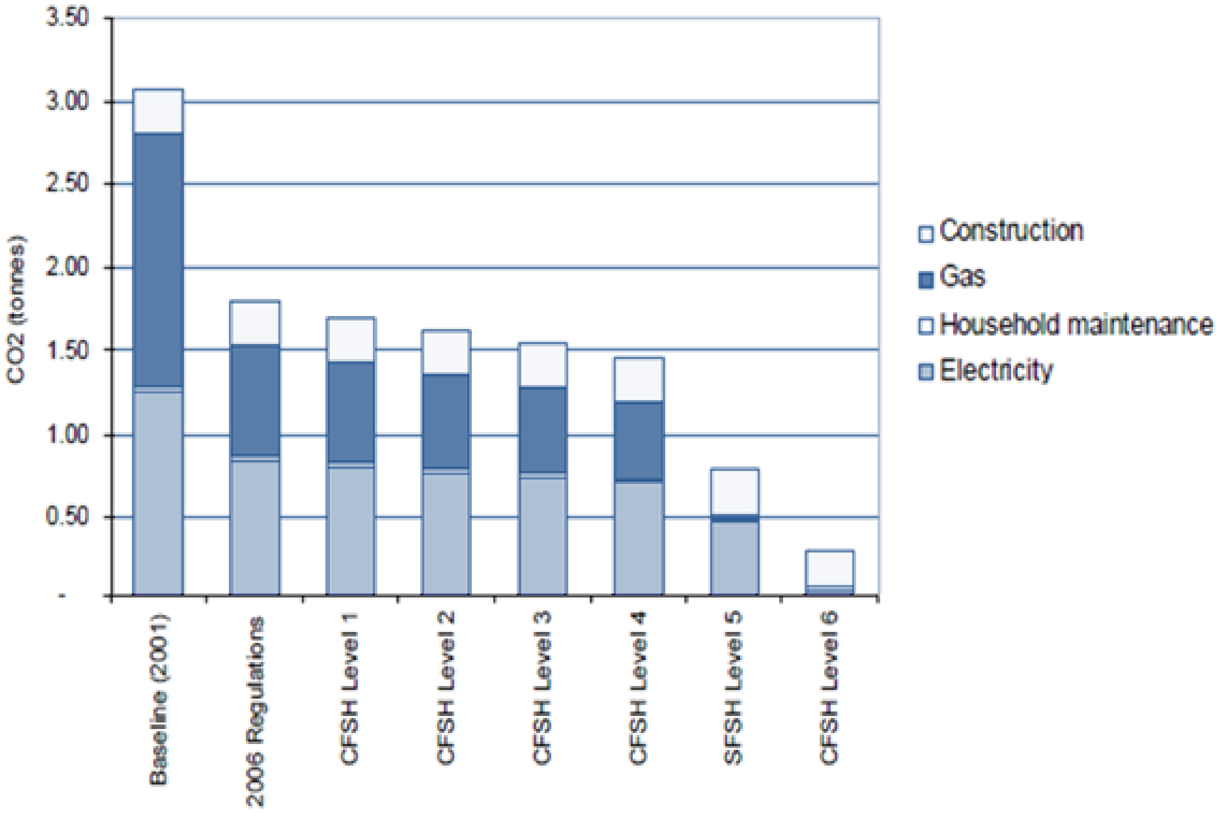


Figure 2.32: Carbon dioxide emissions of the code for sustainable homes (Barrett 2007)

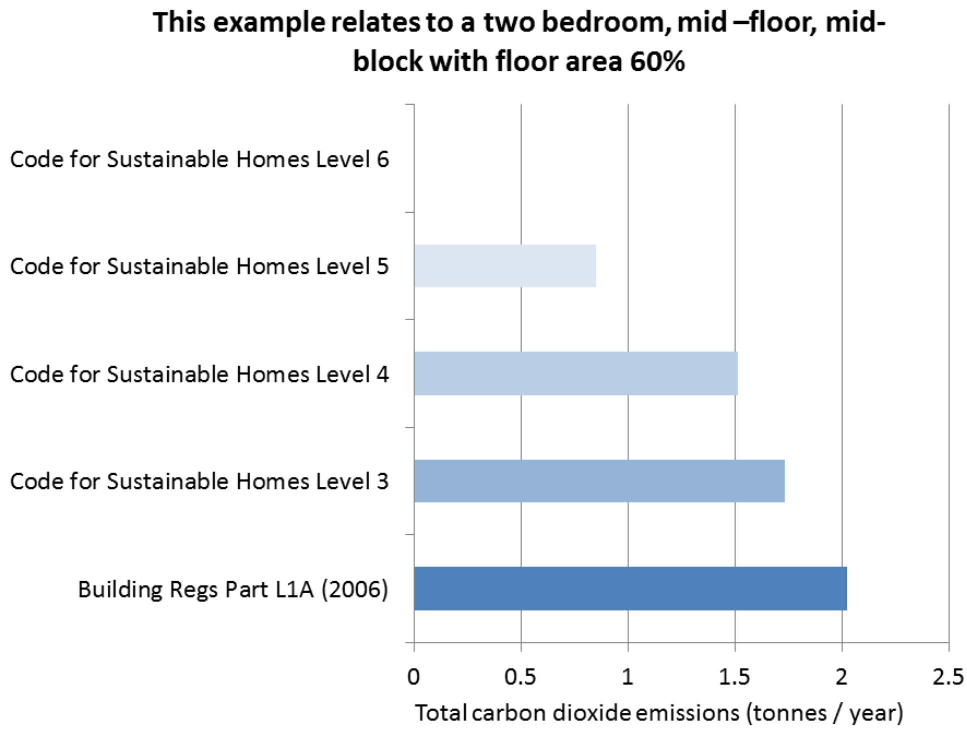


Figure 2.33: Total carbon emissions when different levels of code for sustainable homes is applied for a two bedroom flat (RIBA 2009)

It has been estimated that operation and maintenance programs targeting energy efficiency can save 5% to 20% on energy bills without a significant capital investment (PECI 1999).

The level of post occupancy evaluation (also known as facility performance evaluation or building performance evaluation) undertaken today is minimal so we are failing to learn from the problems that are occurring today in the real world (Bordass 2011). Government soft landings (GSL) using BIM is one approach that sets out to address this. Some large clients have started to realise that a building should not only be considered a physical asset but also as an innovative artefact for leveraging a business's ability to generate more value (Spencer and Winch, 2002). Moves in by the Department of Energy are taking place to develop a building performance database where building performance can be compared (Chen 2013).

2.5.6.5 To Reduce Costs

The normal practice in the UK that cost estimating is undertaken a Quantity Surveyor. The professional institution with which most English-speaking quantity surveyors are affiliated with is the UK-based Royal Institution of Chartered Surveyors (RICS).

Whether architects undertake pricing or this is undertaken by others architects need to be aware of cost implications of design decisions as the project progresses.

Building projects when completed often are not delivered within budget estimates (Flyvberg, B. 2002). The focus of the construction industry is not just to build building but also to adopt and maintain and on-going process of continual improvement and cost reduction. This cost reduction is both in terms of CAPEX and OPEX. New costing mechanisms such as target costing and target value design offer potential methods to control and reduce costs (Macomber et al 2007).

2.6 The Tasks and Processes Undertaken by Small Architectural Practices

2.6.1 Introduction

The role of architectural practice and the specific tasks that architect undertake are reviewed in this section and evaluated.

2.6.2 The Role of the Architect and Architectural Practices

2.6.2.1 Analysis of Architectural Practices in the UK

Architectural practices are heterogeneous in nature and may exist as sole practitioners, partnerships or limited companies. These organisations may just employ architects or contain a wide range of disciplines. These organisations or communities of practice (Lave & Wenger 1991) may be considered to comprise of several interrelated entities (see figure 2.34).

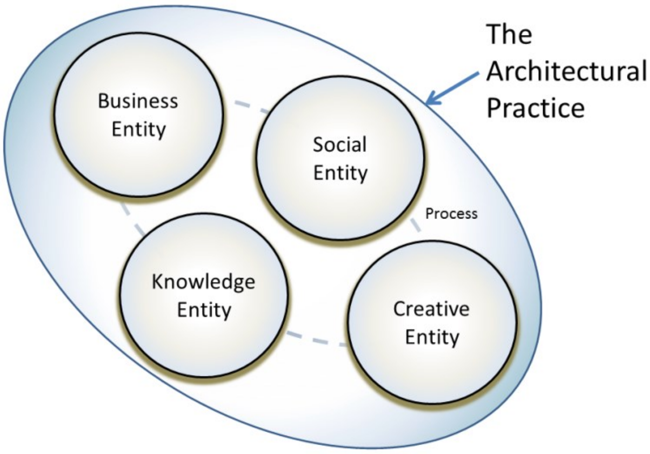


Figure 2.34: The architectural practice as an entity

An architectural practice can be considered as an activity (a professional services firm) that produces architecture. Such a service has been described as:

“A process consisting of a series of more or less intangible activities that normally, but not necessarily always, take place in interactions between the customer and service employees and / or physical resources or goods and / or systems of the service provider, which are provided as a solutions to customer problem."

Gronross 2000

Organisationally, architectural practices stand at a three way intersection between the creative industries, professional services and the construction industry (Smyth 2011). Architectural practice can be thought of as the interaction of people, processes and technology (Arayici 2011).

The distribution in terms of size of architectural practices is shown (see figure 2.35). 79% of Architects Practices in the UK are fewer than 10 people (RIBA/Colander Business Benchmarking Survey 2010).

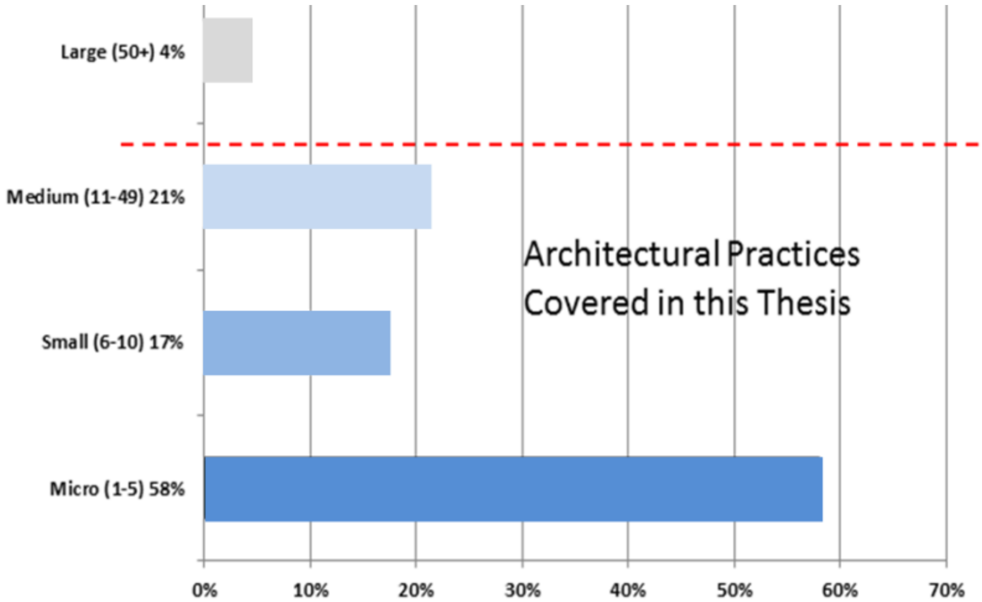


Figure 2.35: Number of employees (as a percentage) in Chartered Architectural Firms (RIBA 2008)

The average earning per employee is greater in larger architectural practices (Mirza & Nacey Research Ltd 2011).This raised the question asked why is there are so many "micro" practices? One explanation for this is that micro practices allow a single owner to know and manage all the workings of the company. Also a small scale provides the best conditions for creativity (an important element of architectural practice). Even large firms will carry out projects in small teams. Small practices attract many of the best of Britain's architects.

According to research the main driver for innovation in architectural practice in the UK is improving the product and service quality (see figure 2.36).

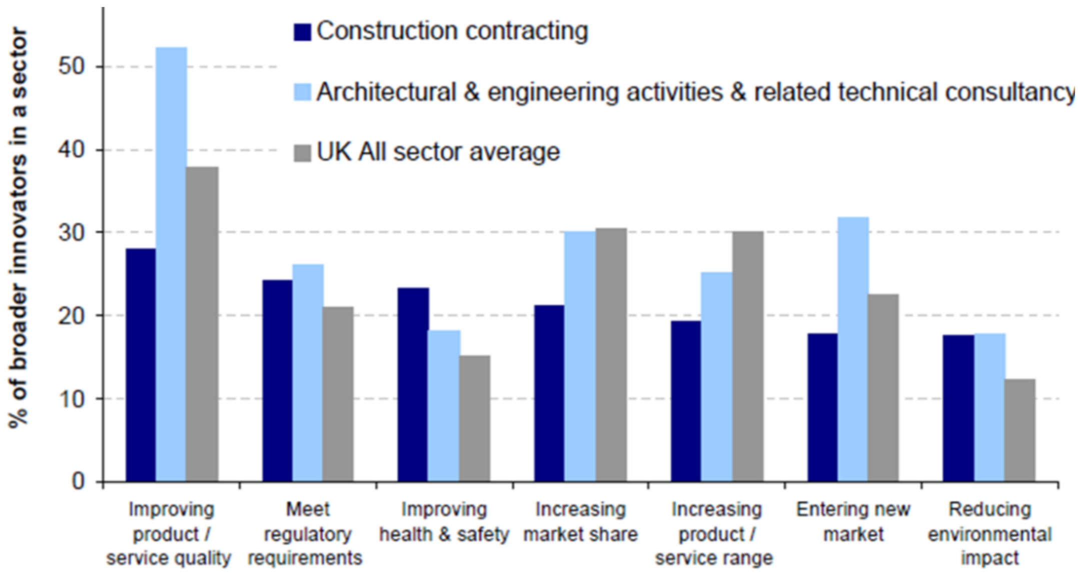


Figure 2.36: Reported main drivers of innovation among broader innovators in construction (BIS Community Innovation Survey 2011)

2.6.2.2 The Practice of Architecture

The work of architects is prescribed by the directions of clients and developers. It is the re numeration from these bodies that allows for the continued existence of architectural practices (see figure 2.37).

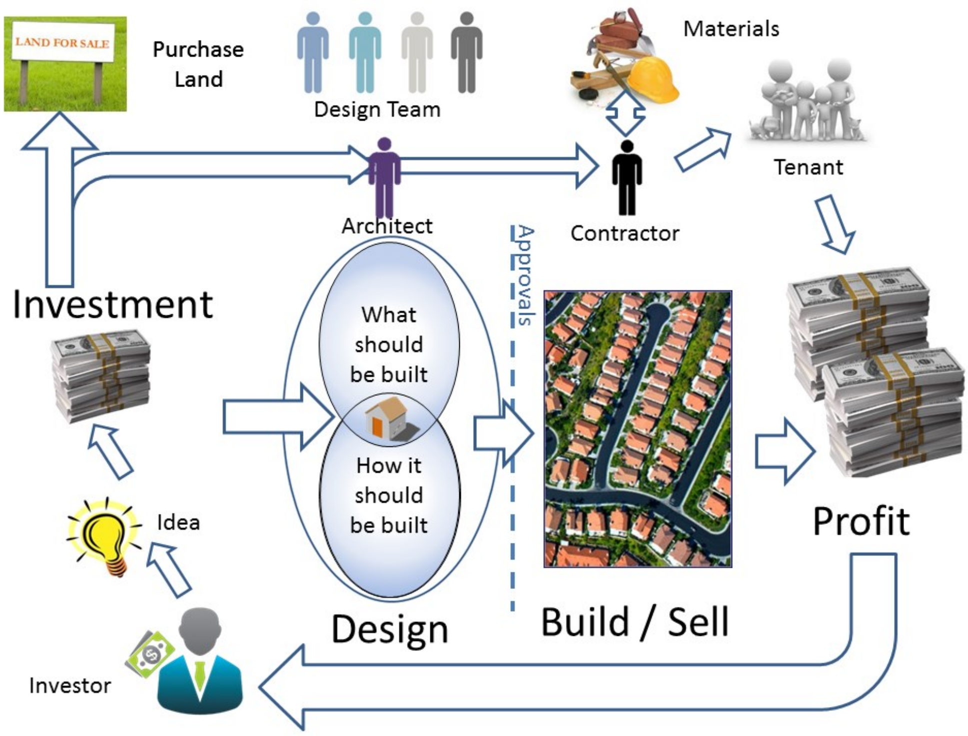


Figure 2.37: The architect within the development process

The role of architects is to increasing value of land and the assets on that land through considered and insightful change.

Architects are usually the critical element in ensuring that buildings work effectively at a holistic level. Architects also have a major influence on the selection of products and sustainable issues. Elegant solutions, which are both refined and simple, to complex problems are one of the benefits that good architectural design can produce. Architects involvement early in the development process means the way they do their work and the designs they produces can have radical implications on the efficiencies and effectiveness achieved downstream in the development process.

Providing creative solutions remains one of the primary challenges to architects. The law requires professional consultants (architects) to meet the standards of competence prevailing in their professions at a particular time (see figure 2.38).

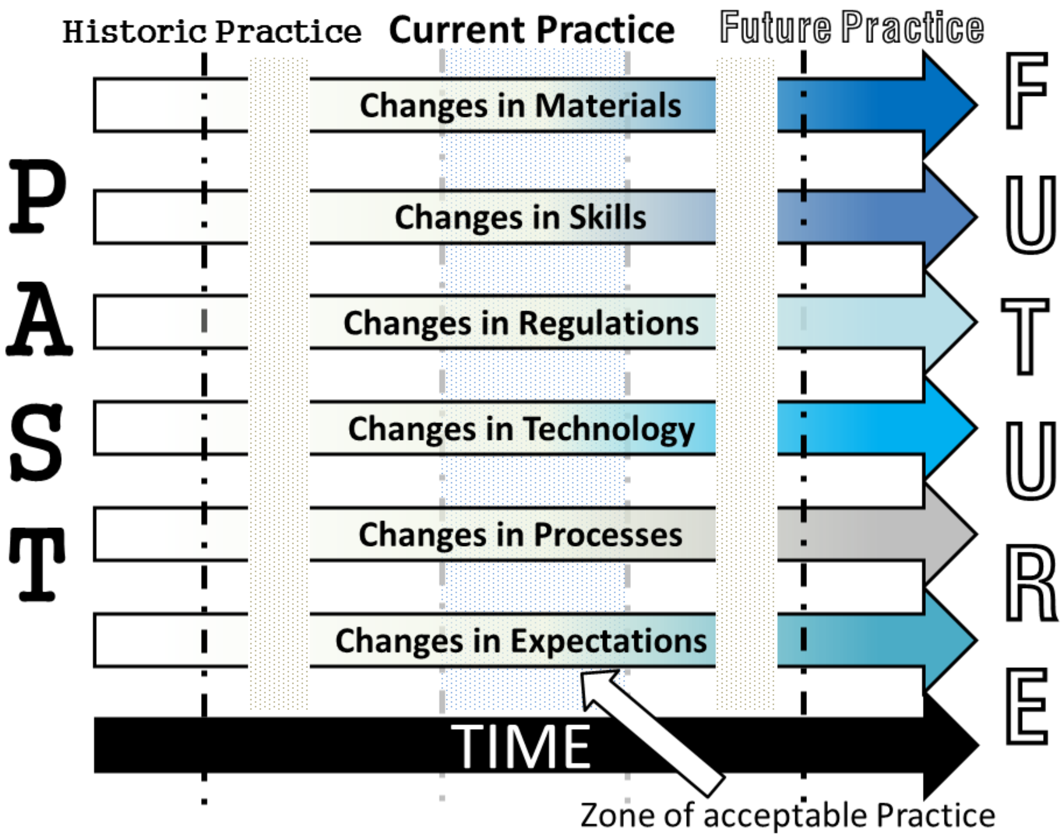


Figure 2.38: Changes continually taking place within the architectural professions

Architects require many areas of knowledge and skill sets in order to undertake their work (see figure 2.39).

A study of construction project teams found that 83% of the information used on project is tacit knowledge (i.e. based on the cumulative past experiences of the individuals involved and not from explicit sources such as guides, standards, or other documents) (Hanlon & Sanvido, 1995). This makes understanding what is taking place difficult for an outsider to understand.

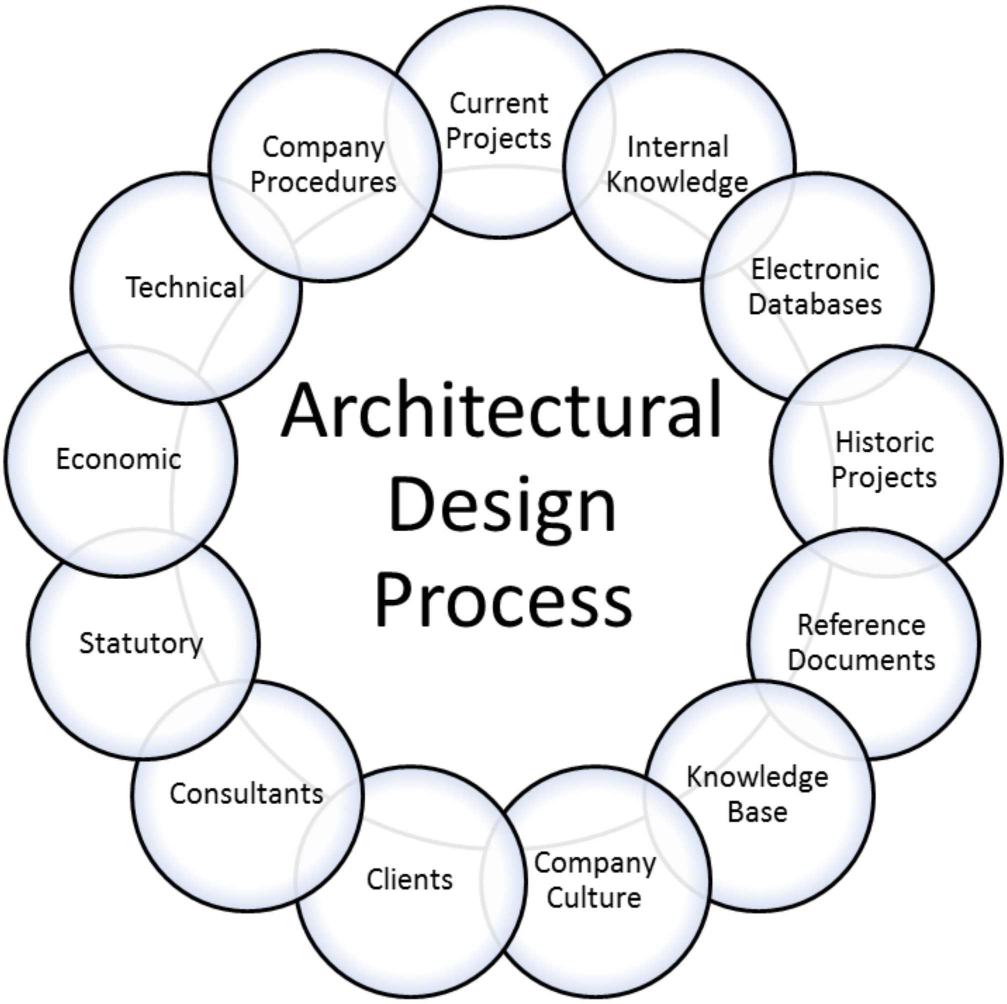


Figure 2.39: Knowledge need during the architectural design process

2.6.3 The Emerging Demands to be Placed on Architectural Practice

The success of architectural design is significantly predetermined by the quality of the briefs developed (RIBA 2013). The general requirements that are normally to be met by architects are set out in the Whole Building Design Guide (see figure 2.40).

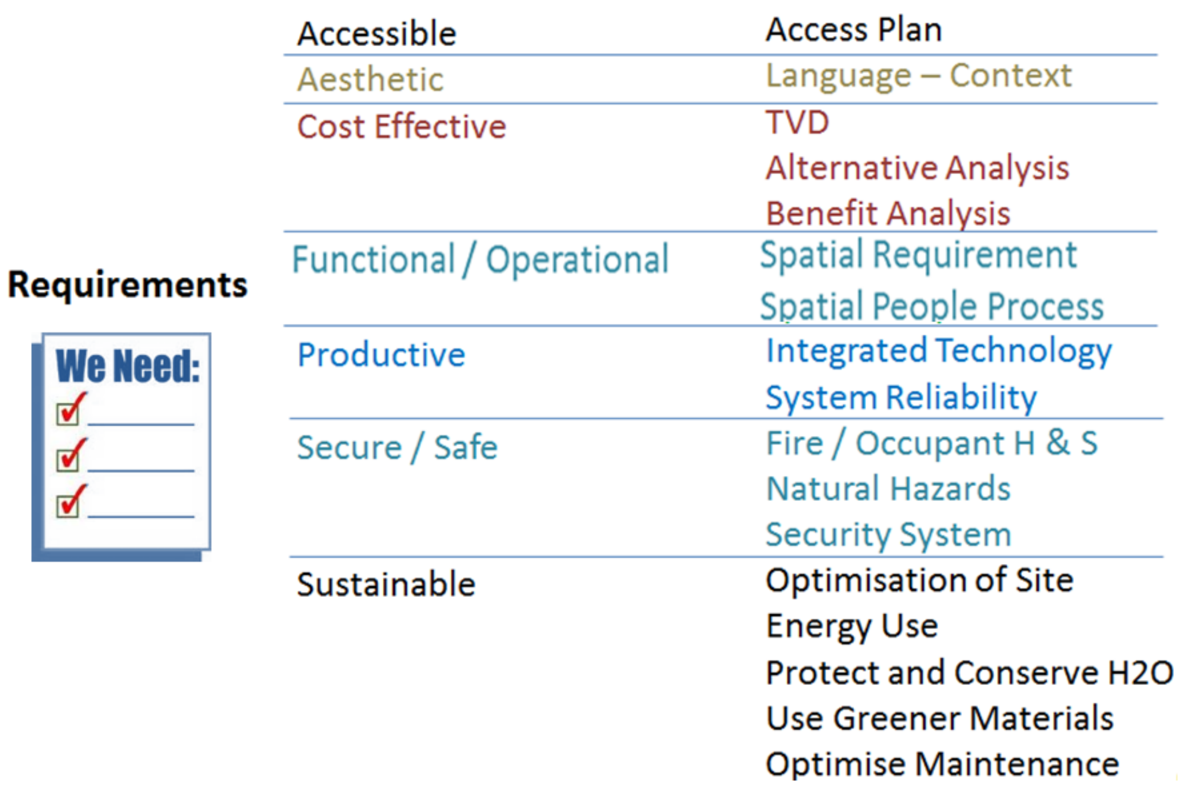


Figure 2.40: The building requirements normally to be met by architects (Whole Building Guide 2013)

According to Fridstein (2012) architectural practices face many challenges to stay in business (see figure 2.41).

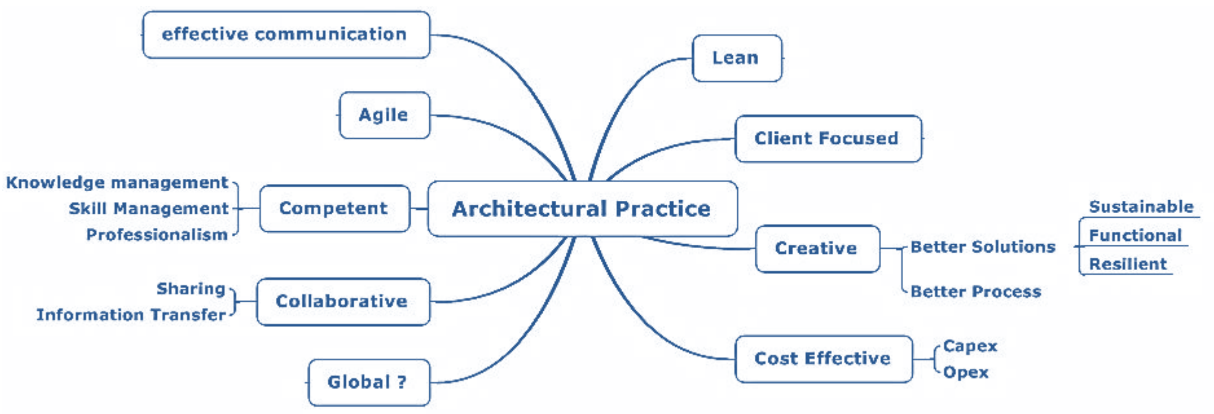


Figure 2.41: The challenges facing an architectural company (adapted from Fridstein 2012)

According to Mason (2000) the challenges that face an architectural practice include:

- Developing an appropriate business plan
- Developing a marketing plan
- Managing people
- Finding Clients

- Finding employees
- Managing accounts
- Reducing time wasted
- Managing Finances
- Office management

Some of the challenges demand a change in operation, others demand a change in the product produced and some demand higher levels of cooperative organisation.

When considering the product produced by the construction industry (buildings) three perspectives have been suggested. These perspectives are the return on investment, occupant and functional needs and environmental needs (Leaman et al 2010).

The new demands facing the construction industry and the architectural profession particularly were identified (see figure 2.42).

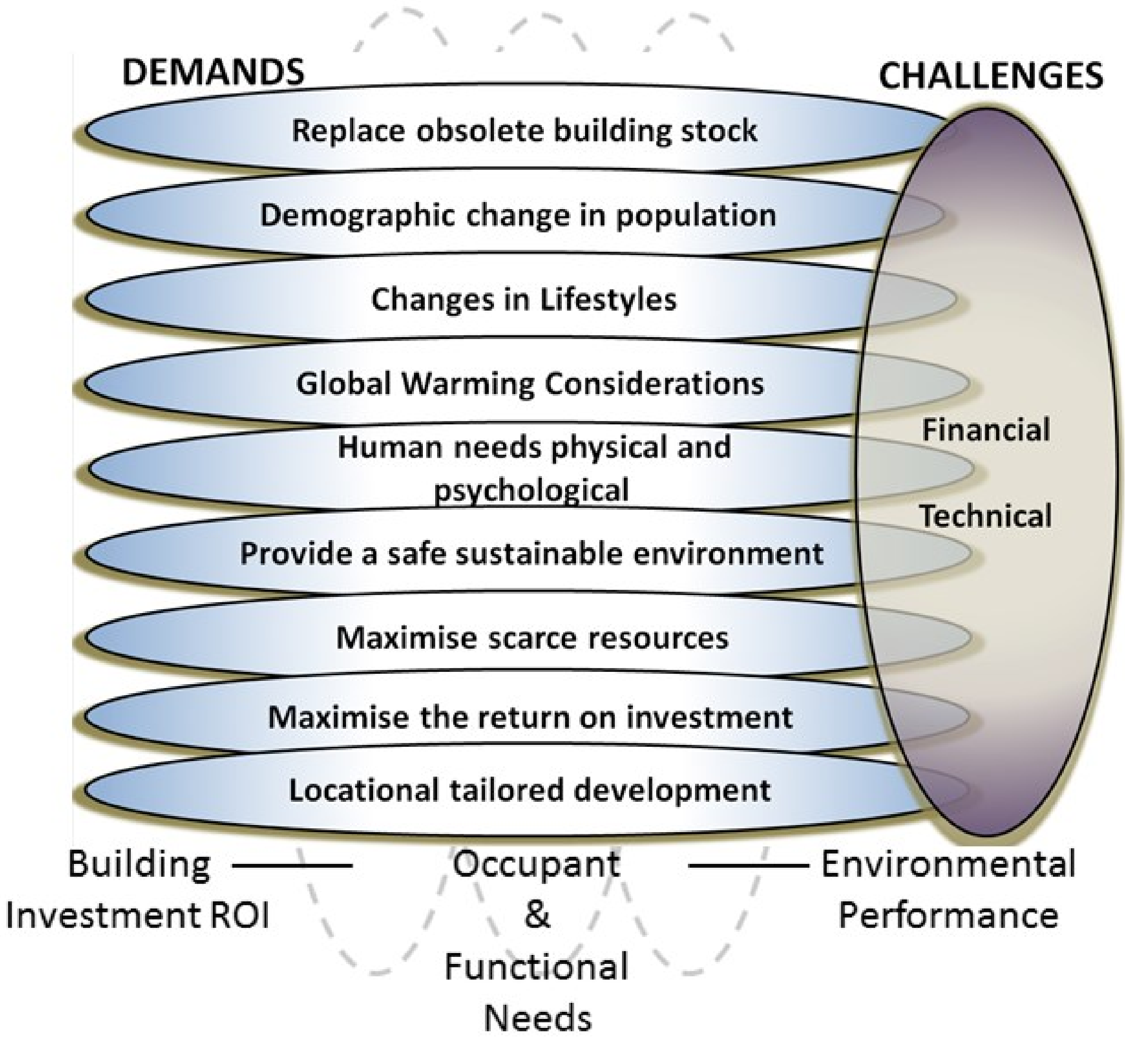


Figure 2.42: Demands facing our Built Environment

2.6.4 Obsolete Buildings

38% of the building stock currently in the UK was built before 1944 (see figure 2.43). For non-domestic buildings 31% are pre 1940.

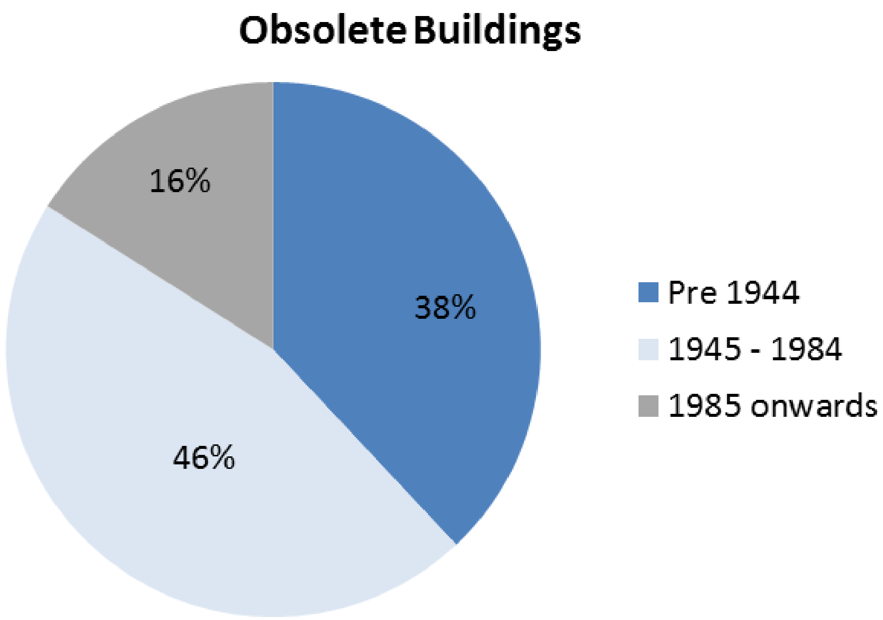


Figure 2.43: The Age of Housing Stock in the UK (Source: CLG Live tables, table 110: Year Built by Region)

Buildings become obsolete for several reasons. They may become obsolete functionally, environmentally, economically, in terms of location or by failure to meet current standards. Property consultants claim that one in 10 commercial buildings will be "rendered obsolete" by proposed regulation to prevent the sale or lease of offices that do not meet strict environmental standards (Neate 2010).

Two options exist to address the demand of obsolete buildings:

- To find and implement ways of stopping buildings becoming obsolete

- To find cost effective ways of replacing obsolete buildings

Stopping buildings becoming obsolete to some extent is determined by good design, good product selection and the design of flexible buildings.

2.6.5 Demographic Changes

Demographic transition may also result in buildings becoming obsolete. Britain's current population is expected to grow from 61 million to 71 million by 2031 (ONS 2012). The fastest growing age group in the population are those aged 80 years and over (see figure 2.44).

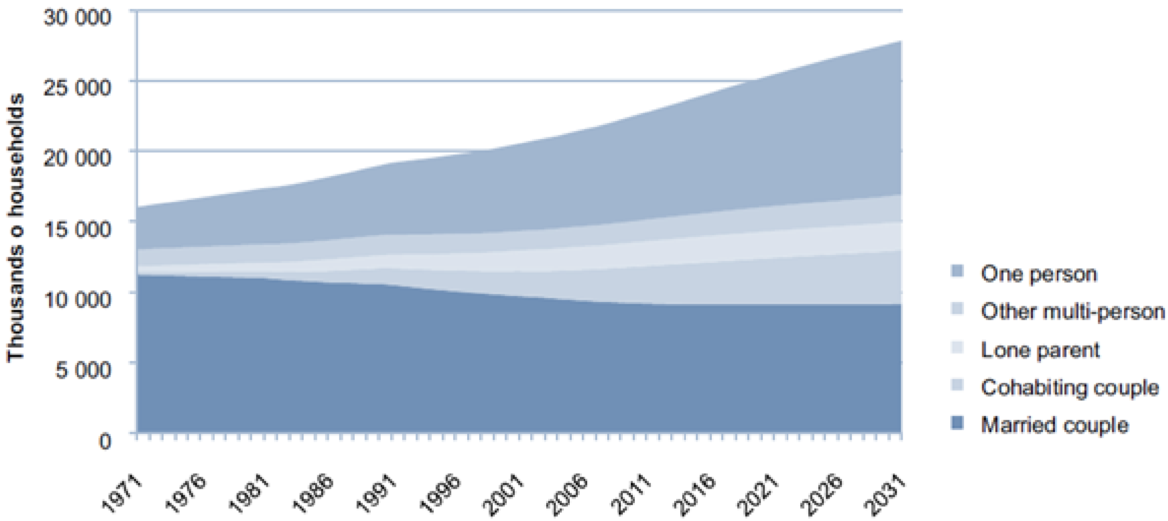


Figure 2.44: Household estimates and projections by household type, England
Source : CLG Live Table 402 (Goodier 2010)

With an aging population comes increasing levels of disability (see figure 2.45).

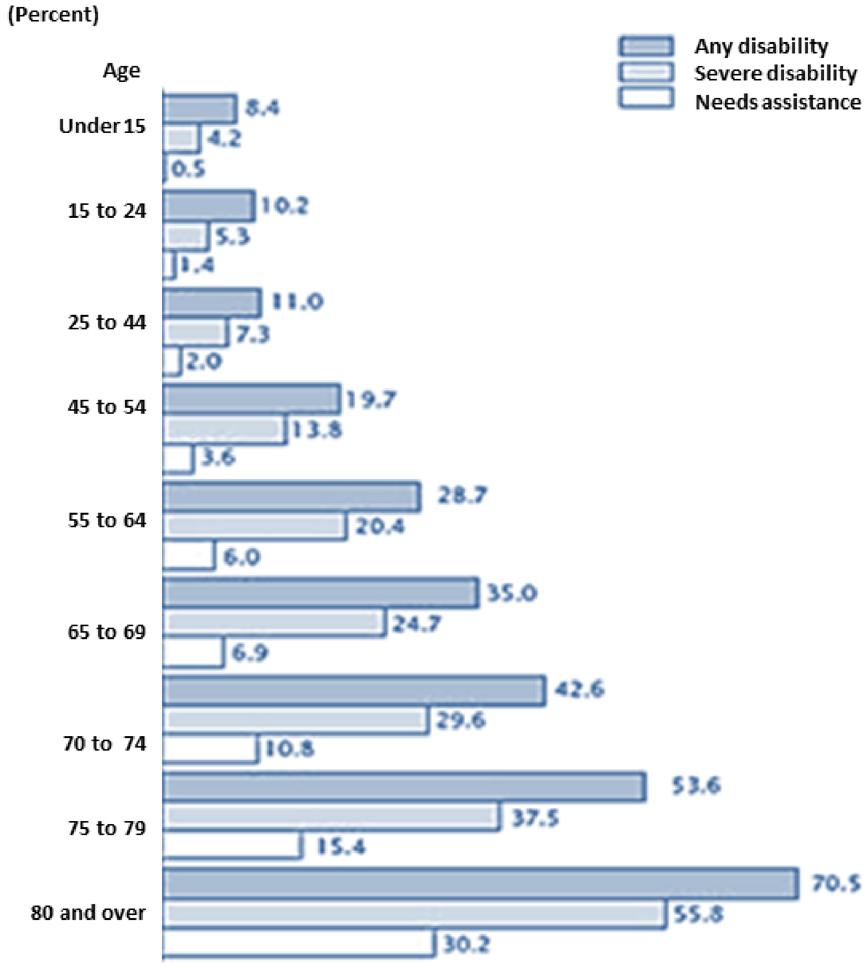


Figure 2.45: Disability Prevalence and the Need for Assistance by Age: 2010

(Source US Census Bureau, Survey of Income and Program Participation May – August 2010)

To cope with these changes both new and existing buildings will need to be modified. As a result of the Disability Discrimination Act (DDA) service providers are now legally obligated to make "reasonable adjustments" to the physical features of their premises to overcome physical barriers to access. In future additional legislation is likely to change the built environment to make it more suitable for an aging population. The number of houses required will also be affected by the current baby boom (see figure 2.46) and the increasing levels of immigration (see figure 2.47).

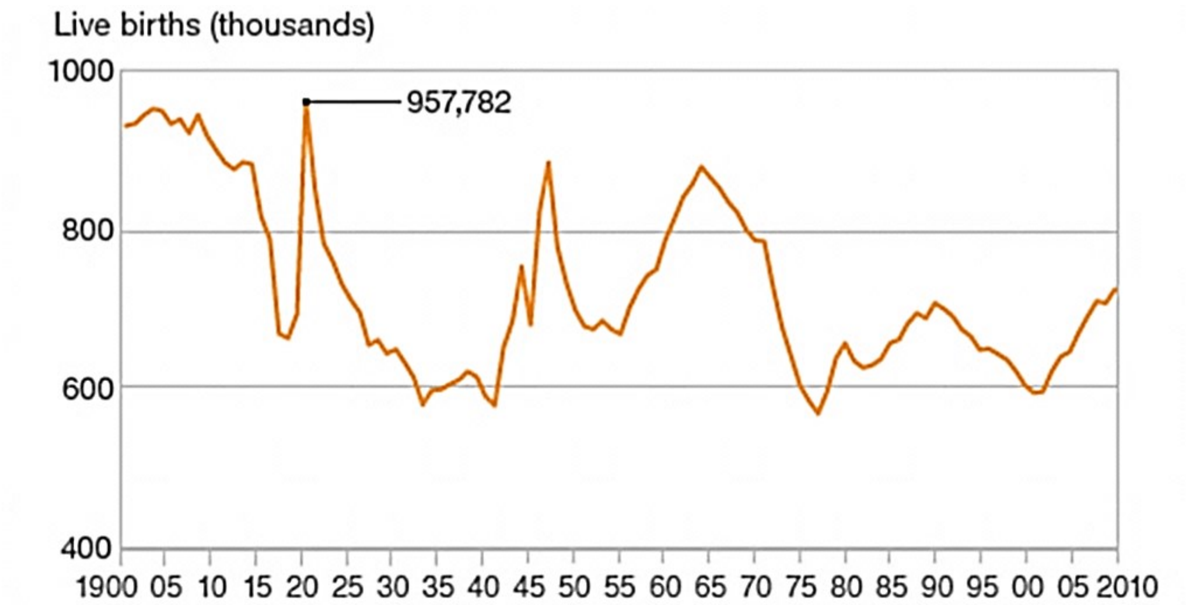


Figure 2.46: Live births: England and Wales 1900 – 2010 (Blastland 2012)

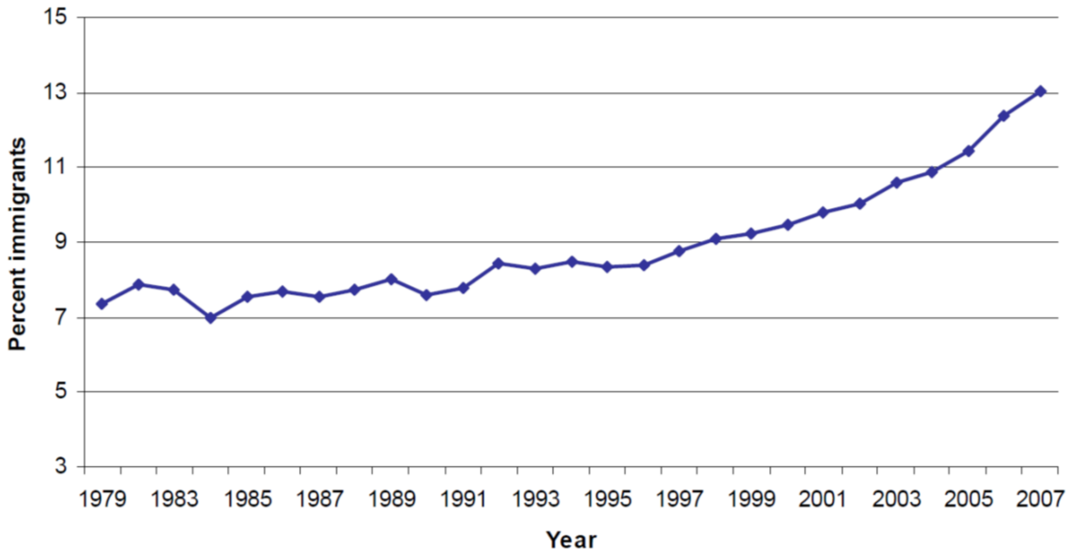


Figure 2.47: Share of Immigrants in the UK Working – Age Population, 1979 to 2007 (Somerville 2009)

Demographic changes are also likely to affect the architects and contractors available to work in the construction industry. Although architectural schools can increase or decrease the number of architects entering the profession they cannot alter the number of experience architects at the later stages of their careers. More senior architect can develop skills and an insight that junior architects do not have. A shortage of more experienced architects is likely to mean that increased demands are place on those that are available or a change in the methods used to produce production information.

These demographic changes will mean that new forms of buildings will have to be developed or existing building will need to be modified to meet new demographic demands. This will be the challenge for reduced number of architectural and construction professional.

2.6.6 The Tasks Undertaken by Architects

A scope of services list is provided which indicates to activities that architects may perform and seek re numeration for (see figure 2.48). Further analysis was undertaken of these tasks was undertaken breaking them down into the key activities of collecting information, creating solutions and connecting or communicating with others (see figure 2.49).

A standard reference for the works architects perform is the RIBA plan of works (see figure 7.26).

Checklist: Scope of Services

This chart is a typical checklist of services offered by the architect and his or her sub-consultants.
The nature of the individual project and the services customized to the client's needs will determine the scope of services required.

Project Inception — *Project Assessment* — *Concept Approval* — *Approvals from Authorities* — *Awards of Construction Contract* — *Substantial Performance of Construction/Occupancy Permit*

1.0 PRE-DESIGN

ARCHITECT'S SERVICES
- ○ Facility Programming
- ○ Space Relationships/Flow Diagrams
- ○ Project Development Scheduling
- ○ Project Budgeting
- ○ Life Cycle Cost Studies
- ○ Economic Feasibility Studies
- ○ Agency Consulting/Review/Approval
- ○ Site Selection/Analysis Utilization
- ○ Environmental Studies
- ○ Energy Studies
- ○ Existing Facilities Surveys
- ○ Client-Supplied DataCoordination
- ○ Services Related to Project Management
- ○ Presentations
- ○ Marketing Studies
- ○ Special Studies
- ○ Re-Zoning Assistance
- ○ Project Promotion

SPECIAL CONSULTANTS' SERVICES
- ○ Legal Survey
- ○ Geotechnical Analysis
- ○ Project Financing

2.0 SCHEMATIC DESIGN

ARCHITECT'S SERVICES
- ● Client-supplied Data Coordination
- ● Program and Budget Evaluation
- ● Review of Alternative Design Approaches
- ● Architectural SchematicDesign
- ● Schematic Design Drawings and Documents
- ● Statement of Probable Construction Costs
- ● Client Consultation
- ○ Interior Design Concepts
- ○ Special Studies (Future Facilities, Environmental Impact, etc.)
- ○ Special Submissions or Promotional Presentations
- ○ Special Models, Perspectives or Computer Presentations
- ○ Project Management
- ○ Agency Consultation

CONSULTANTS' SERVICES
- ● Structural Design Concepts
- ● Mechanical Design Concepts
- ● Electrical Design Concepts
- ● Statements of Probable Costs

SPECIAL CONSULTANTS' SERVICES
- ○ Civil Design Concepts
- ○ Landscape Concepts
- ○ Statements of Probable Costs

3.0 DESIGN DEVELOPMENT

ARCHITECT'S SERVICES
- ● Client-supplied Data Coordination
- ● Design Coordination
- ● Architectural Design Development
- ● Design Development Drawings and Documents
- ● Statement of Probable Construction Costs
- ● Client Consultation
- ○ Interior Design Development
- ○ Special Studies/Reports (Planning Tenant or Rental Spaces, etc.)
- ○ Promotional Presentations
- ○ Models, Perspectives or Computer Presentations
- ○ Project Management
- ● Agency Consultation

CONSULTANTS' SERVICES
- ● Structural Design Development
- ● Mechanical Design Development
- ● Electrical Design Development
- ● Statements of Probable Costs

SPECIAL CONSULTANTS' SERVICES
- ○ Civil Engineering Design Development
- ○ Landscape Development
- ○ Detailed Construction Cost Estimates or Quantity Surveys

4.0 CONSTRUCTION DOCUMENTS

ARCHITECT'S SERVICES
- ● Client-supplied Data Coordination
- ● Project Coordination
- ● Architectural Construction Documents (Working Drawings, Form of Construction Contract and Specifications)
- ● Document Checking and Coordination
- ● Statement of Probable Construction Costs
- ● Client Consultation
- ○ Interior Construction Documents
- ○ Alternative Bid Details and Special Bid Documents
- ○ Project Management
- ○ Agency Consultation

CONSULTANTS' SERVICES
- ○ Structural Construction Documents
- ○ Mechanical Construction Documents
- ○ Electrical Construction Documents
- ○ Statements of Probable Costs

SPECIAL CONSULTANTS' SERVICES
- ○ Civil Engineering Construction Documents
- ○ Landscape Documents
- ○ Detailed Construction Cost Estimates or Quantity Surveys

5.0 BIDDING OR NEGOTIATION

ARCHITECT'S SERVICES
- ● Client-supplied Data Coordination
- ● Project Coordination
- ● Issue Bidding Documents
- ● Issue Addenda
- ● Bid Evaluation
- ● Construction Contract
- ● Client Consultation
- ○ Separate Bids or Negotiated Bids
- ○ Services Related to Bidders' Proposals
- ○ Project Management

CONSULTANTS' SERVICES
- ● Issue Bidding Documents
- ● Issue Addenda
- ● Bid Evaluation

SPECIAL CONSULTANTS' SERVICES
- ○ Issue Bidding Documents
- ○ Issue Addenda
- ○ Bid Evaluation

6.0 CONSTRUCTION – CONTRACT ADMINISTRATION

ARCHITECT'S SERVICES
- ● Field Review
- ● Progress Reports/Evaluation
- ● Process Certificates for Payment
- ● Interpretation of Contract Documents
- ● Review of Shop Drawing Product Data/Sample
- ● Change Orders
- ● Substantial Performance Report and Certification
- ● Client Consultation
- ○ Interior Construction review
- ○ Full-time Project Representation
- ○ Administration of Separate Contracts
- ○ Project Management
- ○ Promotional Material
- ○ Record Drawings
- ○ Agency Consultation

CONSULTANTS' SERVICES
- ● Structural review/Reports
- ● Mechanical review/Reports
- ● Electrical review/Reports
- ○ Record Drawings
- ○ Certification of Progress

SPECIAL CONSULTANTS' SERVICES
- ○ Civil Construction review
- ○ Landscape Inspection
- ○ Detailed Cost Accounting

7.0 POST-CONSTRUCTION

ARCHITECT'S SERVICES
- ● Field Review
- ● Deficiency Assessment
- ● Review of Warranties
- ● Total Performance Inspection and Certification
- ● Client Consultation
- ● Start-up Assistance
- ● One-year Warranty Inspections

OTHER SERVICES
- ○ Fine Arts/Crafts/Graphics
- ○ Non-building Equipment Selection
- ○ Building Analysis and Reports
- ○ Services Related to Alterations and Demolition
- ○ Life Cycle Cost Monitoring
- ○ Environmental Monitoring
- ○ One-year Warranty Inspections

CONSULTANTS' SERVICES
- ○ Start-up Assistance
- ○ Systems Performance Review
- ○ Non-building Equipment Selection
- ○ Life Cycle Cost Monitoring
- ○ Services related to Alterations and Demolition

● Basic Services as per Base Percentage Fees shown on page 10
○ additional services

Figure 2.48: Tasks performed by Architects (source http://www.aapei.com/pdfs/RAIC-Architectural-Fees.pdf)

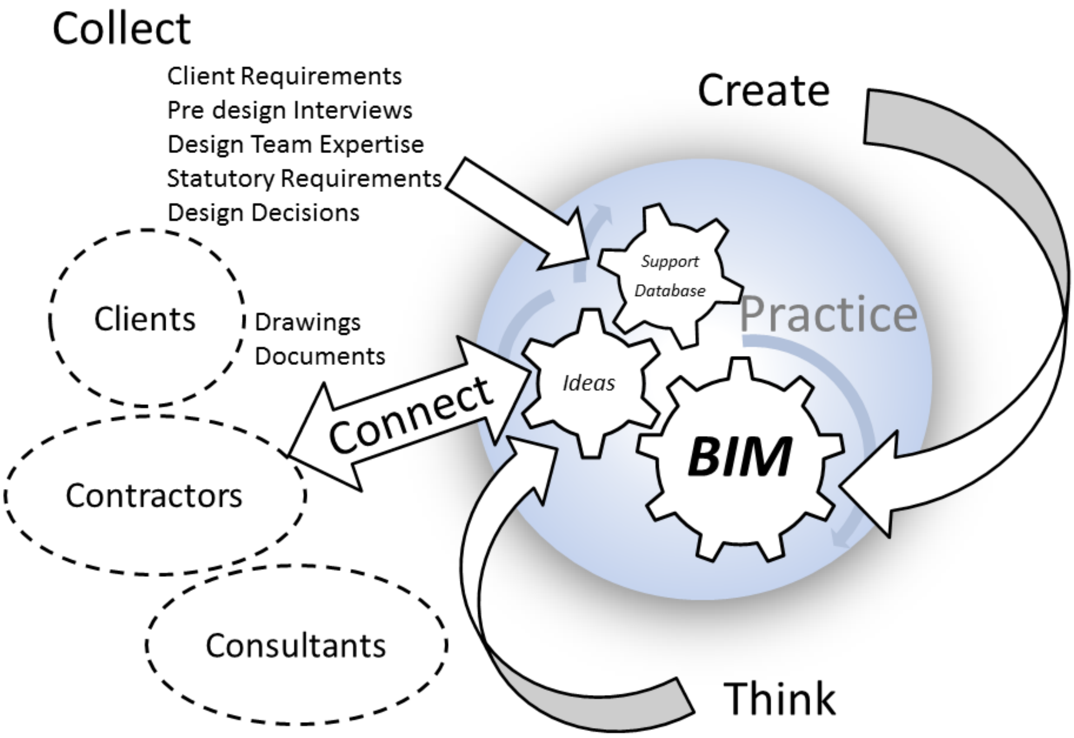


Figure 2.49: The core of the architectural project process

To better understand how architects work an interaction diagram of the interactions of architects with other stakeholders was developed (see figure 2.50 Appendix A). Typically the architectural process requires many interactions and these were reviewed as part of this research. This figure is included to explain the inner operations of an architectural practice. The figure shows the relationship between project and business processes. It shows the importance of external interactions in the architectural process. The figure was generated as a result of the action research undertaken as part of this research. Figure 2.51 shows the major tasks performed by architects.

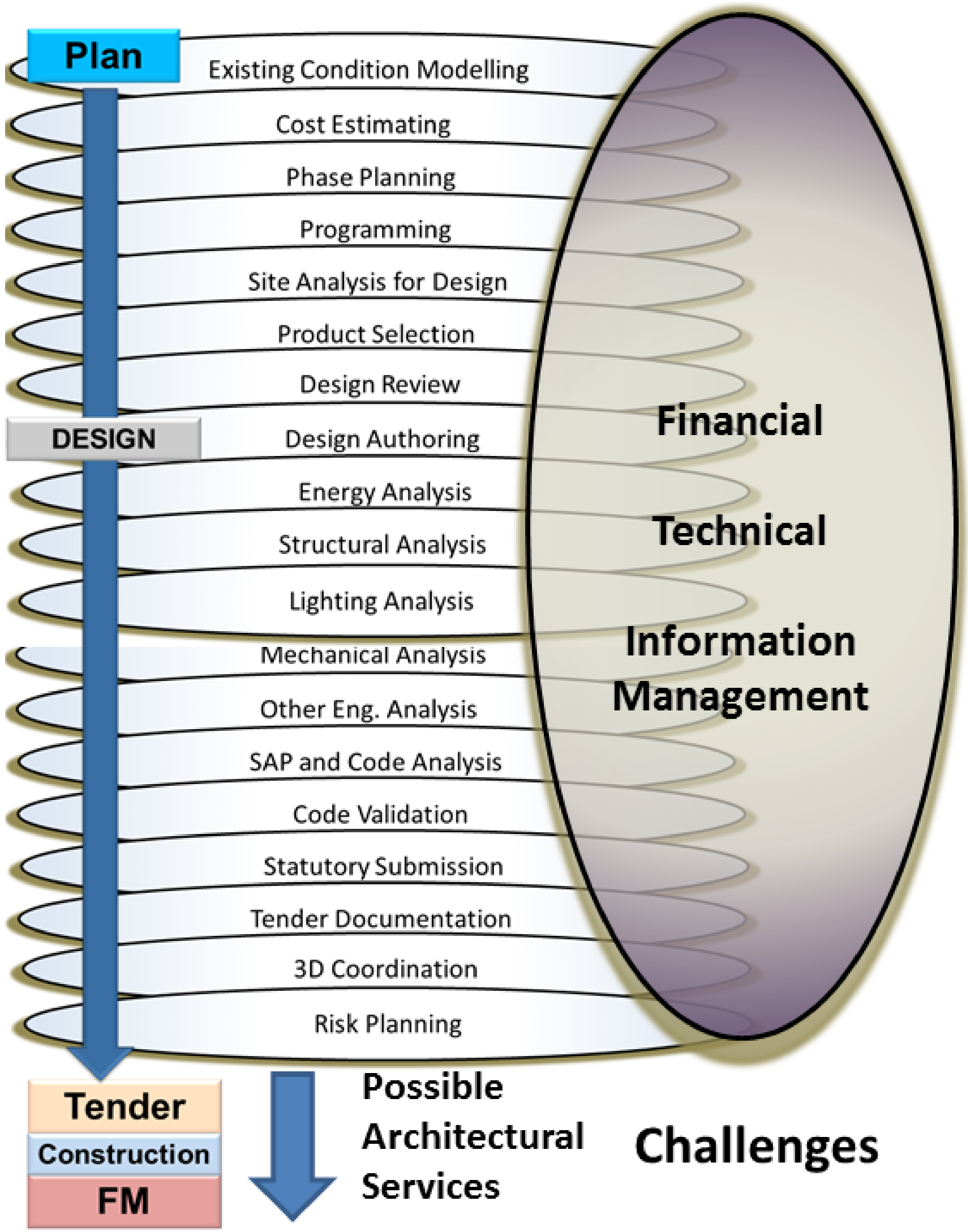


Figure 2.51: The major activities performed by architects to achieve effective project delivery

This list in part was generated as a result of the research undertaken at the case study company and experience derived from working at other companies.

2.6.7 Existing Condition Modelling

The major risk in building construction is undefined site conditions. These conditions may relate to geotechnical issues or existing structures on site. New technologies have become available so more accurate information may become part of development information. Lidar and lasers scanning can provide data of existing conditions that can be used to develop more accurate production information.

2.6.8 Procurement, Phase Planning and Project Programming

Architects are often asked to give advice on how projects should be conducted. Design decisions need to be made to an agreed time line so progress can be maintained.

2.6.9 Site Analysis and Design

Maximising what is possible to develop on a site is a key architectural skill. The architect often is expected to “get a quart into a pint pot”.

2.6.10 Product selection

Products or elements that go to make up a building can be defined in several ways.

- The exact product may be specified
- A limited range of products or solutions may be suggested
- A performance specification maybe provided

To effectively be able to make a selection architects need to be aware of the products available and be able to make an informed selection.

2.6.11 Design Review

An important element of the architectural process is the review and reflection that needs to take place. This review can be standardizes and example of this is given in section 9.14 of this thesis. Where values are of a numerical nature the review can be automated. Although because of the wide range of multiple criteria that need to be balanced as part of design review it is difficult to automate this process.

2.6.12 Structural consideration

Structures and mega structures have been built without the use of computers. But computerised tools enable projects to be achieved in reduced timescales requiring a reduced input in terms of the designer’s time.

Here again on complex projects structural engineers may be used. On smaller projects structural calculations may be undertaken by the architect. Structural requirements are part of the building regulations therefore appropriate information must be provided.

2.6.13 Lighting Analysis

The level of lighting required is determined by the tasks to be performed in the building.

2.6.14 Mechanical Analysis

On larger projects mechanical and electrical engineers maybe employed. But again on smaller projects often undertaken by smaller practice such systems maybe designed by the project architects.

2.6.15 SAP and Code Analysis

The code for sustainable homes provides nine measures of sustainable design:

- energy/CO2
- water
- materials
- surface water runoff (flooding and flood prevention)
- waste
- pollution
- health and well-being
- management
- ecology

Part L1a of the Building Regulations requires that SAP (Standard Assessment Procedure) calculations are carried out on all new build developments to prove that they are not contributing excessively to carbon emissions.

2.6.16 Statutory Submission

Most buildings in the UK need to be approved by the local authority before construction can take place. This requires a submission usually of drawings and supporting documents both for planning and building control approval.

2.6.17 Tender Documentation

The development of information so contractors can competitively bid to construct building is an important part of the work of architects. Historically Bills of Quantities were often prepared to help the contractor with the bidding process. Using quantity take off from BIM models the need for a Bill of Quantities is reduced. If Bills of Quantities are no longer necessary to provide this represents a major saving in terms of time and effort for the building team.

2.6.18 3D Coordination

Coordination is an important and historically time consuming issue to ensure construction is undertaken without abortive work. The role of coordination is often allocated to the architect. But in order to reduce project time scales this role can also be allocated to the contractor.

2.7 The fundamental internal issues that affect the adoption of BIM in Small Architectural Practices

According to Chibelushi (2009) the problems facing small companies are as follows:

- Lack of IT (or good IT) support
- Lack of IT Literacy
- Lack of formal procedure and discipline
- Uneven IT awareness and management skill
- Lack of Financial resources
- Lack of Human Resources
- Lack of experience of using consultants

These are all problems that will need to be considered as part of a BIM adoption in small architectural practices. But small companies have the advantage of potentially being more agile being rapidly able to reinvent themselves if they have the imagination and drive to do so.

2.8 Summary of Chapter

This chapter introduced the literature research undertaken on objective A. Investigation into this objective took place during and after the period of action research. Interviews with contractors, architects and stakeholders also were undertaken. Undertaking the FAST analysis and generating flowchart of interaction further illuminated the actions undertaken in architectural practice.

Chapter 3

Chapter 3: This explains the BIM concept as a new way of working for architectural practices. The current use and implementation of BIM in architectural practice and related challenges and issues in its implementation are also considered. Thus the research objective B is addressed.

CHAPTER 3 BIM as a New Way of Working

3.1 Introduction

This chapter sets out to clarify "what is BIM" and the concepts behind BIM. "Big BIM" is described with its many facets and capabilities. Big BIM is BIM that takes advantage of interoperable and interdisciplinary benefits (Jernigan 2007).

Using both an understanding of what BIM is, how BIM can be implemented and the existing references and guidance on BIM implementation are then reviewed.

At the start of this research a BIM literature mind map was referred to highlighting the literature which could be considered (see figure 3.01 Appendix A).

Through using BIM, the aim is to achieve new improved results and address both the historical and the new challenges and demands faced related to our built environment (see figure 3.02).

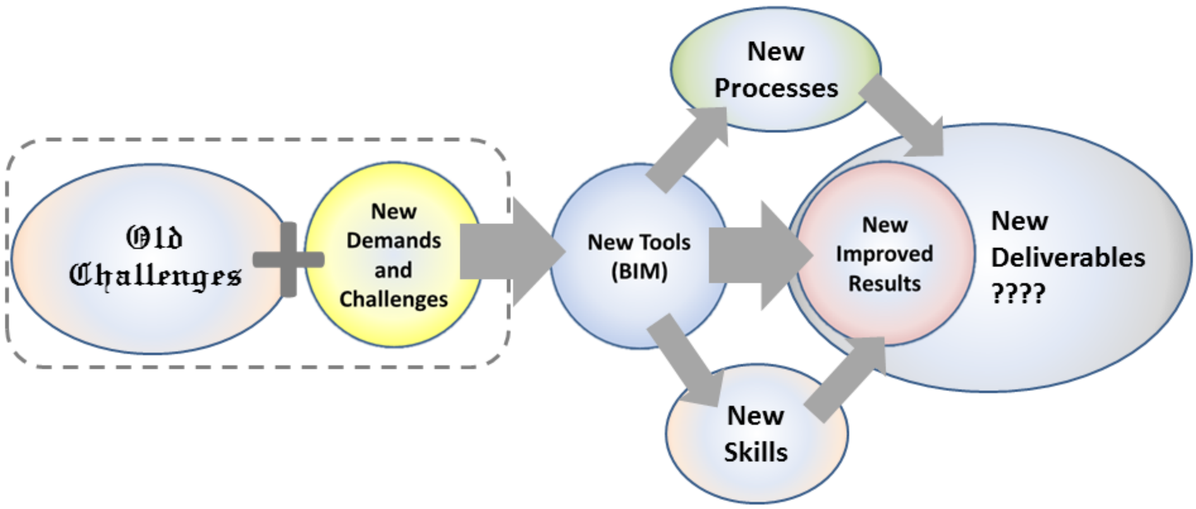


Figure 3.02: New demands and new tools leading to improved results

This change in the media of design will affect the way we think in the AECOO process (see figure 3.03).

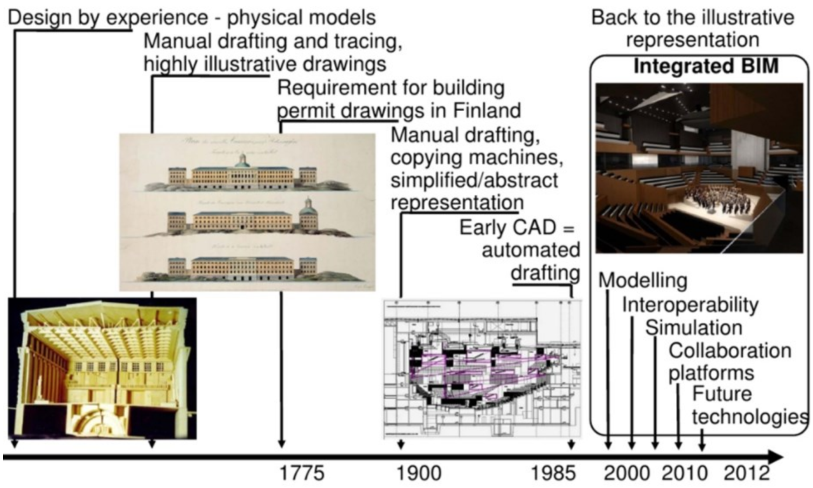


Figure 3.03: The Media affects our thinking (Thomas 2013)

There are some things and concepts that are better explained using 3d rather than 2d (see figure 3.04).

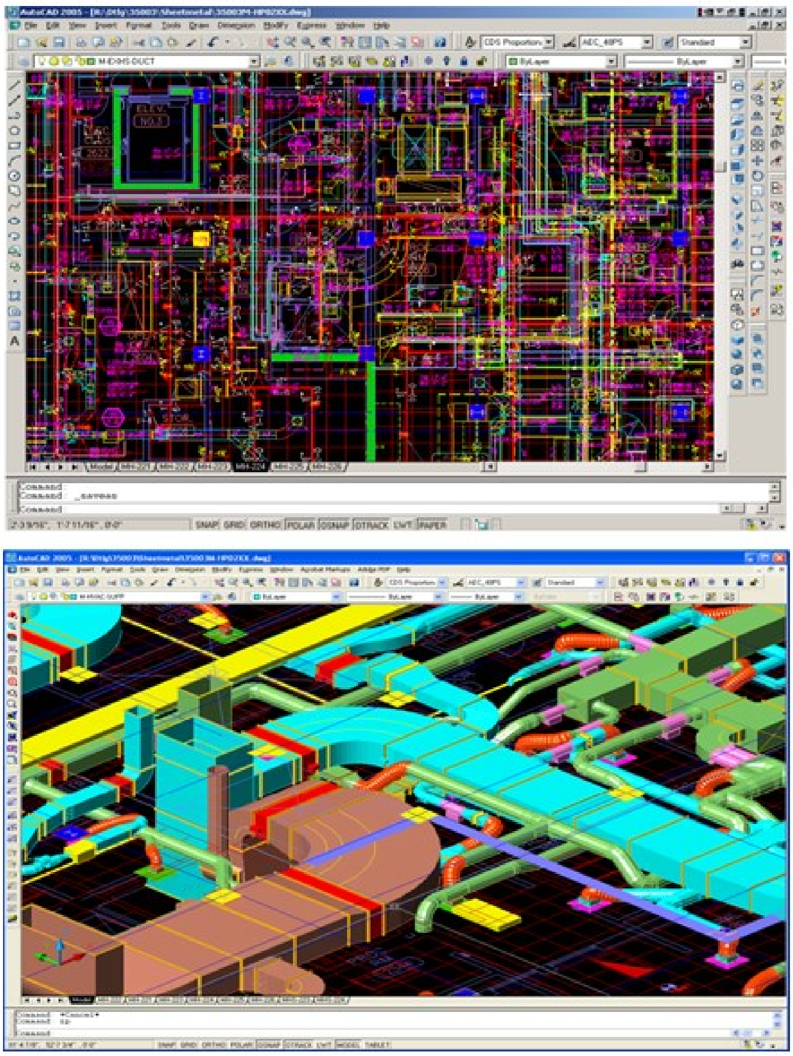


Figure 3.04: Using 3d to better explain concepts (Hall 2013)

At individual, practice, project or industry level BIM initiates transition from using documents to using data and the models and constructs which can be created from utilizing such data (see figure 3.05).

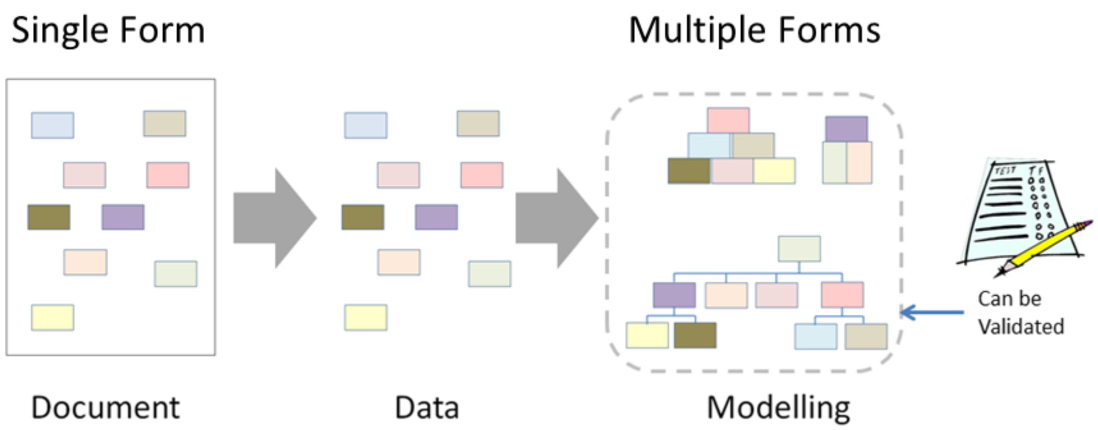


Figure 3.05: The move from documents to data and modelling

Using a data driven approach, the multiple relationships of data and the real world objects they represent can be created. Building can be represented as models in to reveal many different characteristics (see figure 3.06).

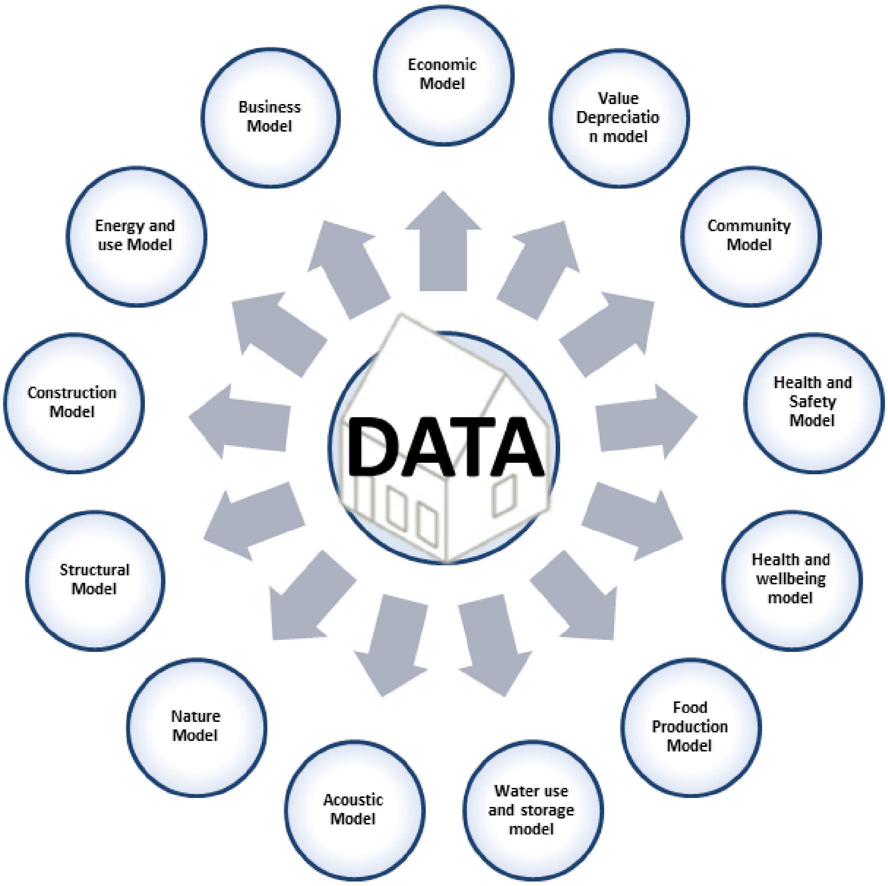


Figure 3.06: Buildings being modelled to exhibit different characteristics

These models can be interrogated through redefining the focus, and structure of the data under consideration. Using this approach, new insights can be revealed and therefore potentially better design decisions can be made. These new amended data structures (models) and the speed and volume of data that can be interrogated makes significant benefits possible.

The use of the data is not limited to its creator, but with the development of effective methods of transfer (interoperability) the relational data maybe used many times and in multiple forms. Thus the data is decoupled from the application that was used to create it. Data accessed through federated workspaces offers an alternative to data transfer. The crux of the BIM approach is standard data structuring within a logical and appropriate framework linked to modelling engines designed to facilitate the man/machine cognitive process.

By adopting BIM many processes can be improved (see figure 3.07).

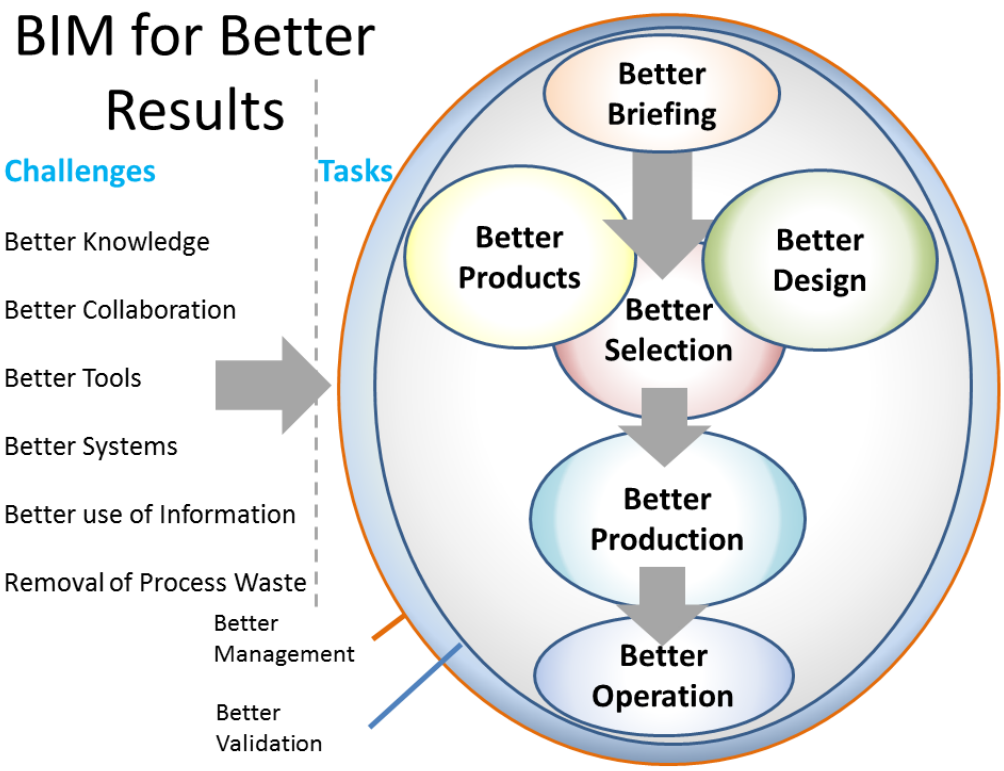


Figure 3.07: BIM for better results

3.2 What is BIM – Introduction

"Some see BIM as the modelling tools sold by vendors. Limiting yourself to a descriptive term for products sold by software companies diminishes the power and the benefits you receive from BIM."

(Jernigan 2007)

BIM represents a design environment, a concept potentially larger than a single tool or software application (Levy 2012). Ideas of interconnected inputs sub divided by discipline are not a new concept (Richens 1984) (see figure 3.08).

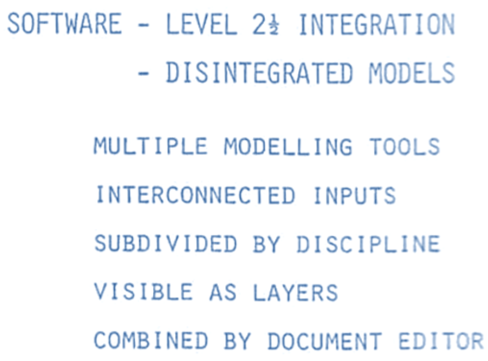


Figure 3.08: What a system of the future might look like (Richens 1984)

Computers are regarded as a necessity in most architectural organisations. However, the processes, activities and graphical and textual deliverables have changed little from the manual processes they precede.

Terms such as computer desktop, file, folder and document adopted from historical methods of working are all commonly used to describe computerised entities and practices (Colburn 2008). As new digital capabilities develop the terms used to describe them and the associated thought processes can easily become out dated. This may restrict their development and more general usage in practice. According to Pulsifer (2012) certain digital concepts and the terms associated with them need reconsidering. These changes in concept are:

- Archives - changing to - Digital Records
- Documents / models - changing to - Intelligent Containers
- Project folders - changing to - Project Repositories
- Central filing - changing to - a Global Repository
- Documents - changing to - Digital Assets
- Document Management - changing to - Digital Asset Management

Underlying all of these changes is the creation and use of accessible data to provide benefit though out the project life. These changes will have an important impact on how operations are conducted within a computerised architectural practice.

Typically architectural endeavour is conducted through discrete discontinuous undertakings. From a sustainable point of view the term project should include the lifecycle of the architectural design to decommission considerations. Data from the project initiation to the projects decommission can be collected structured and utilized using BIM. Taking the C2C (cradle to cradle) approach (Stahel 1970) developed by Brauhgart and McDonough (2002) data has the potential to be passed to the users of the products, after the decommissioning of the building.

The document / models represent the logical or legacy containers of the data which is understood within the AECOO (architecture, engineering, construction owners and operator) industries. In time it is likely the construction industry will move away from documents / models to a more data driven approach.

Interoperability allows disparate information systems from multiple vendors to readily work together and exchange data (Microsoft 2013). Interoperability is facilitated in the BIM environment by the use of the IFC (Industry Foundation Classes) data model. Using the IFC approach object related data can be transferred between applications potentially without loss of fidelity. Using BIM applications this data can be interrogated to assist in decision support though out the building lifecycle. Using multiple models and associated information a project repository can be built up from multiple formats of files and data. By being able access and query this disparate information sources new questions can be asked and addressed. These questions can be asked at object, space, building or portfolio levels.

The files and data themselves in such a repository maybe spread across multiple physical locations. Data and functionality from disparate sources has the potential to be used in created on demand “mashups” to answer questions that could not be address by other means (Boeykens et al 2013). Shared access to information effectively provides a global repository to assist all members of the building team and an increasing range of stakeholders. Considering documents / models and the data they contained as digital assets suggests their new importance. So the deliverable of the AECOO industries are becoming both a hybrid of physical and digital assets. To achieve the new demands being placed on the construction industry, the documents / models and the data they contain need to be structured, maintained and utilized.

Such concepts may seem over sophisticated for small architectural practices but these trends in the future are like to pervade all sections of the construction industry.

There are many views of what BIM is (Building Information Modelling (BIM) Task Group 2013) (Bedricks 2005). The 3D modelling element of BIM is what observers often initially see and therefore understand to be BIM. Creation of 3D models alone is not BIM as the entities involved may lack all but geometric definition.

BIM models often benefit from a parametric ability built into the objects from which they are constructed (Autodesk 2007) (see figure 3.09). This gives the ability for elements (objects) to be expanded and stretched in 3D. This enables the graphical entities in BIM models to be rapidly amended, thus aiding the process of design development. The use of parametric design can also be linked to the use of dimension driven design or constraints which can be applied to the BIM models. A more sophisticated concept of parametric design is parametric properties where the properties of objects can interact with each other.

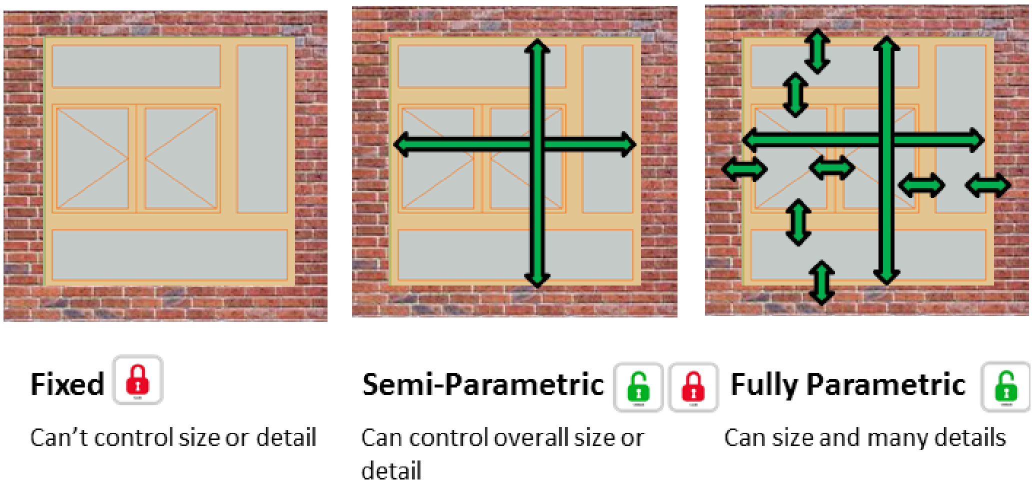


Figure 3.09: Showing the differences between fixed, semi-parametric and fully parametric modelling

Another view is that BIM has developed to overcome the informational islands that have historically existed in the AECOO industries (see figure 3.10). These islands to some extent still exist because although data transfer through IFC and other mechanisms has been developed, different standards are used by different construction disciplines.

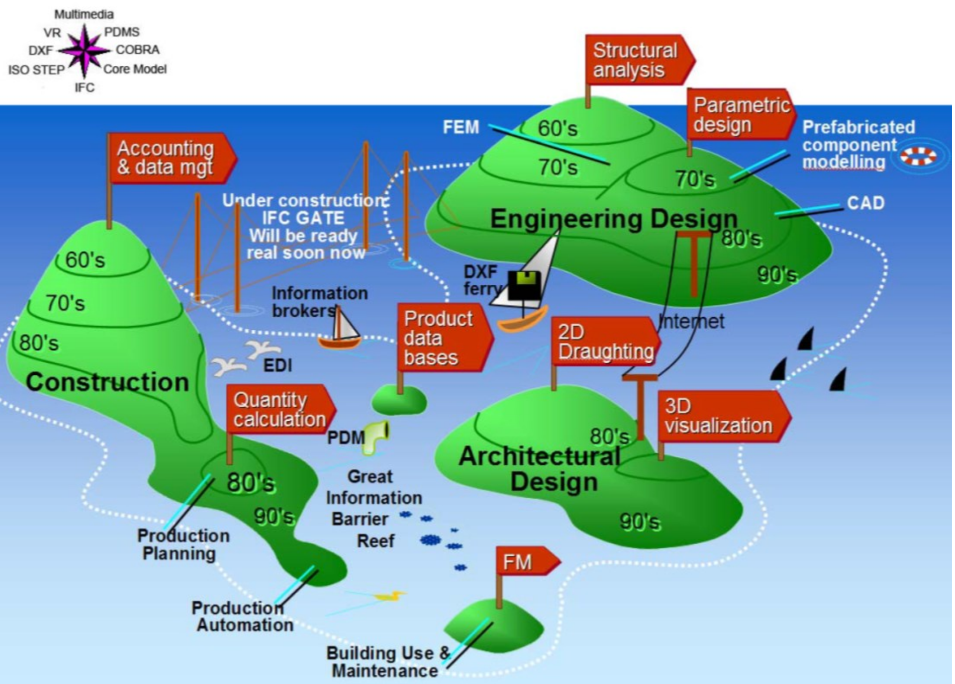


Figure 3.10: Informational islands that have historically existed in the AEC industries (Hannus 1995)

The concepts behind BIM are listed (see Table 3.1). These are provided to help make sense of what BIM represents. This list has been produced as a result of knowledge distillation from the literature review, the conferences attended and the conversations and interviews undertaken.

Concept	Comment
Using digital objects (as opposed to geometry) with data attached	Multiple types of data can be linked or contained in virtual objects that can be used for building analytics (Azhar 2009)
Using a limited number of protocols for data exchange between disciplines	IFC and CIS2 are protocols facilitating the exchange of data between disciplines. This effective sharing of data reduces unnecessary rework.
Using models to validate the real world	Using the data and running simulations BIM tools can be calibrated and give representations of real world conditions
Coordinated output from a single source	Although using a single source BIM model is not the preferred method of operation at this time for many this represents a future vision of many BIM related industries. The Crossrail project in London is pioneering the single model approach (Oliver 2012).
Providing a hierarchical structure of data and information	Information concerning buildings is by its nature hierarchical. BIM allows information to be reviewed at the portfolio, facility, building, room, assembly, element and component levels.
A system that can be developed	IFC is and expandable system allowing user defined property sets which allow increased uses of the BIM data
Providing understanding through visualization	The reason for creating models to create and share understanding
Linking models to other data sources	As BIM data is interoperable it can be used at all stages of the building lifecycle. Links can be made to any document or data. This is often achieved through the hyperlinking of objects to data
Parametric linked objects and the use of constraints	Using parametric models and constrains enables BIM to become an active participant in the design process.
Lifecycle information	Rationalized unified process
Managed Information exchanges	Model view definitions provide a method of providing subsets so specific data requirements can be exchanged
Multiple uses of data	BIM data can be used in multiple BIM tools and therefore can be regarded as multifunctional data
Alignment of processes	BIM has the potential for the product of one process to feed directly into the next

Automated model checking	Through the use of digitized information rule based checking engines can be and have been developed (Nawari 2012)
Synchronous information	The main function of Building Information Modeling is to establish the common internal project-related information for each stage for the whole life cycle of the building (Shiau 2011)

Table 3.01: Concepts behind BIM

These concepts are provided to frame the definition of BIM. By providing this list of concepts it is not meant to imply that they are applicable or appropriate in all instances.

3.2.1 Defining BIM

According to Laiserin (2002) the first documented use of the phrase "Building Information Model" in the English language appeared in the paper Automation in Construction published by G.A. van Nederveen and F. Tolman in December 1992.

To allow a systematic investigation into the issues surrounding the adoption of BIM we must define what BIM is (Laiserin 2002). Many different parties and organisations, both academic and commercial, have disparate views of what BIM is.

Different views of what the initials BIM stand for currently exist. The general accepted meaning of BIM is a Building Information Model, or Building Information Modelling. While Tekla (a major BIM vendor) and others, describes BIM as Building Information Management (Tekla 2012) (Race 2012) (TRADA 2012). The Institute of Civil engineers in the UK has adopted the term BIM(M) (building information modelling and management).

The different applied meanings can in part be attributed to the vested interests of the organisations involved. Software vendors may also wish to differentiate their products by using different interpretations of the term BIM. Also different parties as a result of their obligations within the development process perceive the relative importance of issues differently.

Part of the ambition of those promoting the BIM approach is to overcome such "Silo thinking". This is so that decisions are taken are to generate overall efficiency and benefit. This is opposed to sub optimisation of the operation of individual disciplines which may result in overall inefficiencies. This lack of agreement on what BIM is leads to difficulties particularly when engaging in discussions related to multi-disciplinary BIM.

Both the terms building information management and building information modelling have their merit. The data which is an important element of BIM needs to be managed, but also to make much of the data comprehendible it needs to be modelled. Modelling is the creation of an abstraction to provide understanding.

BIM does not just relate to buildings. It relates to any objects and the properties of those objects that the BIM author wishes to create. This may be a landscape design, a drainage layout, a cityscape or it may just be a building. BIM maybe be used to record both features above and below ground (see figure 3.11). BIM is as much about the whole built environment as it is about buildings themselves (Peters 2012).

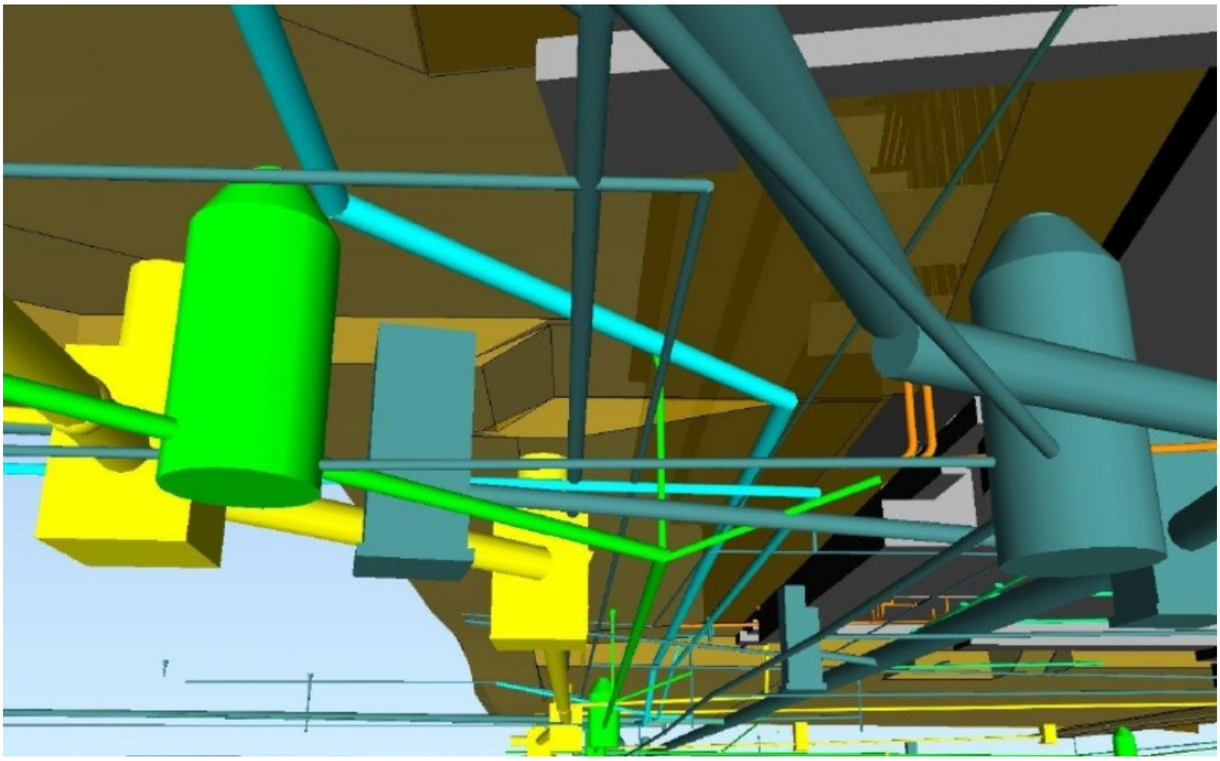


Figure 3.11: An example of BIM being used for services modelling (Prince 2010)

Although the term information is used, what is contained in BIM models is data. In some cases this data may be related to other data. An example of such a relationship is that a window in a BIM models "know" the wall into which it is fixed. Bateson (1979) defines information as "a difference that makes a difference" hence information is relational. It is through the modelling of data that decisions can be made. Thus the data in BIM though modelling becomes information.

Terms and definitions such as BIM can be considered in several ways. It is possible to achieve clarity of concept by showing BIM's relationship to other terms and concepts (see figure 3.12). It is also possible to look for a definition of BIM by breaking it down into it constituent parts but a reductionist approach can also be misleading. An example of this reduction was undertaken by Succar (2008) (see figure 3.13).

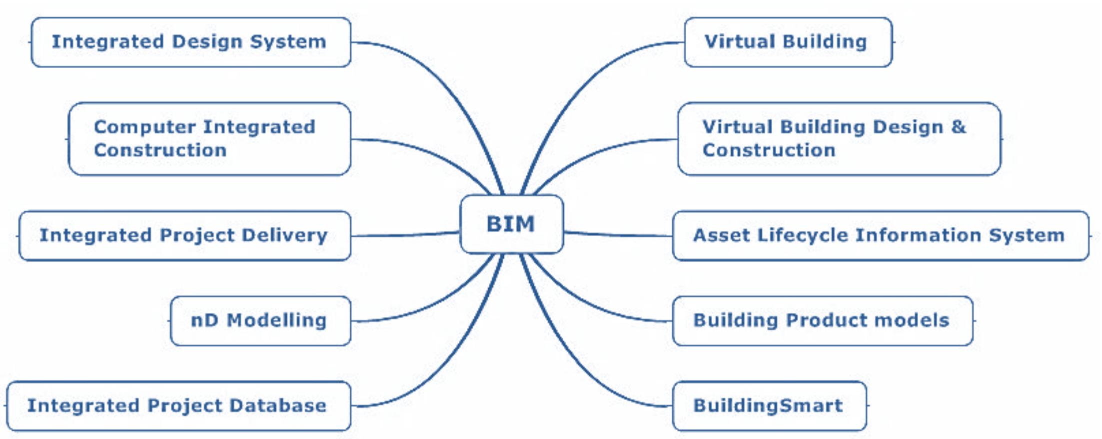


Figure 3.12: Showing the relationship of BIM with other concepts

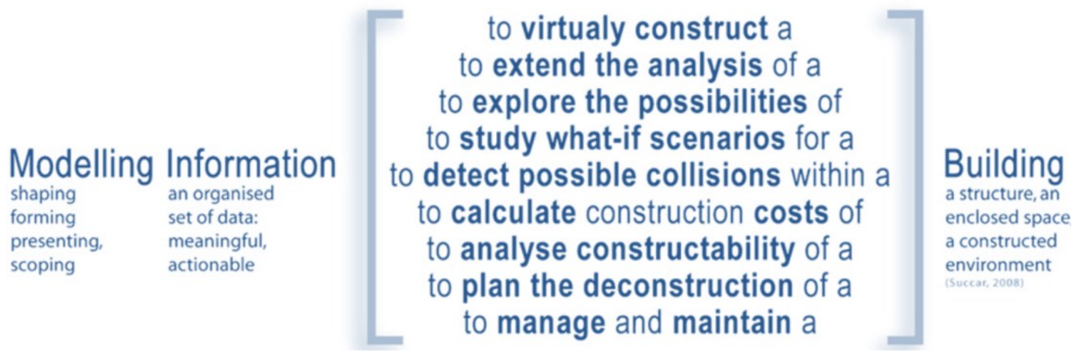


Figure 3.13: Reduction of the words Building, Information and Modelling (Succar 2008)

Here several well-known definitions of BIM are provided. By analysing the commonality of these definitions it is hoped to get a clearer picture of what is meant by BIM.

Definitions of BIM Shared, Digital, Aids decisions, Life Cycle
By Chuck Eastman et al, The BIM Handbook "an intelligent simulation of architecture." To enable us to achieve integrated delivery, this simulation must exhibit six key characteristics. It must be: (a) Digital, (b) Spatial (3D), (c) Measurable (quantifiable, dimension-able, and query-able), (d) Comprehensive (encapsulating and communicating design intent, building performance, constructability, and include sequential and financial aspects of means and methods), (e) Accessible (to the entire AEC/owner team through and interoperable and intuitive interface, and (d) Durable.
By National Institution of Building Sciences

BIM is best thought of as a digital representation of physical and functional characteristics of a facility…and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.
BS ISO 29481-1 2010 - Building Information Modelling Information Delivery Manual Shared digital representation of physical and functional characteristics of any built object (including buildings, bridges, roads, etc.) which forms a reliable basis for decisions
CPIC / RIBA - Proposed Definition Building Information Modelling is a digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition
buildingSMART Building Information Modelling (BIM) is a new approach to being able to describe and display the information required for the design, construction and operation of constructed facilities. It is able to bring together the different threads of information used in construction into a single operating environment thus reducing, and often eliminating, the need for the many different types of paper document currently in use.
Penttilä, (2006) Building Information Modelling (BIM) is a set of interacting policies, processes and technologies producing a "methodology to manage the essential building design and project data in digital format throughout the building's life-cycle".
Coates (2010) "as a language allowing interoperability or as a method of codifying knowledge or as a method of human machine interaction or as a method of applying parametric behaviours or as the process of creating and using digital object orientated models for design, construction and operations of projects."

Table 3.02: Definitions of BIM

From these definitions several key and common aspects emerge. BIM refers to a "Digital representation" which exists over the "building lifecycle". BIM also is used as the “basis for decisions”. Watson (2010) describes BIM as an information centric view of the lifecycle of a building.

Because of the lifecycle considerations there is a commonality between the concept of BIM and the concept of PLM (project lifecycle management). In future there is a potential likelihood of the merger of BIM and PLM software capabilities.

The digital BIM representations contain characteristics of the real world. This can be used to aid decisions and develop “shared” understandings.

Using the classical theory of concepts a BIM was defined by the following characteristics (Eastman et al 2011).

- Building components that are represented with digital representations (objects) that carry computable graphical and data attributes that identify them to software applications, as well as parametric rules that allow them to be manipulated in an intelligent fashion.

- Components that include data that describe how they behave, as needed for analysis and work processes, for example, quantity take off, specification, and energy analysis.

- Consistent and non-redundant data such that changes to component data are represented in all views of the component and assemblies of which it is a part.

- Coordinated data such that views of the model are represented in a coordinated way.

Digital BIM information which may initially take time and effort to create can be utilized by multiple parties in the building lifecycle. The single input and the multiple utilization of data are one of the major saving in terms of cost, time and consistency when using BIM.

Arto Kiviniemi on the 10th of November 2010 set out the solution components necessary for BIM (see figure 3.14).

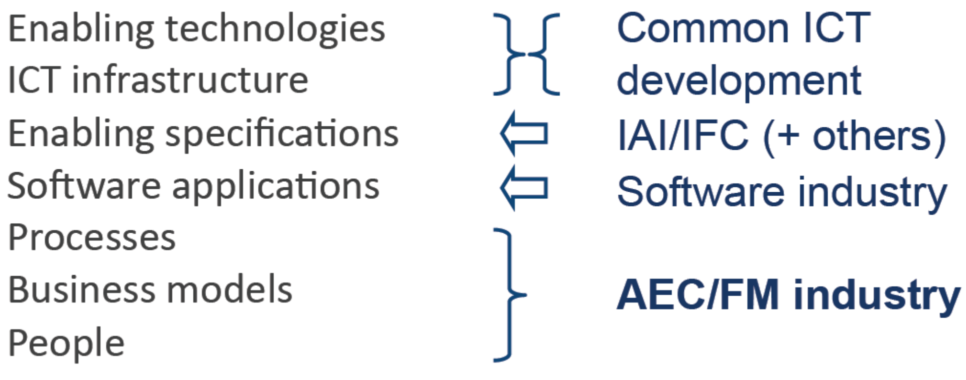


Figure 3.14: Solution Components of BIM (Kiviniemi 2010)

Many of these “BIM solution components” are outside the direct control of parties within the construction industry unless they developed knowledge more normally found with the IT development industries. This is particularly true for small architectural practices and organisations which have limited resources at their disposal.

Developing technologies, ICT infrastructure, enabling specifications and software applications are usually outside the domain of architectural practice. In terms of BIM implementation architects need to address the issue of process, business models and people. But in order to get the maximum benefits architects should also be actively involved with the development of supporting BIM tools and standards.

An increase in complimentary software tools developed to interrogate and utilize BIM and IFC data is taking place (Ogueta 2012). This development is likely to come from individuals in the larger architectural or multi-disciplinary organisations and modelling collaborative systems (MCS) developers. Historically particularly in the late 1980’s architectural firms developed their own software (RUCAPS, SONATA).

For small architectural practices software creation is likely to be outside their current skill set, although BIM software customisation in the BIM environment may offer many benefits. Educational courses do exist such as the MSc in Adaptive Architecture and Computation at the University of College London, where software programming skills within the architectural profession are taught. But such courses are rare.

BIM has been defined jointly as a product, activity or system (Maunula 2008) (see figure 3.15).

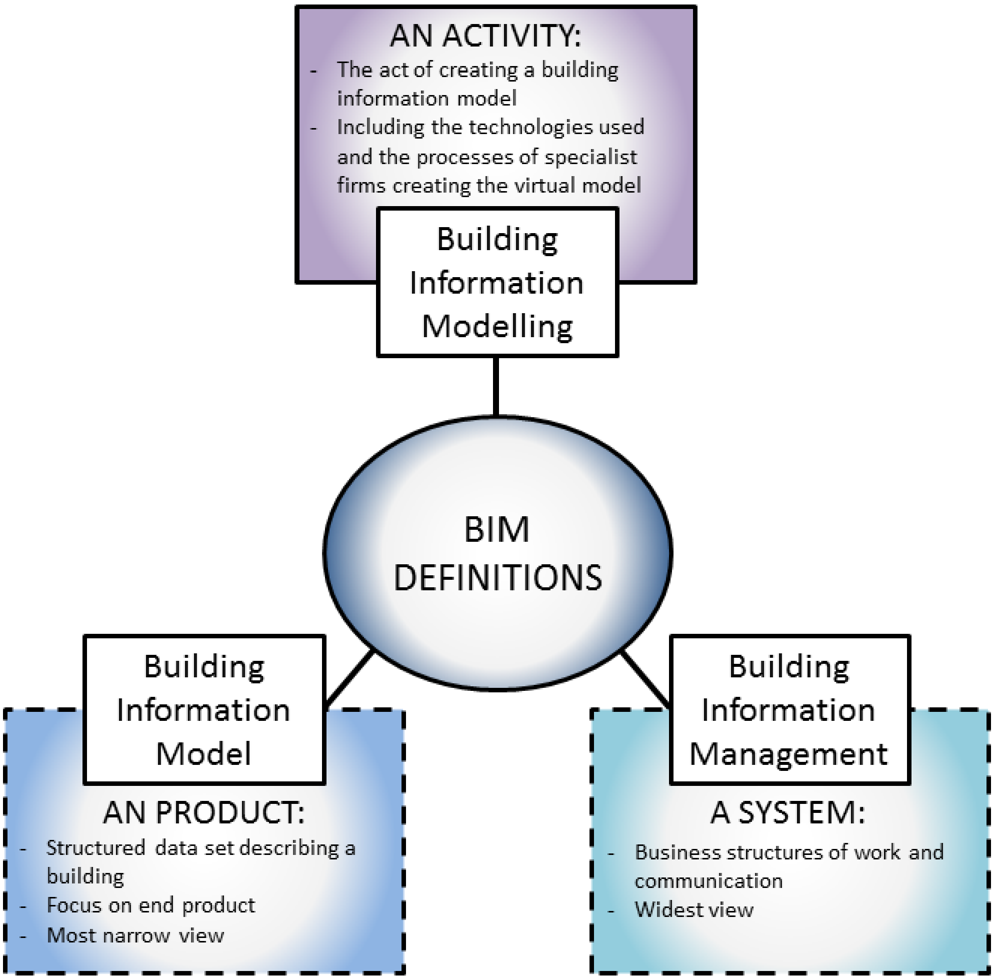


Figure 3.15: Different ways of looking at BIM (Maunula 2008)

If we take a systems view, BIM can be considered as part of a decision support system (DSS), part of an executive information system (EIS), part of an office automation system (OAS) or part of a project management system or part of an electronic design system.

People are part of these systems. BIM operatives whether they create or use BIM models require the appropriate development of skills and concepts. Considering BIM in this way cannot be detached from consideration of the information literacy of the users. The National Forum on Information Literacy defines information literacy as "...the ability to know when there is a need for information, to be able to identify, locate, evaluate, and effectively use that information for the issue or problem at hand." These are skills required by those who create BIM models as well as those who use BIM models.

According to Sebastian (2010) BIM comprises of two main aspects an intelligent model and an approach for integrated collaboration. BIM also encompasses both a framework and technology (see figure 3.16).

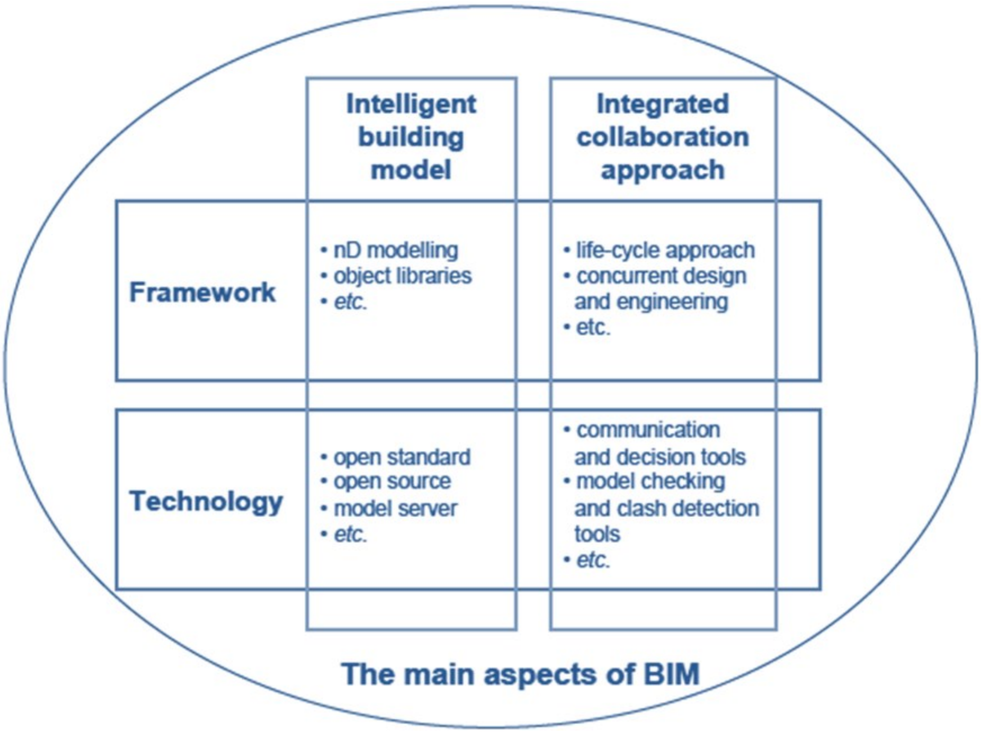


Figure 3.16: BIM as an intelligent building model with integrated collaboration (Sebastian 2010)

Another way to consider BIM is the balanced integration of people, process and technologies (see figure 3.17). It is the synergy of these elements that is necessary for a successful BIM adoption.

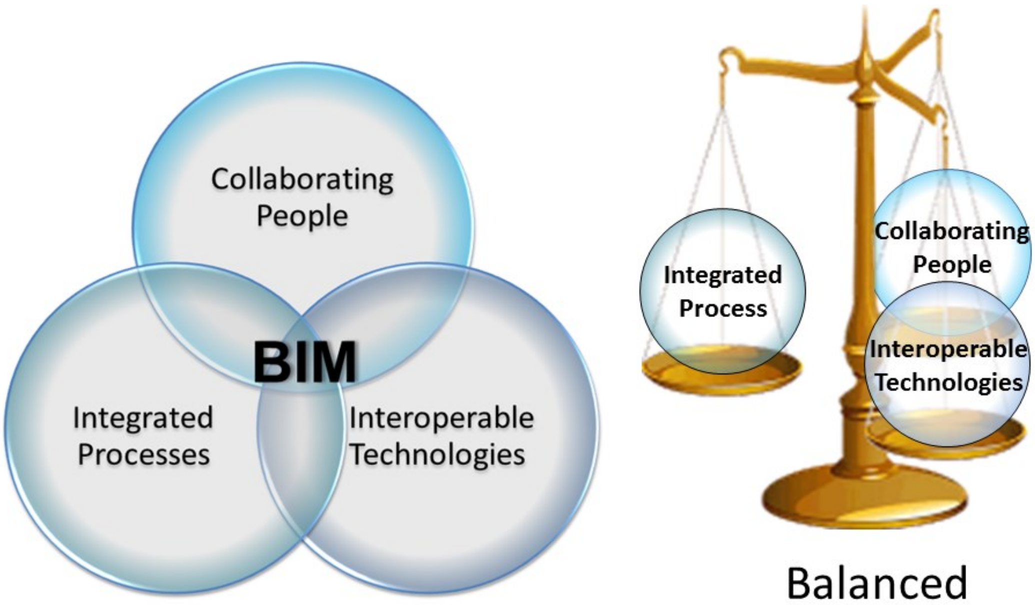


Figure 3.17: The three imperatives of BIM (adapted from Amor 2011)

Interoperability an important element of BIM is defined as "... the ability to manage and communicate electronic product and project data between collaborating firms' and within individual companies' design, construction, maintenance, and business process systems" (Gallaher et al.,2004). The lack of interoperability in the construction sector in the past has been a significant drain on the productivity and efficiency of the construction industry. A NIST study estimated the cost burden on the industry in 2002 at $15.8 Billion (Gallaher et al., 2004).

Central the use of BIM is the adoption of classification systems. In the UK Uniclass 2 has been integrated as part of the BIM approach while in the US the Omniclass classification system has been adopted.

Regional differences and the use of different languages represent one of the challenges facing BIM. This has led to the development of IFD (the international framework of dictionaries) as part of the BIM approach. Information Delivery Manual (IDM) and is devised for filtering out portions of a building model for specific contractual situations. Thus BIM relies on definition of data, terms and process (see figure 3.18).

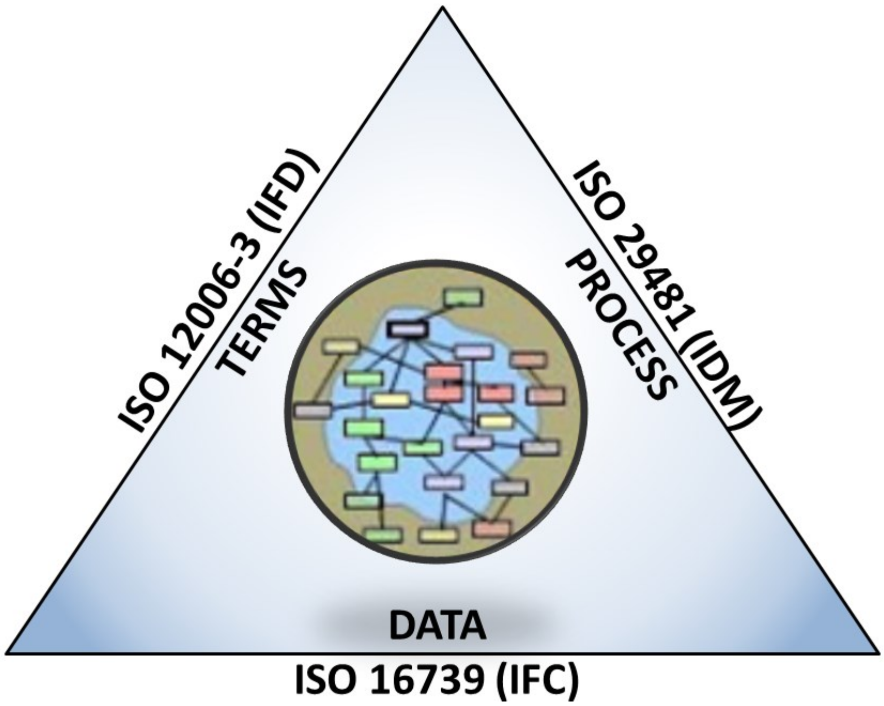


Figure 3.18: BuildingSMART standards triangle (Liebich 2011)

Design organisations are social systems and BIM needs to integrate with these systems (Morgan 1997) (Deutsch 2011).The socio technical dimension of BIM is illustrated (see figure 3.19). Our social practices co-evolve with our use of new tools (McLuhan 1964). The social elements of BIM documented by Kennerley (2012) are:

- Synchronous Collaboration
- Coordinated work practice
- Institution and cultural frameworks

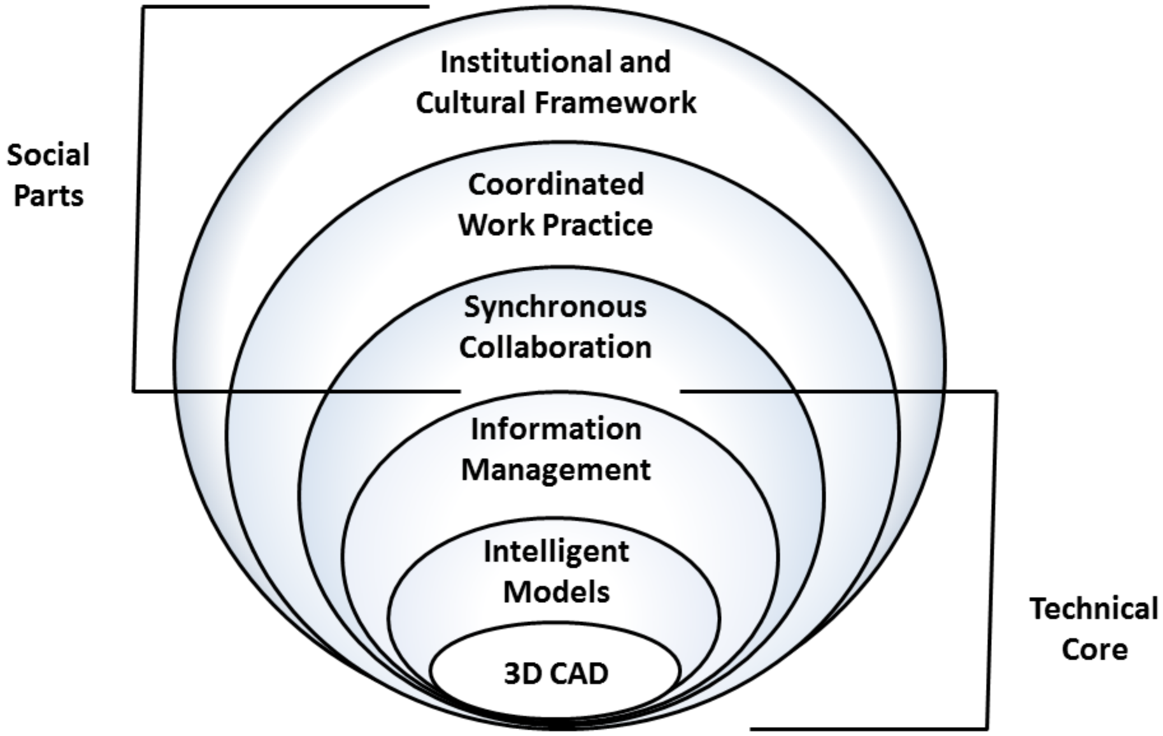


Figure 3.19: BIM viewed as a sociotechnical system with technological base of social components (Kennerley 2012)

3.2.2 The Role of BuildingSMART

The development of the BIM concept has been driven by the BuildingSMART organisation. BuildingSMART aims to cover all stages of the building lifecycle (see figure 3.20).

Figure 3.20: The BuildingSMART Logo

BuildingSMART brings together organisations who share the 'buildingSMART' vision of improving industry processes through the use of information sharing. CITE (the Construction Industry Trading Electronically) is also part of Building Smart in the UK.

The Industry Alliance for Interoperability initiated by Autodesk was the organisation that evolved into the BuildingSMART organisation. The year 2006 saw a re-naming and re-branding of the IAI consortium to buildingSMART®.

The twelve founding members of the IAI were AT&T, Archibus, Autodesk, Carrier, HOK, Honeywell, Jaros Baum & Bolles, LBNL, Primavera, Softdesk, Timberline and Tishman (Brown 1995). From 1st of January 2013 the engagements of Building Smart UK Limited are to be taken over by BRE formally known as the Building Research Establishment.

The mission of BuildingSMART is to contribute to a sustainable built environment through smarter information sharing and communication sharing using open international standards in the building and construction sector, private and public.

The standards originated by buildingSMART international have been:

- Building Information Model – IFC (Industry Foundation Classes) – ISO/ PAS 16739 :2005
- Terminology – IFD (International framework for dictionaries)– ISO 12006-3:2007
- Process Model – IDM (Informational delivery manual) – ISO / FDIS 29481-1:2009

3.2.3 Prototype Applications

Several prototype applications addressing the integrated project data model and the implementation of integrated project databases have been undertaken. These form the basis of the BIM approach. These include:

- ATLAS (Greening and Edwards 1995)
- COMBINE (Augenbroe 1995, Sun and Parand 1998)
- COMMIT (Construction Modeling and Methodologies for intelligent integration of information) (Brown et al 1996)
- ICON (Integration of construction Information) (Aouad et al, 1994)
- OSCON (Open Systems for Construction) (Aouad, 1997)
- GALLICON (Aouad et al 2001)
- WISPER (Web based IFC Shared Project Environment) (Faraj et al 2000)
- DIVERCITY (Distributed virtual workspace for enhancing communication and collaboration within the construction industry) (Arayici and Sarshar, 2002)

3.2.4 The Role of Industry Foundation Classes

There are two main open-standard protocols which provide object-based product data models to support BIM. These are the CIMSteel Integration Standard version 2 (CIS/2) and Industry Foundation Classes (IFC). Both of these protocols have as a foundation the Standard for the Exchange of Product Model Data (STEP) — ISO 10303.

Industry foundation class (IFC) entities allow data to be transferred between softwares certified by BuildingSMART. The IFC schema is developed as an "Express" schema (.exp) it is also available as an XML schema (.xsd) or a UML Rose schema (.rc1).

Using an interoperable file format means that software developers do not need to develop bespoke drivers to communicate with other software platforms. Adopting this approach represents a considerable cost saving when developing BIM applications.

IFC entities may be rooted or non-rooted. Rooted entities have an identity and a GUID (globally unique identifier). These GUID's like bar codes are an important element in object tracking in the real world. The IFC root class can contain object definitions, relationships and property sets. A simplified and full IFC illustration are given (see figures 3.21 and 3.22 Appendix A).

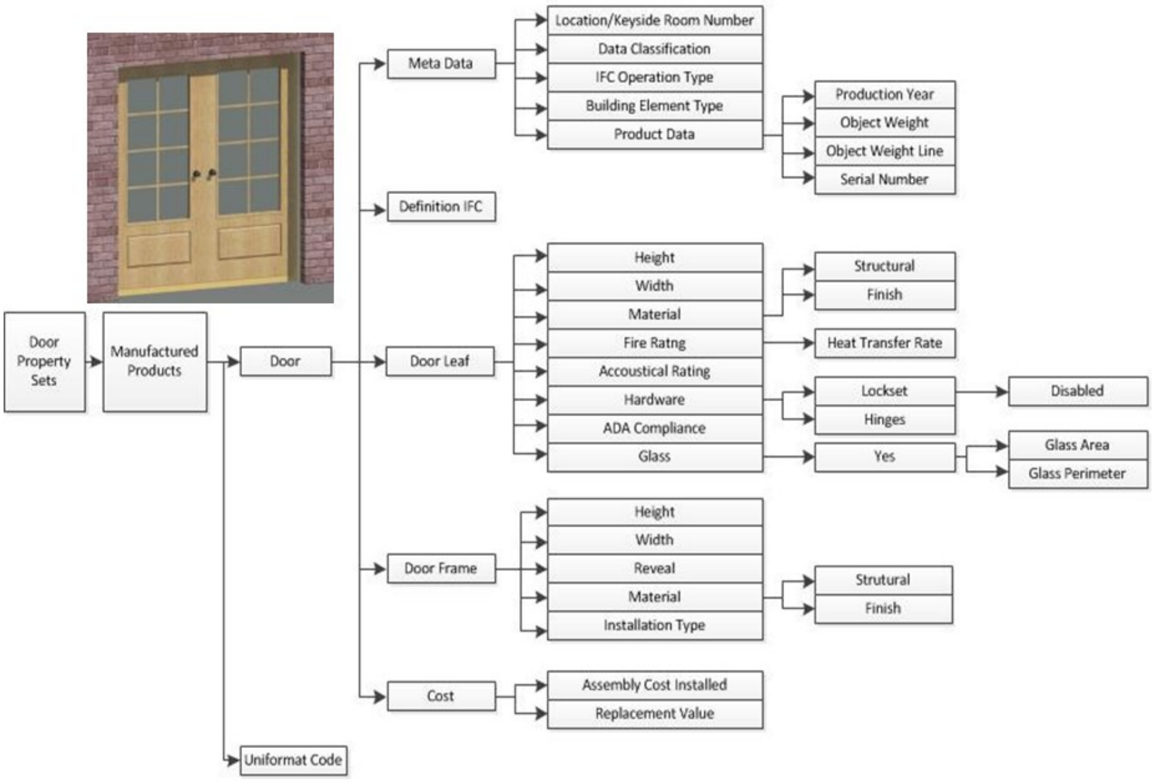


Figure 3.21: The IFC fields used to describe a door's elements, simplified

There are seven fundamental types of IfcObject (Liebich 2007):

IfcProcess - Processes are actions of, e.g. acquiring, constructing, or maintaining

IfcControl - Controls are concepts that constrain other objects e.g. guide, specification, regulation, that has to be fulfilled.

IfcResource - Resources are concepts describing the use of an object within a process

IfcActor - Actors are human or organizational agents

IfcGroup - Group is an arbitrary collection of objects.

IfcProduct - Products are physical things (manufactured, supplied or created).

IfcProject - Project is the undertaking of activities leading towards a product.

According to ISO16739 the following categories can be used in IFC objects: (see figure 3.23).

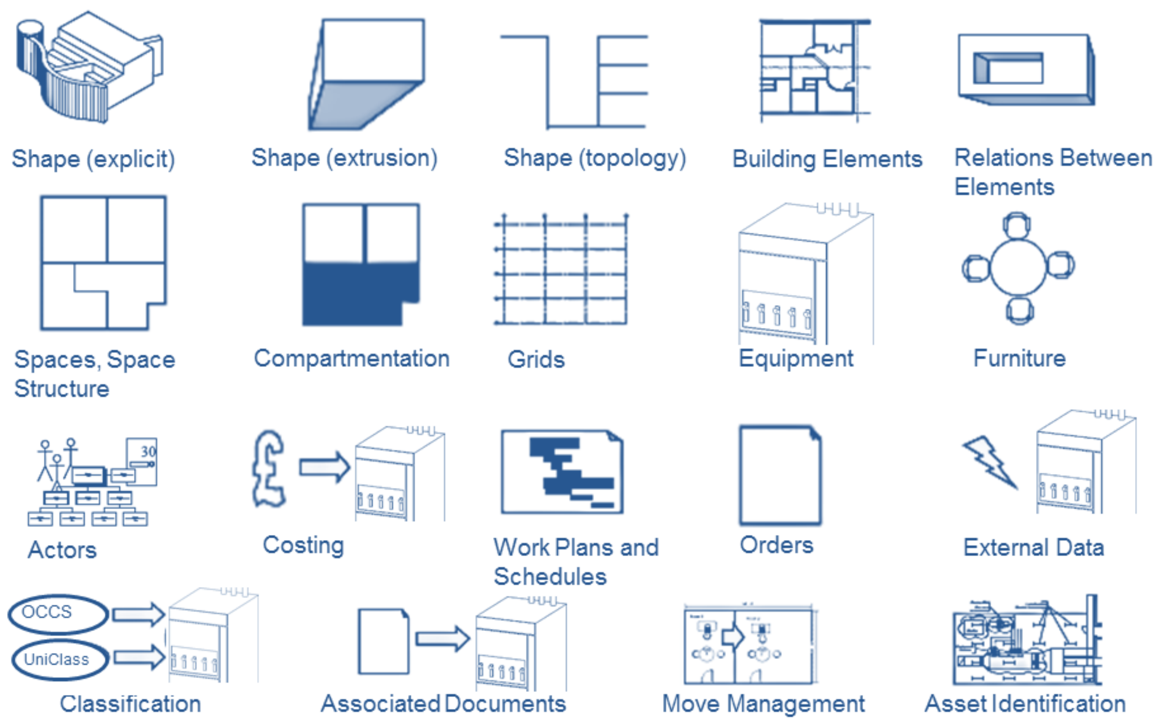


Figure 3.23: IFC categories that can be used in BIM objects (adapted from ISO 16739)

The schema for IFC continues to develop and expanded. The new IFC4 schema was released on 12.03.2013. Following the release of IFC 4 it may take some time before the translators are available for commonly used BIM tools.

Different areas of the IFC schema have been adopted and are used in the real world to different degrees (see figure 3.24. IFC files are available both in a standard and IFCxml format. *.ifc and *.ifcXML data files can be converted bi-directionally. As xml (Extensible Markup Language) files are texted based. XML files have the advantage they can be edited in text editors although software applications design specifically for xml editing are available and recommended. A *.ifczip file format also exists which is a compressed form of *.ifc or *.ifcxml.

Figure 3.24: Levels of use of different IFC categories 2010 (Smith 2010)

Free IFC file viewers are available such as Tekla BIMSite, BIMShare, Solibri Model Viewer and Nemetschek IFC Viewer . These can be used to interrogate IFC files. Although currently these viewers may not support the new IFC 4 format.

Reduced data sets extractions from BIM models have been developed for specific purposes. Examples of the reduced data sets are GBxml, VExml, AECxml and there are many more. These are usually designed to provide the reduced data sets required for specific BIM tools. By reducing the data set translated the number of potential errors can be reduced.

The use of IFC's is not without its critics. Some suggest that IFC is too complex, too large, and too fragile to survive in the real world of live projects (Crotty 2012). To provide a 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 end users cannot blindly trust the IFC mapping process (Pazlar, Turk 2008)(see figure 3.25).

Results and Problems of interoperability tests (Architectural object: Wall, Generated in Revit Architecture)

Wall		Orign(*.rvt)	ArchiCAD	Revit Architecture	Digital Project	SMC
Geometry	1.Center Line 2 Left Line 3. Right Line 4. Curve 5. L-connections					
Property	A. Type Name B. Material	A-1. Family : System Family: Basic Wall A-2. Type : 1. Center_Line_Wall 2. Left_Line_Wall 3. Right_Line_Wall 4. Curve_Wall 5. L-connection_Wall B. Structure : Concrete	A. ID : 1. Basic Wall:Cent 2. Basic Wall:Left 3. Basic Wall:Righ 4. Basic Wall:Curv 5. Basic Wall:L-co B. Cut Fill : Concrete	A-1. Family : System Family : Basic Wall A-2. Type : 1. Basic Wall: Center_Line_Wall:135892 2. Basic Wall: Left_Line_Wall:135721 3. Basic Wall: Right_Line_Wall:135760 4. Basic Wall: Curve_Wall:135797 5. Basic Wall: L-connections_Wall:135824 B. Structure : Concrete	A. Type: 1. Basic Wall: Center_Line_Wall:130035 2. Basic Wall: Left_Line_Wall:130232 3. Basic Wall: Right_Line_Wall:130361 4. Basic Wall: Curve_Wall:131423 5-1. Basic Wall: L-connectionsWall:131423 5.2. Basic Wall: L-connections-Wall:131487 B. Material: Concrete	A. Name : 1. Basic Wall: Center_Line_Wall:135892 2. Basic Wall: Left_Line_Wall:135721 3. Basic Wall: Right_Line_Wall:135760 4. Basic Wall: Curve_Wall:135797 5. Basic Wall: L-connections_Wall:135824 B. Material : Concrete
Problems			ID have limitation (15 characters)	Output form of Type value is different	Name value is indicate in Part Number	Output form of Name value is different

Results and Problems of interoperability tests (PSET, Generated in Revit Architecture)

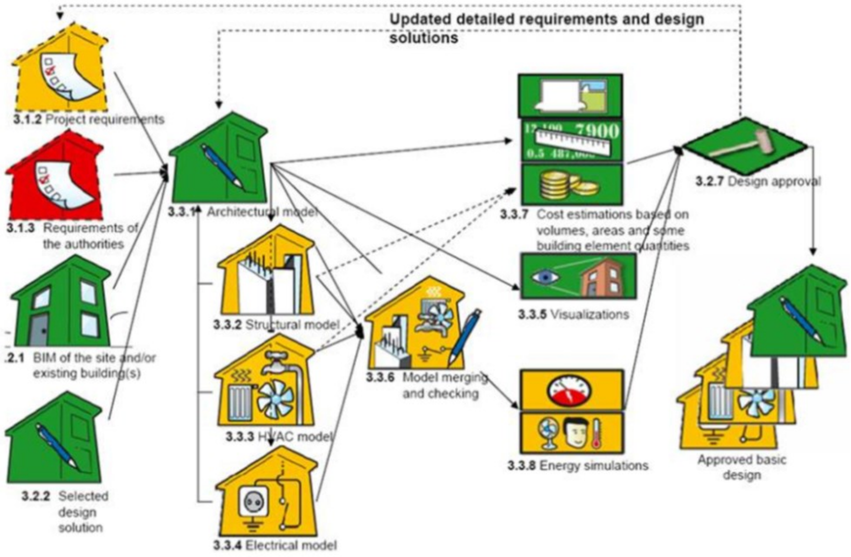
Door	Orign(*.rvt)	ArchiCAD	Revit Architecture	Digital Project	SMC
PSET/Property					
A. Pset_DoorFireResitance B. FireDoorCertification = True C. FireDoorCategory = Gabjong D. FireResistanceHours = 1.5	A. Pset_DoorFireResitance -none- B. FireDoorCertification = True C. FireDoorCategory = Gabjong D. FireResistanceHours = 1.5	A. Pset_Revit_Other B. FireDoorCertification = True C. FireDoorCategory = Gabjong D. FireResistanceHours = 1.5	A. Pset_DoorFireResitance -none- B. FireDoorCertification = -none- C. FireDoorCategory = -none- D. FireResistanceHours = -none-	A. Pset_DoorFireResitance - B. FireDoorCertification = - C. FireDoorCategory = - D. FireResistanceHours = -	A. Pset_Revit_Other B. FireDoorCertification = True C. FireDoorCategory = Gabjong D. FireResistanceHours = 1.5
Problems	New PSET definition is impossible New PSET definition is possible by Pset_Revit_Other	Pset_Door_Resistance is defined by Pset_Revit_Other	Property is unexpressed	Property is unexpressed	Pset_Door_Resistance is defined by Pset_Revit_Other

Figure 3.25: Interoperability results and problems for a Wall generated in Revit (Choi 2012)

3.2.5 The Use of Single Discipline and Federated Models

Currently most BIM projects are conducted as single discipline models that are combined and coordinated at critical milestones of a project development. This is that strategy put forward in the Senaatti Properties BIM Guides from Finland (see figure 3.26).

Clash analysis between the models to avoid abortive work on site is often conducted when the models are combined. BIM tools such as Navisworks, Solibri and BIMreview can be used to undertake clash detection reviews.



Senaatti Properties BIM Guidlines
http://www.senaatti.fi/document.asp?siteID=2&docID=517

Figure 3.26: A typical multi model workflow from the Senaatti Properties BIM Guides

Systems have also been developed that enable the information held within BIM objects to be accessed and used in a federated way. Several types of BIM server have been developed and are listed on the Building Smart website. Federated control amounts to having a common set of policies, practices and protocols in place to manage the identity and trust into IT users and devices across organizations.

Allocating the BIM data in this way is known as DRUM (distributed information management) and has been developed at Aalto University. Suomi (2012) shows the principles of DRUM applied to wall information (see figures 3.27 and 3.28).

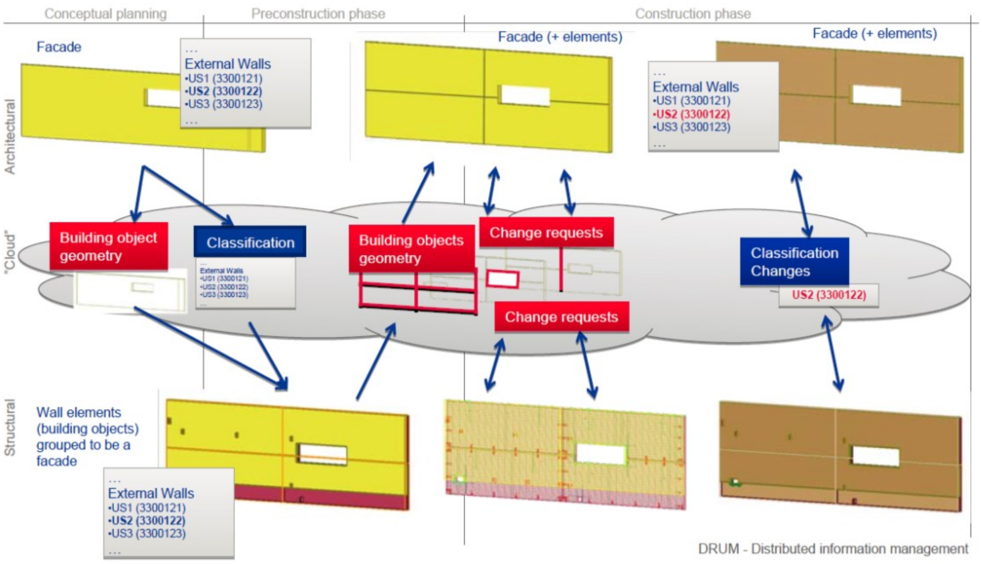


Figure 3.27: Federated Wall Information using distributed information management (Suomi 2012)

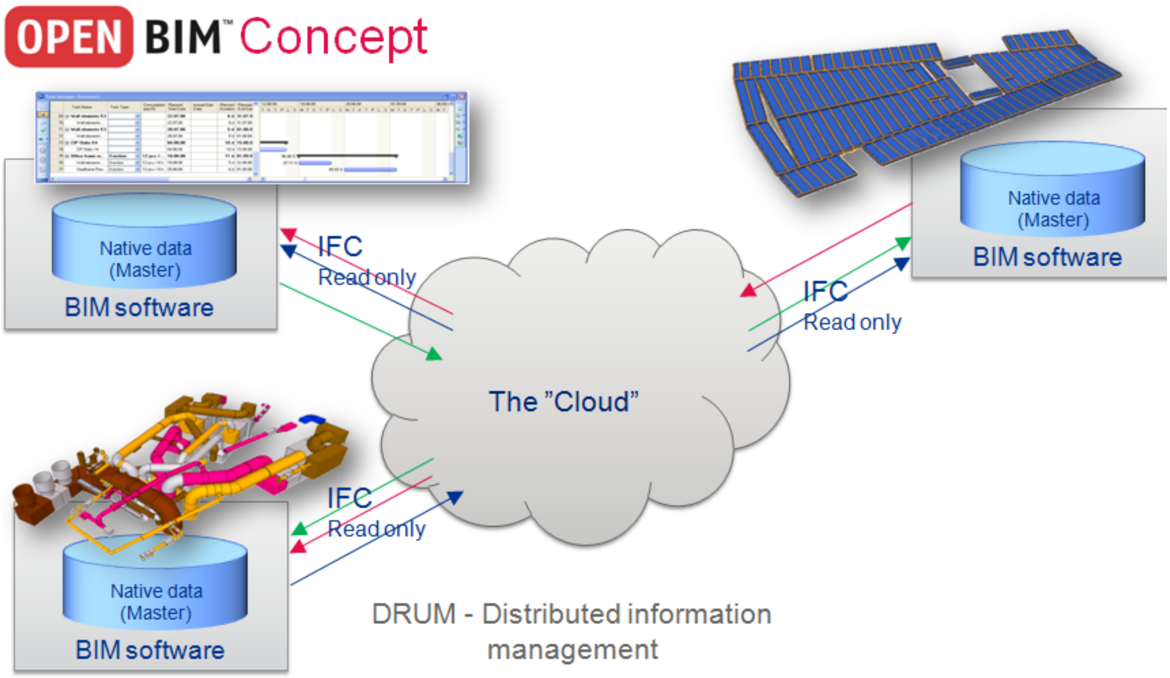


Figure 3.28: DRUM – Distributed Information management (Suomi 2012)

3.2.6 Using Shared Workspaces

When considering undertaking project using BIM how the disciplines will interact with each other is important. The "obeya" or big room concept maybe physical or virtual. The benefits of such spaces have been identified as, reduction of meetings, reduction of overwork, reduction of email, making bottlenecks visible and physical or virtual space saving (Miller 2010).

In the virtual big room disciplines may work on a shared federated model with access being to different elements being allocated to responsible parties.

Another approach is to develop or use a shared workspace to which BIM files are uploaded (Shafig 2013). Suggestions how this upload model should be implemented are contained in BS 1192 (see figure 3.29). The important issue here is the differentiation between approved and work in progress models.

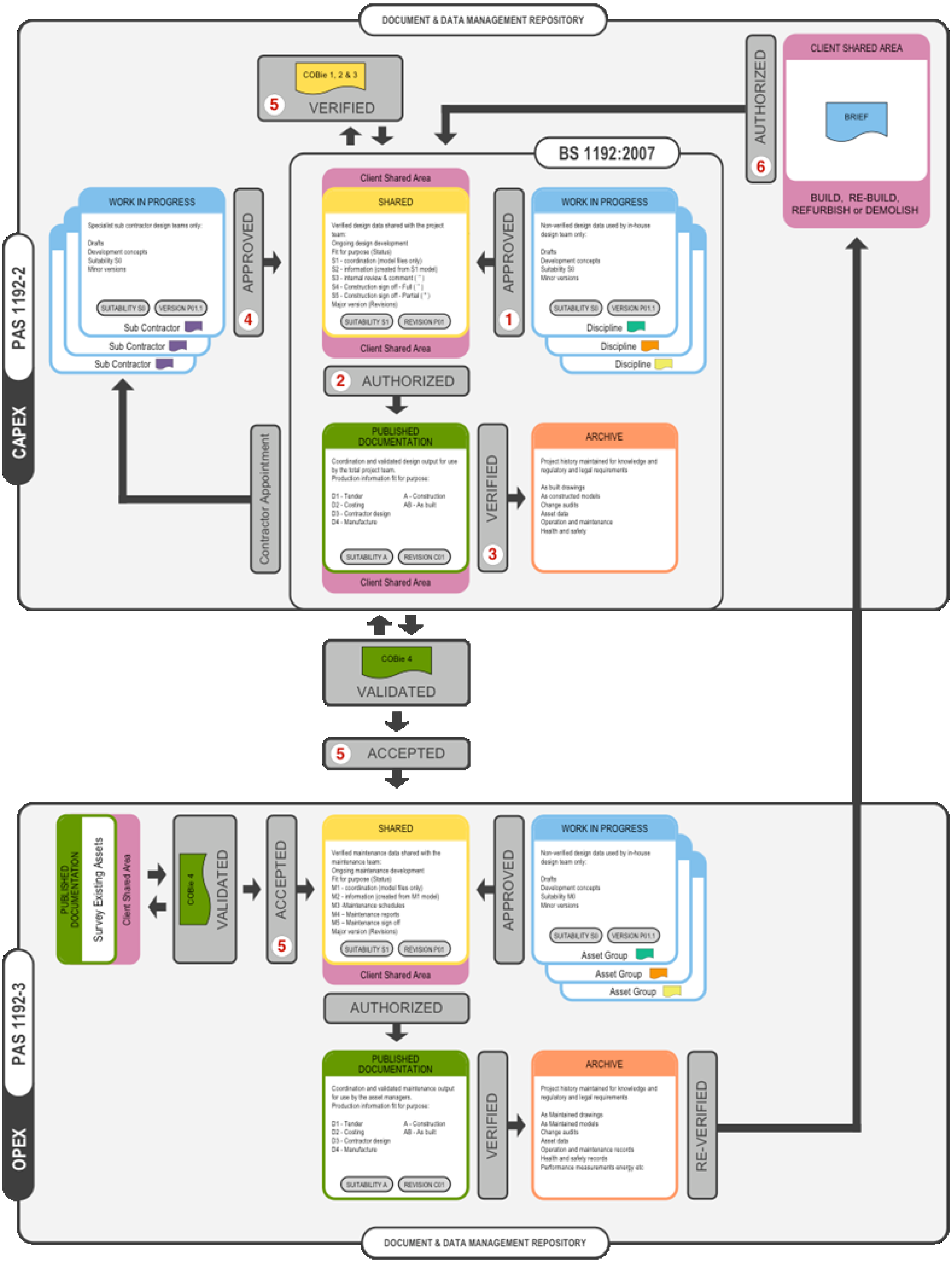


Figure 3.29: The BS1192 recommendations showing how different forms of information may be shared on a project

A diagram of a share workspace is shown (see figure 3.30). There are several software solutions or portals that offer this functionality. These include Asite (see figure 3.31), 4 Projects and Causeway Technologies, Projectwise and Buzzsaw. BIM interrogation capabilities are developing within these portals.

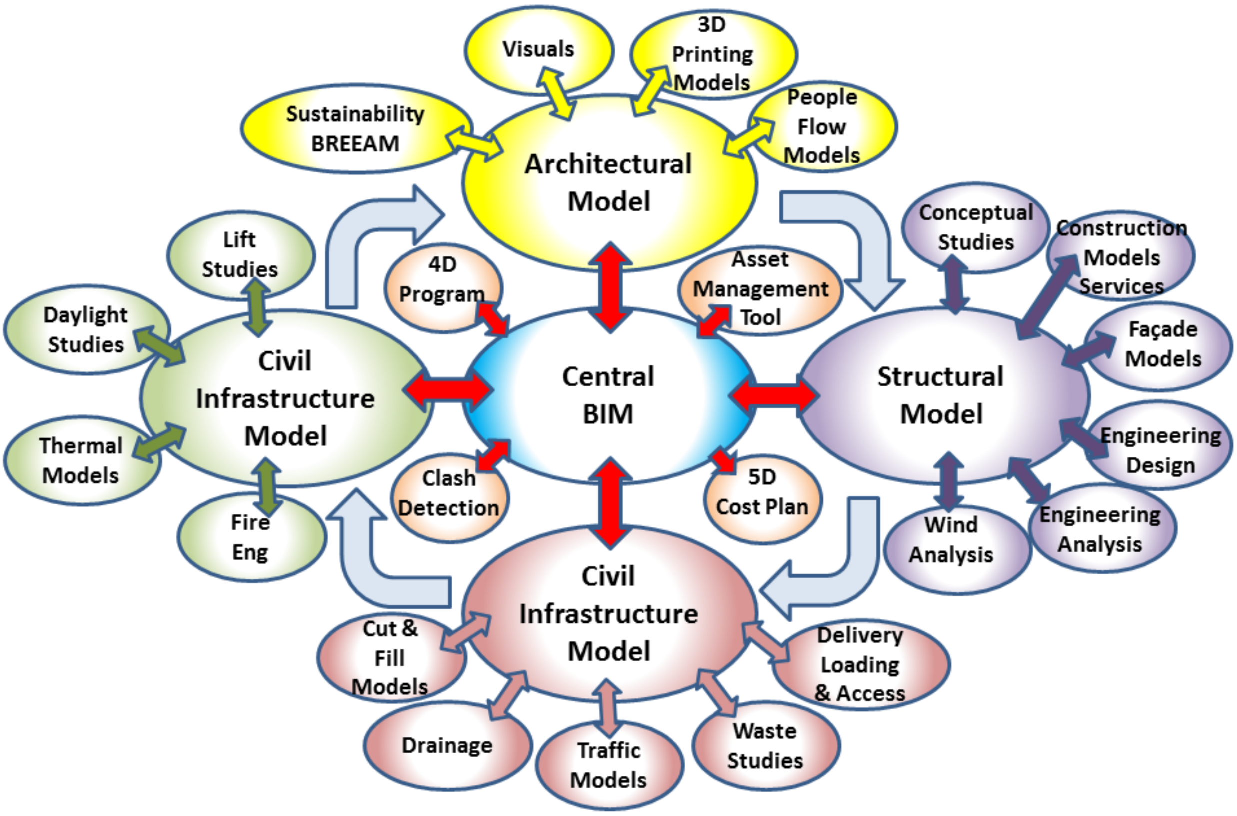


Figure 3.30: Diagram of a shared workspace (source Mott MacDonald)

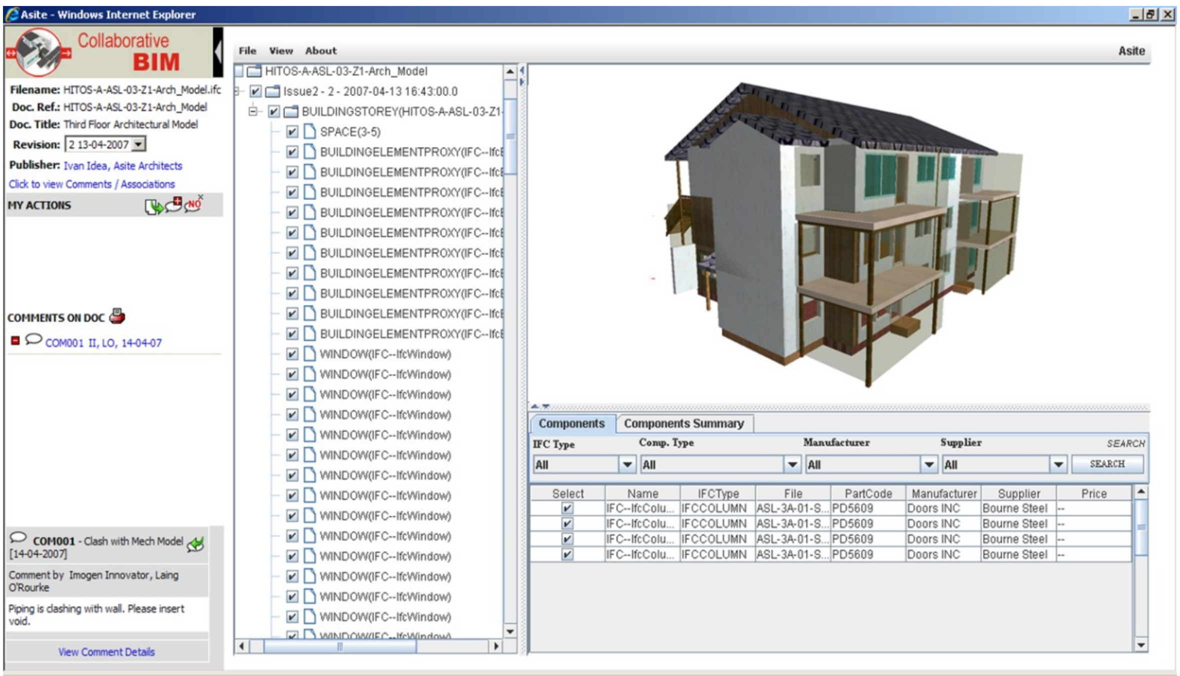


Figure 3.31: A screen shot of the Asite CBIM portal

Autodesk has recently issued it BIM 360 Glue mobile app (see figure 3.32). This allows access on multiple devices to an aggregated model that is the federated from all the individual discipline models. The system will also facilitate clash detection and an RFI system.

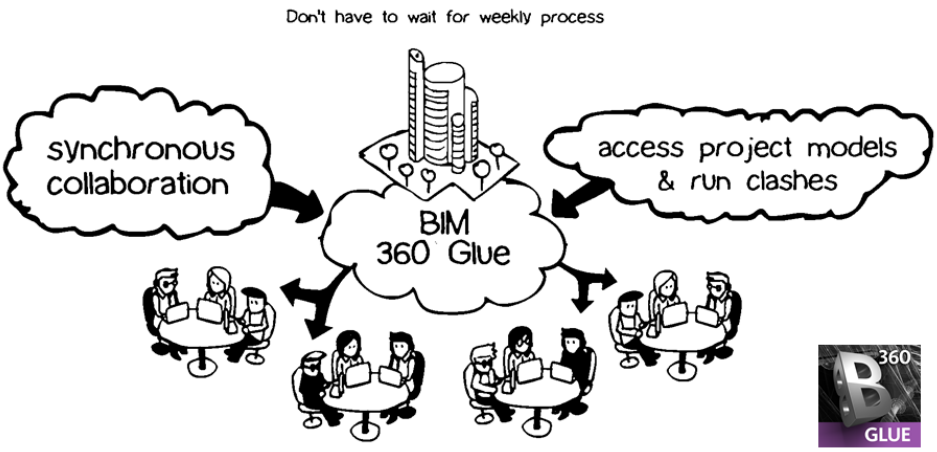


Figure 3.32: The concept of BIM 360 Glue (Autodesk 2013)

3.2.7 The Development and Use of COBie

The construction operation building information exchange (COBie) (East 2007) has also been embraced by buildingSMART and is a major part of the UK governments BIM mandate. COBie was originally developed by NASA and the White House Office of Science and Technology Policy in 2006. The development of COBie according to Stephens (2012) is illustrated (see figure 3.33). Further developments of COBie are to be expected in the UK (particularly to accommodate infrastructure).

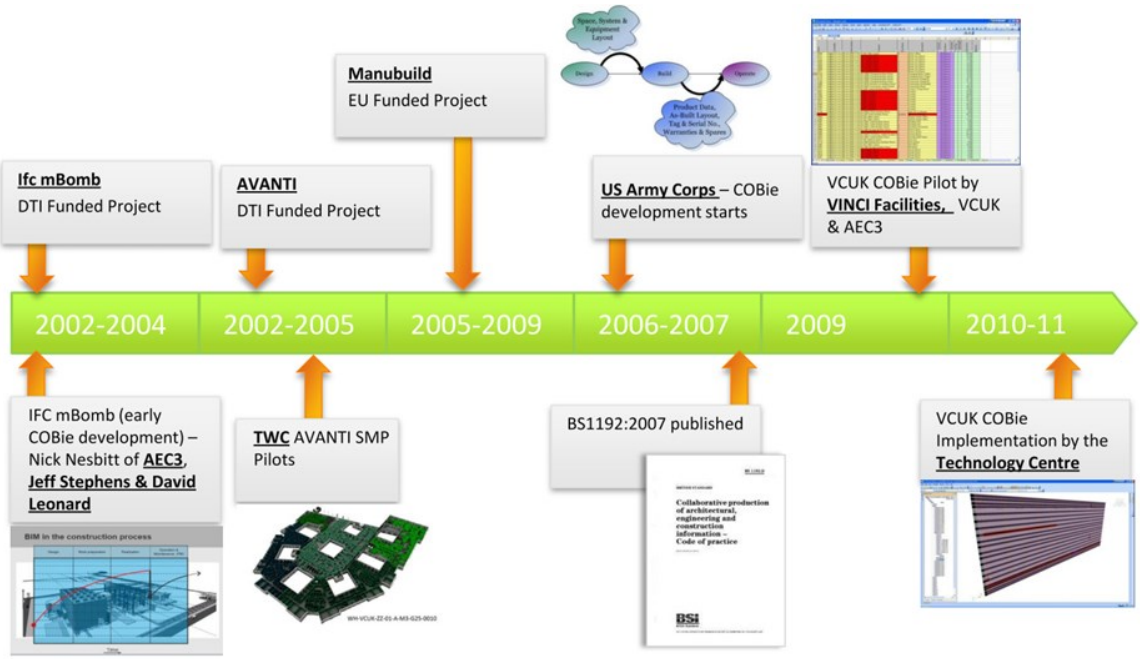


Figure 3.33: The development of COBie (Stephens 2012)

COBie is a vehicle for sharing predominantly non-graphic data about a facility. The major saving emphasized by COBie advocates is the time saving when creating handover information for facilities management operation.

COBie files can be generated from IFC files. AEC3 provide software to convert IFC files to a COBie deliverable. Although, there are other methods of producing COBie.

The UK government has used COBie to define its level 2 BIM requirement. The standard tables which form COBie are shown (see figure 3.34).

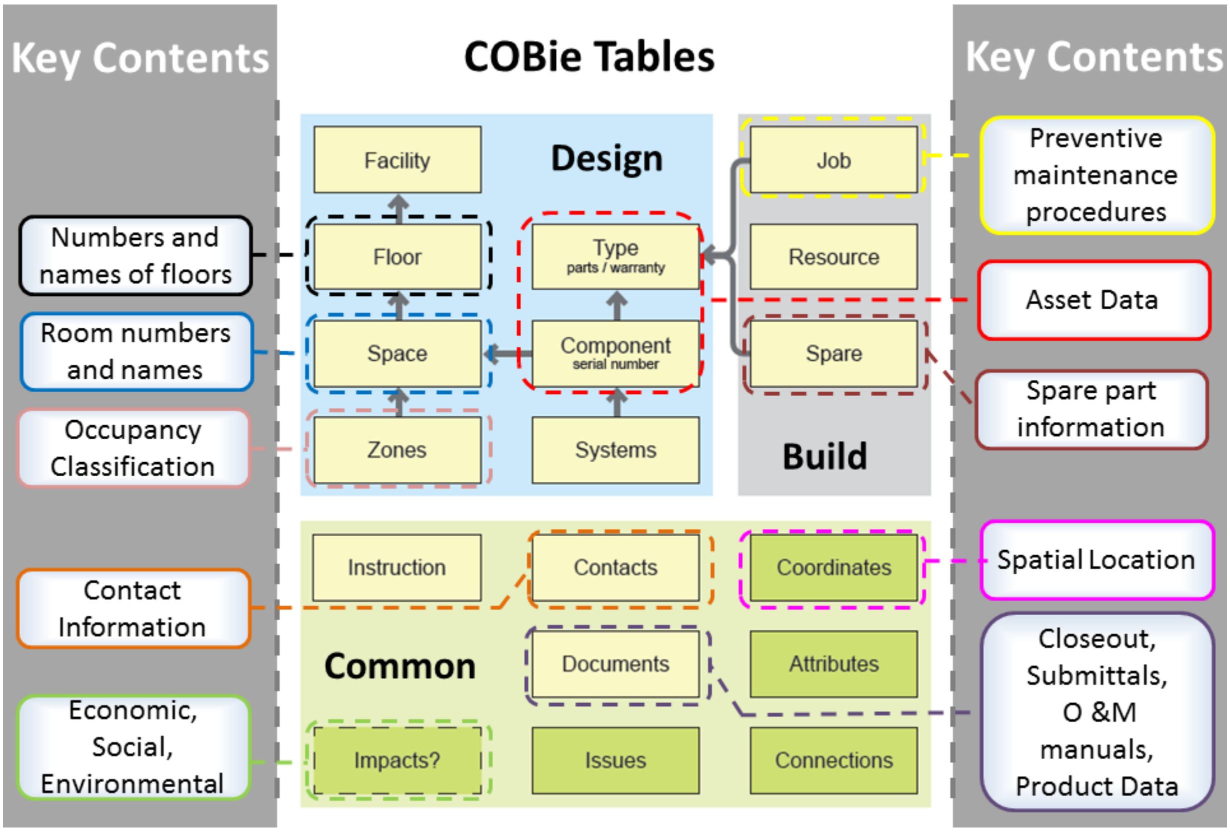


Figure 3.34: The standard tables that go to makeup COBie

The fields commonly used in COBie are shown (see figure 3.35 Appendix A). BIM objects provide both type and instance data in COBie which is required when undertaking facilities management exercise. COBie can be represented in many ways (see figure 3.36 Appendix A).

The suggested COBie information drops (COBie spread sheet information issued to external parties) are set out in the Building Information Modelling workflow (see figure 3.37). Many of the fields in COBie are discretionary, to be provided if required by the client. So to use COBie effectively educated clients are required.

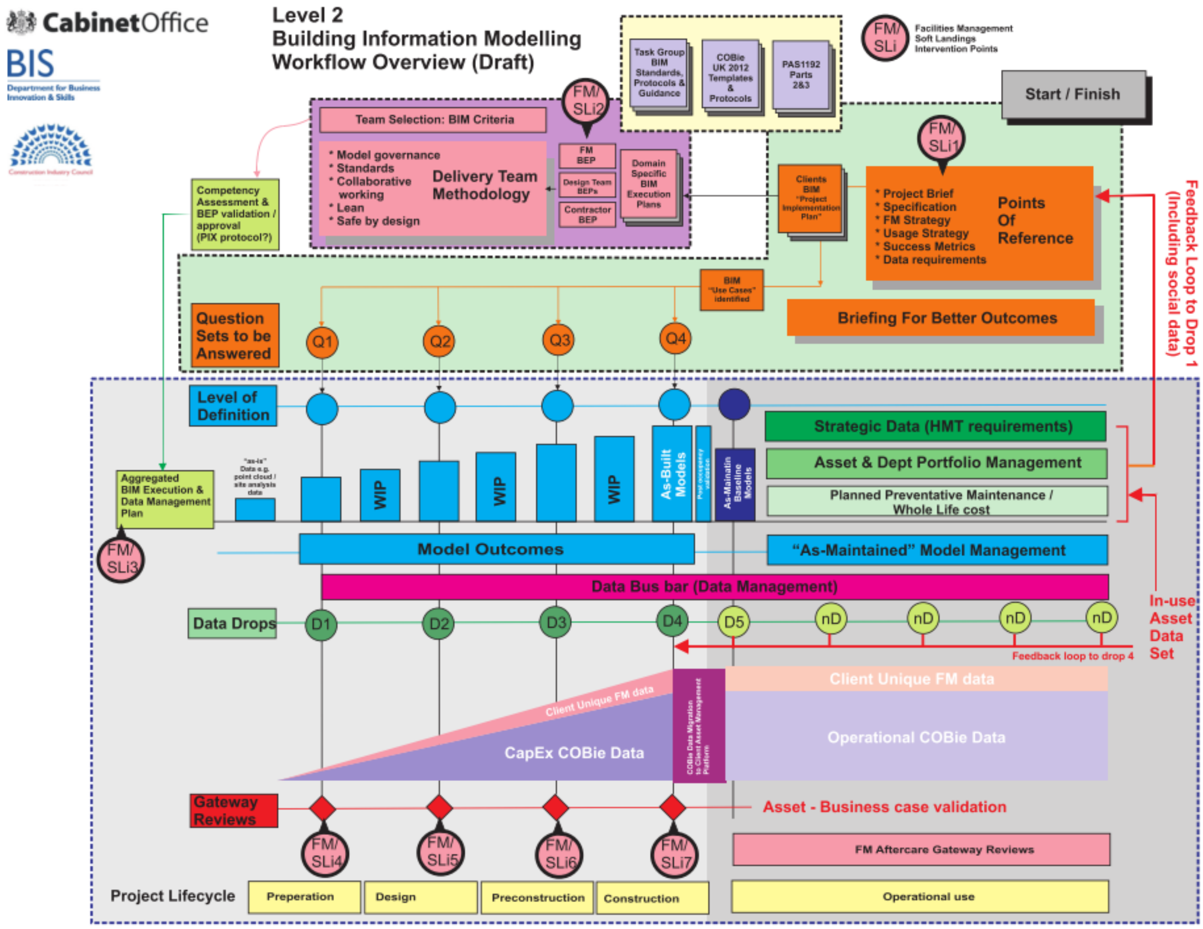
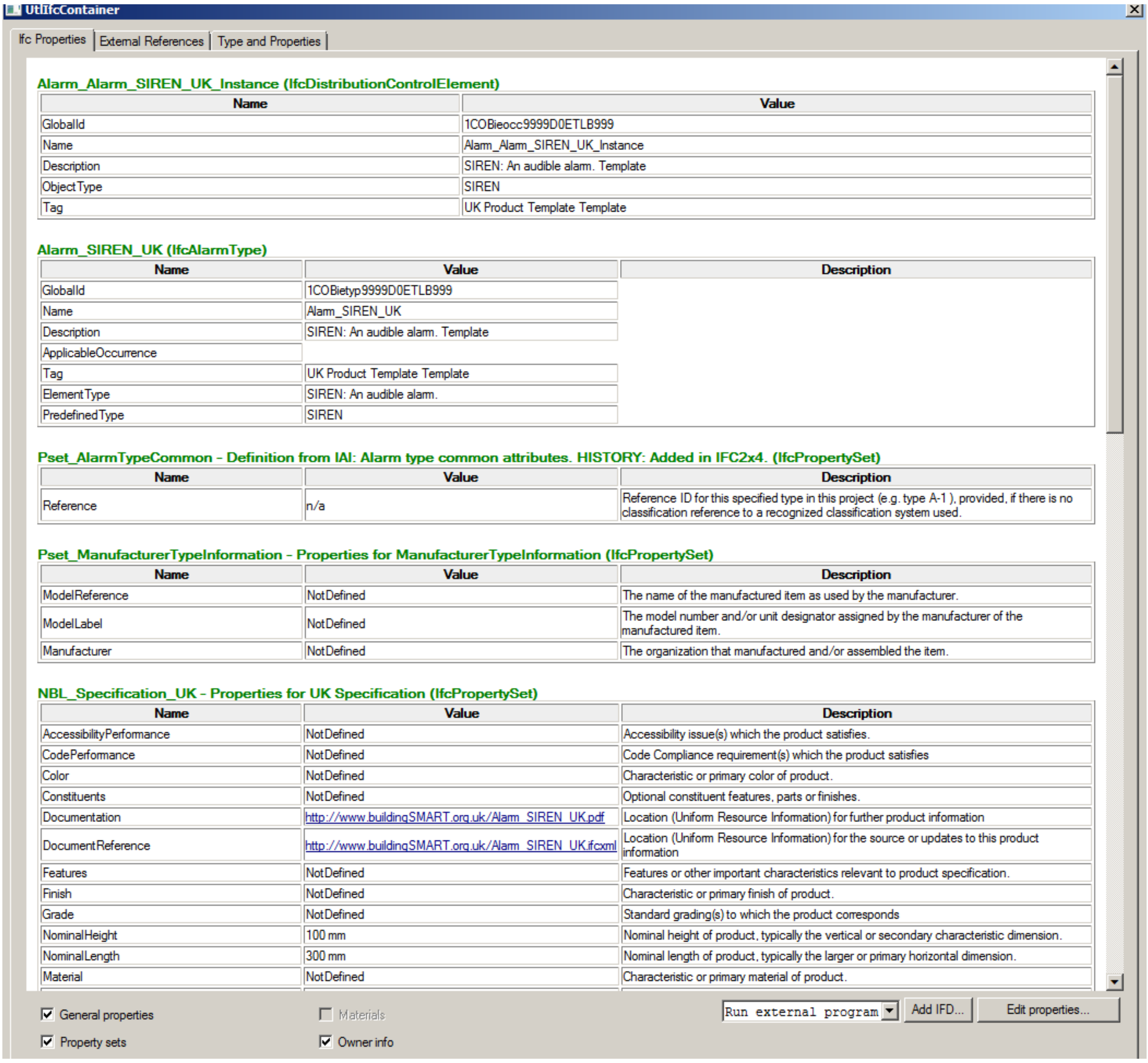


Figure 3.37: The Cabinet Office Building Information Modelling Workflow (Bew et al 2012)

	Project Phases			
COBie Worksheet	Schematic Design	Design Development	Construction Documentation	Construction
Attribute			X	X
Component		X	X	X
Contact	X	X	X	X
Document			X	X
Facility	X	X	X	X
Floor	X	X	X	X
Job				X
Resource				X
Space	X	X	X	X
Spare				X
System		X	X	X
Type		X	X	X
Zone	X	X	X	X

Figure 3.38: COBie tables to be completed at various project stage (Teicholz 2013)

The use of COBie in the UK has been extend to include COBie type templates (see figure 3.39). These can be used to collect the information required as part of the COBie deliverable or replacement parts.


UtlIfcContainer

Ifc Properties | External References | Type and Properties

Alarm_Alarm_SIREN_UK_Instance (IfcDistributionControlElement)

Name	Value
GlobalId	1COBieocc9999D0ETLB999
Name	Alarm_Alarm_SIREN_UK_Instance
Description	SIREN: An audible alarm. Template
ObjectType	SIREN
Tag	UK Product Template Template

Alarm_SIREN_UK (IfcAlarmType)

Name	Value	Description
GlobalId	1COBietyp9999D0ETLB999	
Name	Alarm_SIREN_UK	
Description	SIREN: An audible alarm. Template	
ApplicableOccurrence		
Tag	UK Product Template Template	
ElementType	SIREN: An audible alarm.	
PredefinedType	SIREN	

Pset_AlarmTypeCommon - Definition from IAI: Alarm type common attributes. HISTORY: Added in IFC2x4. (IfcPropertySet)

Name	Value	Description
Reference	n/a	Reference ID for this specified type in this project (e.g. type A-1), provided, if there is no classification reference to a recognized classification system used.

Pset_ManufacturerTypeInformation - Properties for ManufacturerTypeInformation (IfcPropertySet)

Name	Value	Description
ModelReference	NotDefined	The name of the manufactured item as used by the manufacturer.
ModelLabel	NotDefined	The model number and/or unit designator assigned by the manufacturer of the manufactured item.
Manufacturer	NotDefined	The organization that manufactured and/or assembled the item.

NBL_Specification_UK - Properties for UK Specification (IfcPropertySet)

Name	Value	Description
AccessibilityPerformance	NotDefined	Accessibility issue(s) which the product satisfies.
CodePerformance	NotDefined	Code Compliance requirement(s) which the product satisfies
Color	NotDefined	Characteristic or primary color of product.
Constituents	NotDefined	Optional constituent features, parts or finishes.
Documentation	http://www.buildingSMART.org.uk/Alarm_SIREN_UK.pdf	Location (Uniform Resource Information) for further product information
DocumentReference	http://www.buildingSMART.org.uk/Alarm_SIREN_UK.ifcxml	Location (Uniform Resource Information) for the source or updates to this product information
Features	NotDefined	Features or other important characteristics relevant to product specification.
Finish	NotDefined	Characteristic or primary finish of product.
Grade	NotDefined	Standard grading(s) to which the product corresponds
NominalHeight	100 mm	Nominal height of product, typically the vertical or secondary characteristic dimension.
NominalLength	300 mm	Nominal length of product, typically the larger or primary horizontal dimension.
Material	NotDefined	Characteristic or primary material of product.

General properties | Materials | Run external program | Add IFD... | Edit properties...

Property sets | Owner info

Figure: 3.39: A standard COBie template displayed in DDS software

But COBie on its own is not adequate to fulfil the informational needs of facilities management (see figure 3.40). In the US and in certain large organisations in the UK there are moves to extend COBie to address additional issues such as sustainability and deterioration issues (see figure 3.41).

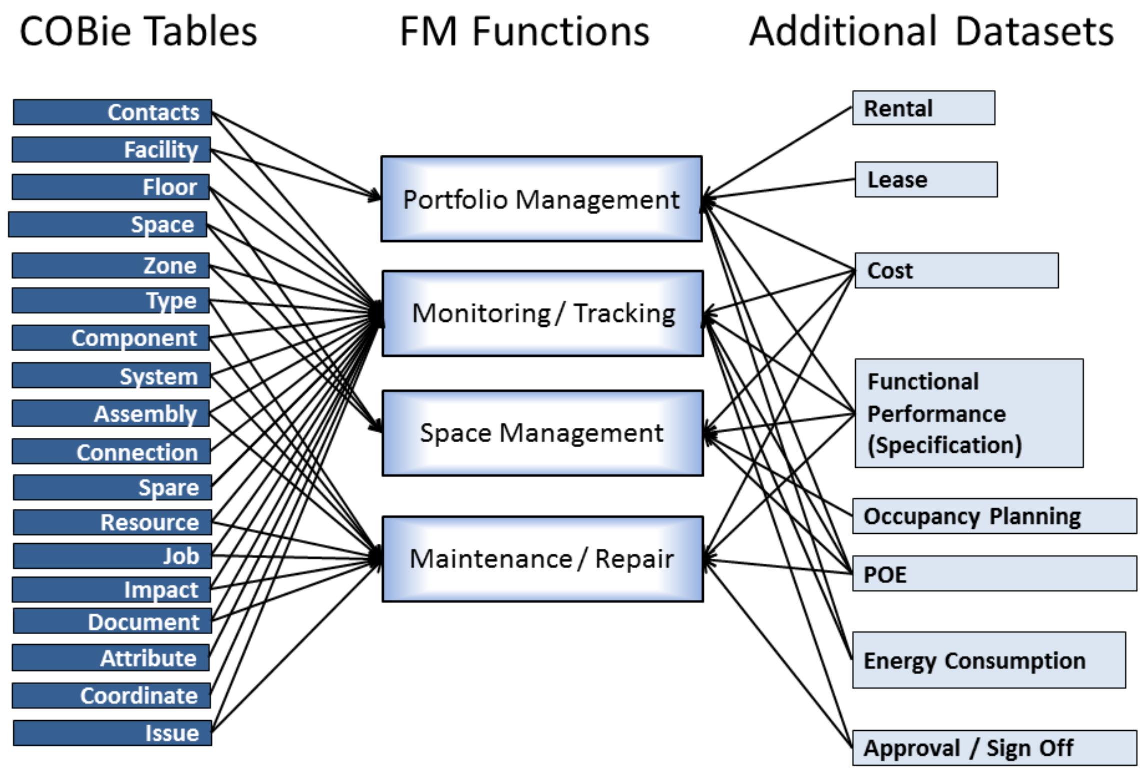


Figure 3.40: Cobie Tables and the additional informational needs to perform FM functions

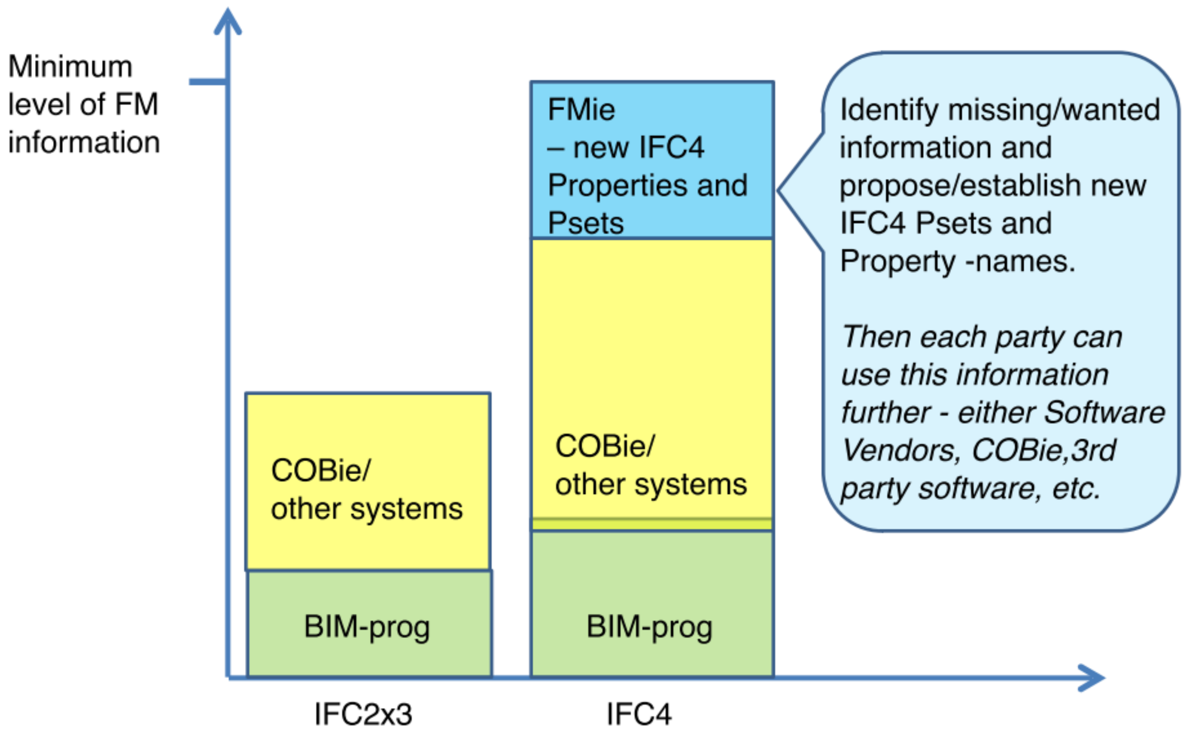


Figure 3.41: Suggested extension to COBie with FMie to meet Facilities management needs (Aarsethl 2013)

3.2.8 BIM as part of Integrated Project Delivery

BIM is sometimes confused with integrated project delivery.

"Integrated Project Delivery (IPD) is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction."

AIA 2007

BIM is one component of integrated project delivery as shown (see figure 3.42 and 3.43).

The effectiveness of BIM to some extent is defined by the contractual mechanisms within which it operates. Guidelines on IPD are available from the AIA in the US. IPD encourages the early involvement of consultants.

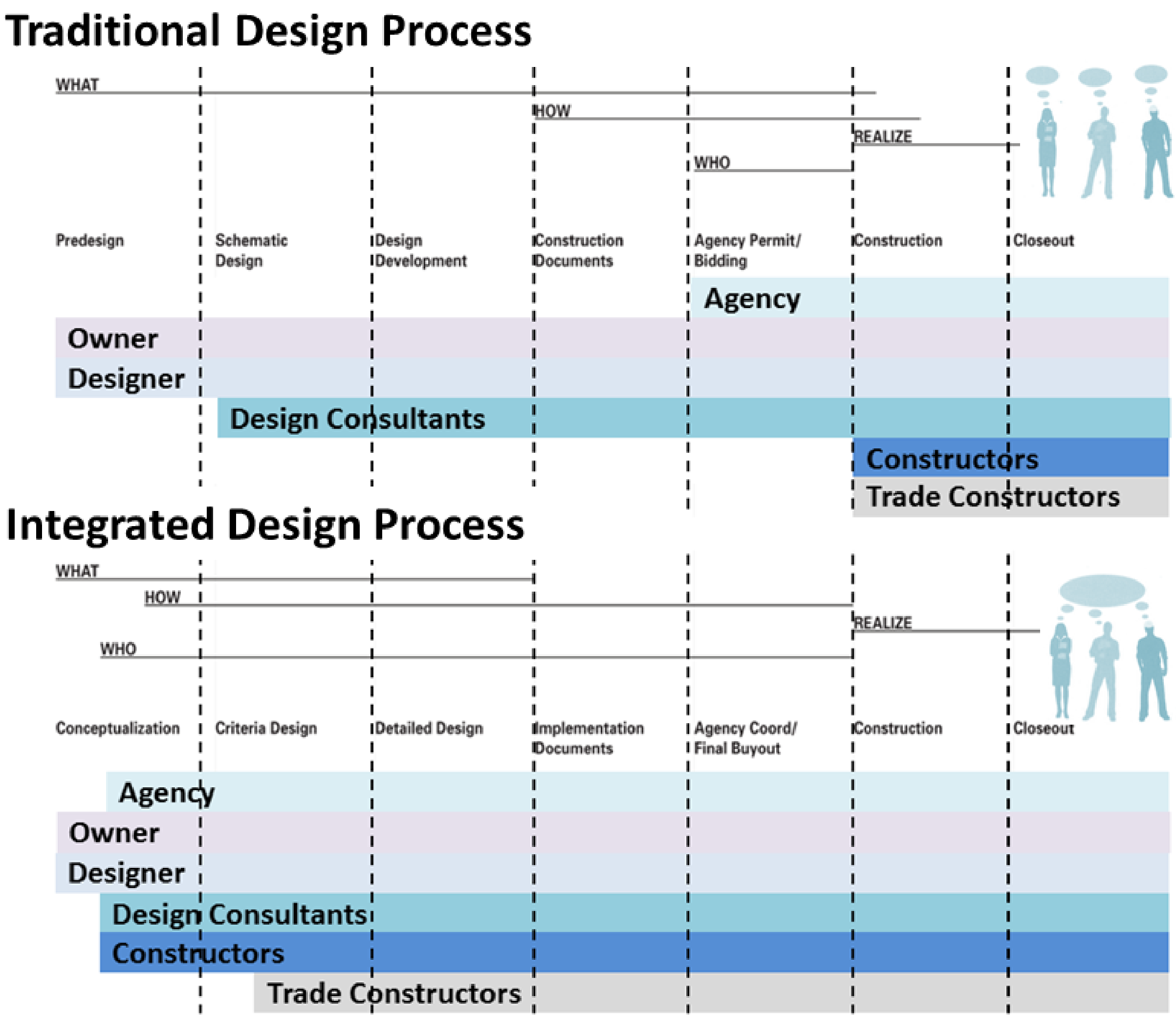


Figure 3.42: Integrated Project Delivery (AIA 2007)

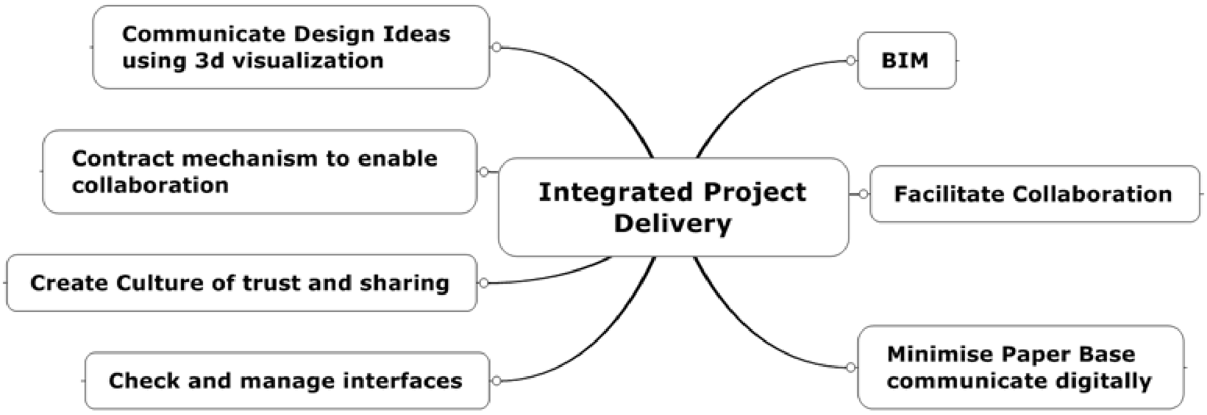


Figure 3.43: BIM as one part of Integrated Project Delivery (adapted from Autodesk 2009)

IPD requires a changing of the relationships within the contract (see figure 3.44).

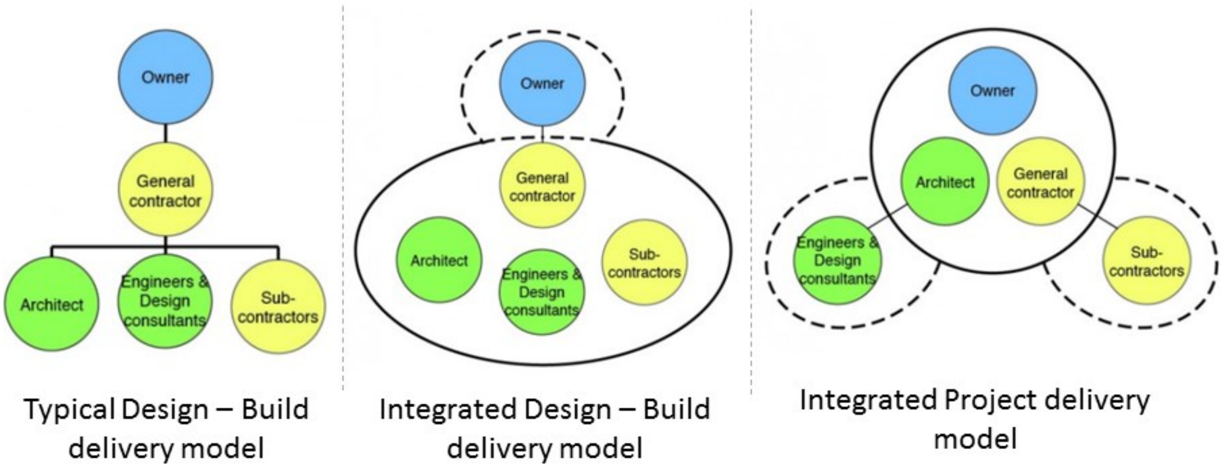


Figure 3.44: Changes in the contractual relationships using IPD (Wilson and Dal Gallo 2013)

Part of the concept of IPD is similar to concurrent engineering (CE) where the product and the downstream production are designed simultaneously (Kamara & Anumba 2000). Job order contracting (JOC) is also similar to IPD and is used in the US for smaller projects.

In the UK the PPC2000 is a relational contract that is being used to deliver building projects. PPC2000 by the ACA now has a BIM supplement for when it is used on BIM contracts.

3.2.9 Level of Detail

The expectation is that the amount of data associated with objects will develop throughout the lifecycle of a project. Thus the informational volume / value of the BIM model increases as the project progresses. The following suggested level of detail classifications for objects are based on the American Institute of Architects (AIA) recommendations:

- 100 Conceptual - Overall building massing suitable for whole analysis (volume, building orientation, cost per sq metre etc.)
- 200 Approximate Geometry (scheme design or design development) - generalised systems or assemblies with approximate quantities, size, shape, location and orientation
- 300 Precise Geometry - suitable for generation of traditional construction drawings
- 400 Fabrication and Assembly - suitable for fabrication this is normally the sub-contractor model information
- 500 As Built - as constructed model suitable for maintenance and operations of the building

Ikerd (2013) has suggested that additional levels of detail are necessary (see figure 3.45).

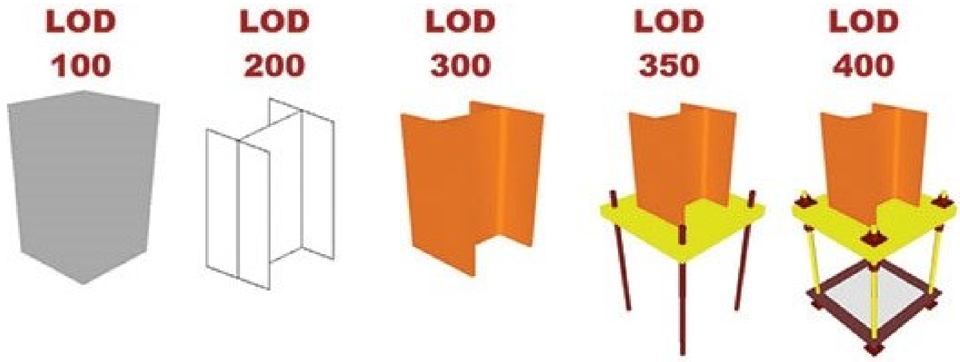


Figure 3.45: Examples of Objects showing different levels of detail (Ikerd 2013)

The AIA BIM Protocol E202 (2008) and E303 (see figure 3.46) can be used to document and define the LOD of objects on a project. This provides the ability for levels of detail to be defined by discipline and by stage and by object type.

AIA BIM Protocol Exhibit E202-2008.)

§ 4.3 Model Element Table

Identify (1) the LOD required for each Model Element at the end of each phase, and (2) the Model Element Author (MEA) responsible for developing the Model Element to the LOD identified.

Insert abbreviations for each MEA identified in the table below, such as "A – Architect," or "C – Contractor."

NOTE: LODs must be adapted for the unique characteristics of each Project.

Model Elements Utilizing CSI UniFormat™					LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	Note Number (See 4.4)
A SUBSTRUCTURE	A10	Foundations	A1010	Standard Foundations													
			A1020	Special Foundations													
			A1030	Slab on Grade													
	A20	Basement Construction	A2010	Basement Excavation													
			A2020	Basement Walls													
B SHELL	B10	Superstructure	B1010	Floor Construction													
			B1020	Roof Construction													
	B20	Exterior Enclosure	B2010	Exterior Walls													
			B2020	Exterior Windows													
			B2030	Exterior Doors													
	B30	Roofing	B3010	Roof Coverings													
			B3020	Roof Openings													

Figure 3.46: The E202 BIM Protocol AIA (2008)

Guidance on level of detail is also to be found in the "BIM matrix" published by the Veterans Affairs department in the US in the form of an excel spread sheet. This defines a range of functionalities possible from BIM and the information required to achieve these functionalities.

If the precise detail of the required object is defined at the outset, working the object up through the levels of detail results in unnecessary effort. Using correctly structured models substituting objects with increasing LOD (Level of Detail) should be a simple exercise. Different models for different disciplines may be required at different levels of detail. Some users prefer to use the term level of development instead of level of detail. The level of detail may related to the COBie drop (see figure 3.47).

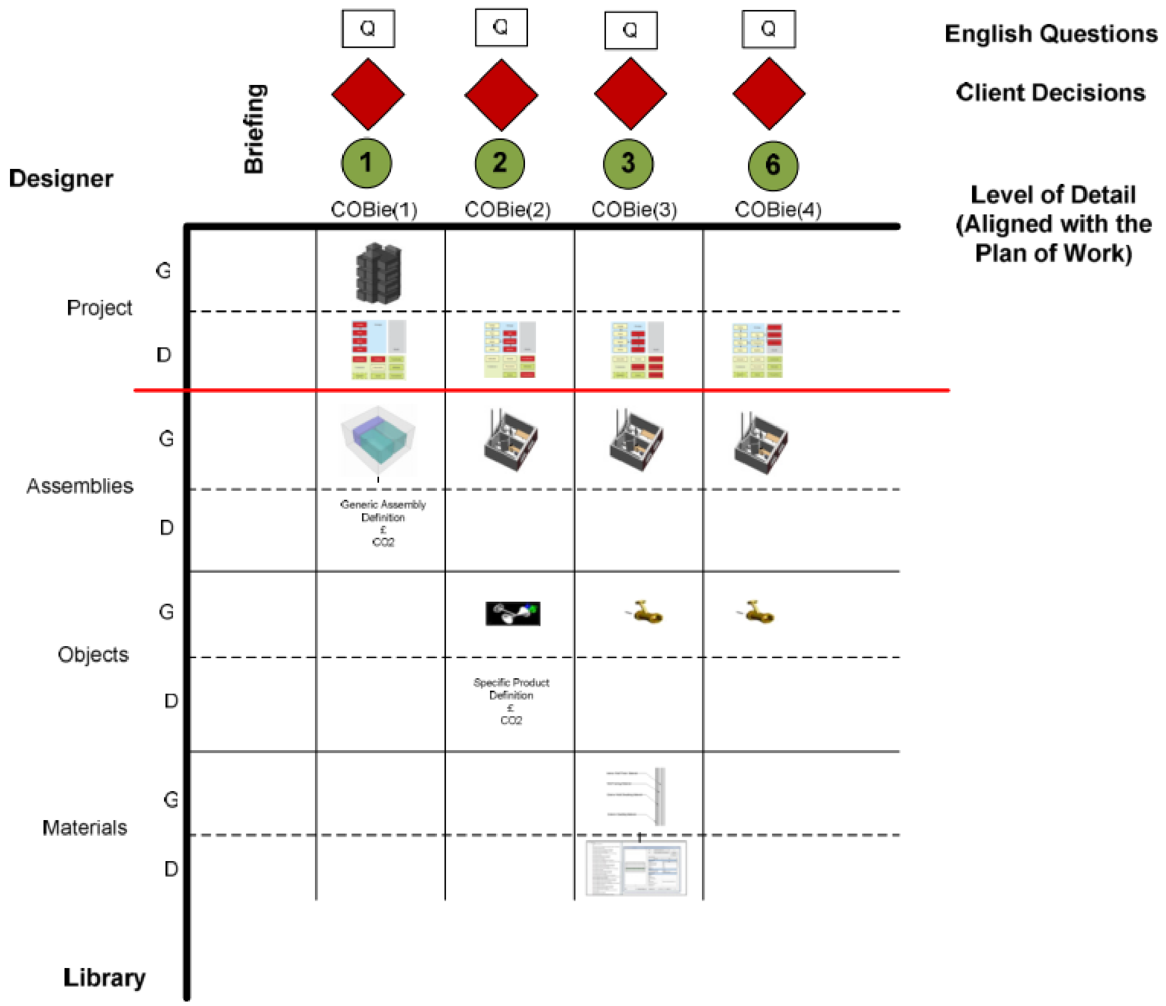


Figure 3.47: Level of Detail Aligned with the COBie drops (The digital plan of work and assemblies 2013)

3.2.10 BIM and Open BIM ™

In 2012 buildingSMART International, members of the Nemetschek Group, Tekla and other leading software vendors joined forces to launch a global program to help promote “Open BIM” collaboration workflows throughout the AECOO industry. Open BIM represents a universal approach to the collaborative design, realization and operation of buildings based on open standards and workflows (Groome 2012).

To achieve the maximum benefits of BIM it has been suggested that it must work at a collaborative level. The need for this new term Open BIM as something different to BIM can be seen as a result of the debasing of the term BIM by some parties and within some organisations. Some of the concepts behind open BIM are shown (see figure 3.48).

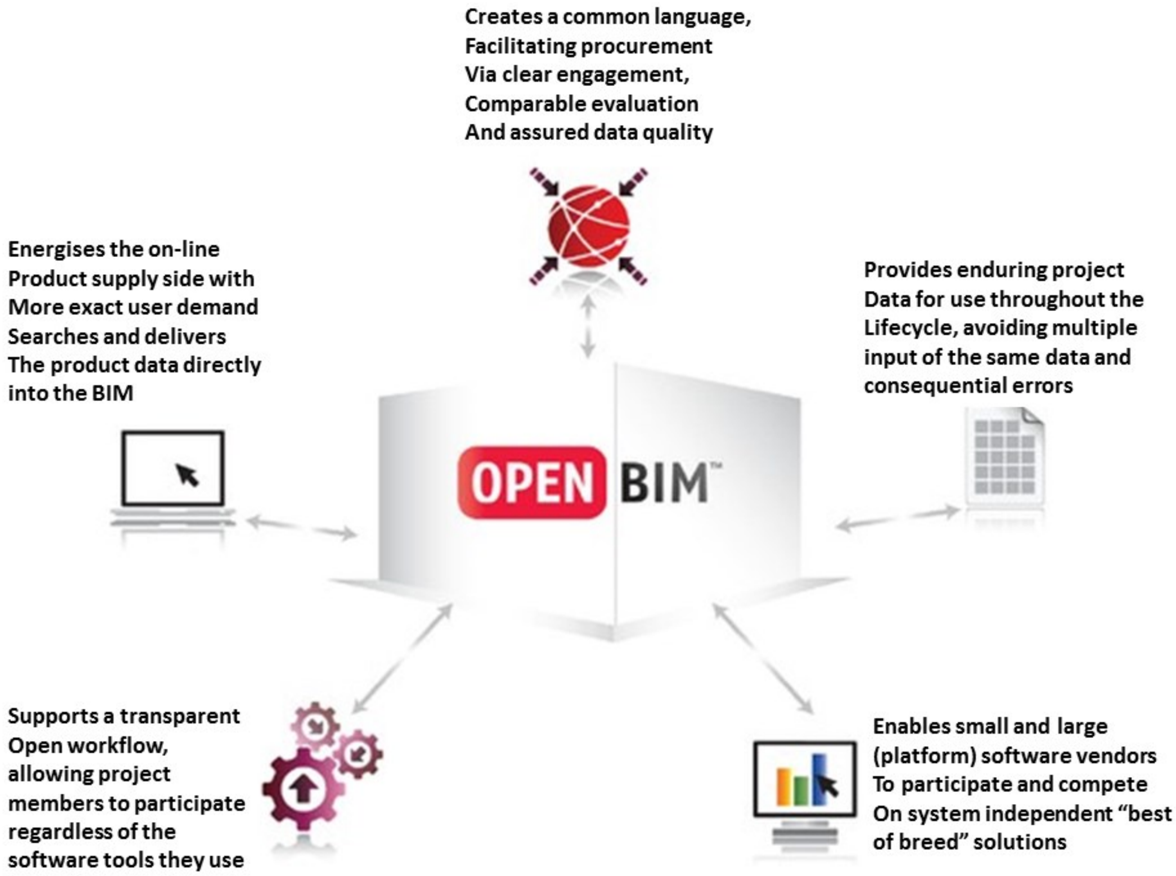


Figure 3.48: The concepts behind Open BIM (Graphisoft Connect 2012)

3.2.11 Standards relevant to BIM and BIM Implementation

A standard is a published specification that establishes a common language, and contains a technical specification or other precise criteria and is designed to be used consistently, as a rule, as a guideline, or as a definition. The standards provide the lexicon within which BIM operates but fall short of prescribing method of operation.

In part the development of BIM relies on standards being in place and being adopted by multiple parties. Currently several standards are being published which are important for the future development of BIM in the UK. The UK government has adopted a phased process working closely with industry groups, in order to allow time for industry to prepare for the development of new standards. How the adoption of BIM relates to the development of standards is illustrated (see figure 3.49).

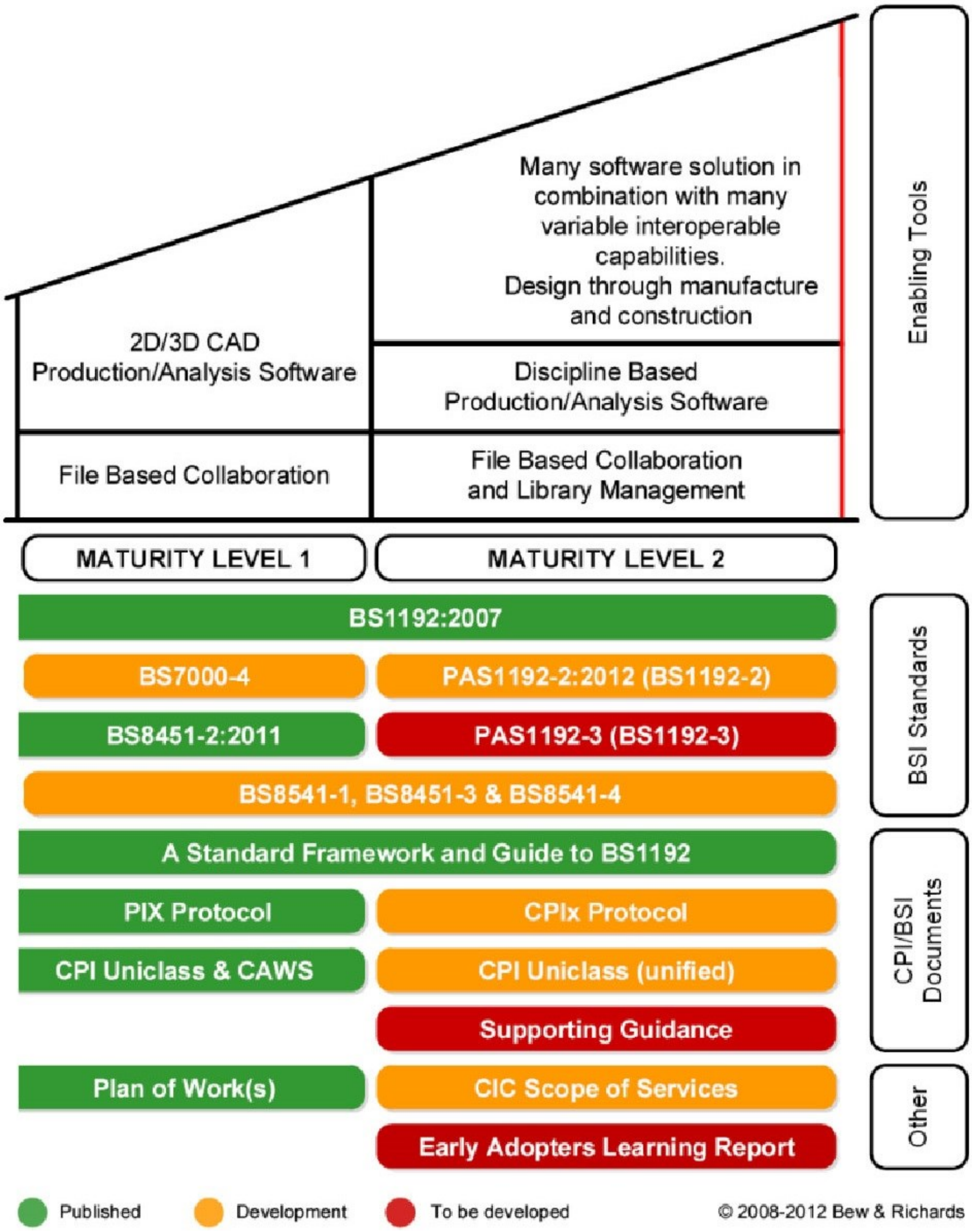


Figure 3.49: Showing how the development of BIM relates to the development of standards (BIM Task Group 2012)

Listed below are some of the standards that form the basis of BIM operation:

- ISO 12006-2:2001 - Building construction - Organization of information about construction works - Part 2: Framework for classification of information
- ISO 12006-3:2007 - Building construction -- Organization of information about construction works -Part 3: Framework for object-oriented information
- ISO 16739 2005 _ Industry Foundation Classes Release 2x Platform Specification (IFC2X Platform)

- ISO 22263:2008 - Organization of information about construction works -- Framework for management of project information
- ISO 29481-1:2010 – Building information models -- Information delivery manual -- Part 1: Methodology and format.
- IFC: Industry Foundation Classes, based on ISO/PAS 16739:2005

- BS 1192:2007 Collaborative production of architectural, engineering and construction information. Code of practice
- BS 8541-2:2011 Library objects for architecture, engineering and construction. Recommended 2D symbols of building elements for use in building information modelling
- BS 8541-1 Library objects for architecture, engineering and construction - Part 1: Identification and classification - Code of Practice
- BS 8541-3 Library objects for architecture, engineering and construction - Part 3: Shape and measurement
- BS 8541-4 Library objects for architecture, engineering and construction - Part 4: Attributes for specification and assessment - Code of Practice
- ISO/ TS 12911 - Framework for provision of guidance on building information modelling
- ISO/WD 16354 - Guidelines for Knowledge Libraries and Object Libraries
- ISO/CD 29481-2 - Building information modelling - Information delivery manual - Part 2: Transaction framework

Standards under development

- ISO/WD 16757 - Product Data for Building Services Plant Models

3.2.12 BIM and ICT (Information Communication and Technology)

It is important to understand that BIM is just one of a range of construction IT related capabilities that is and can be used and are becoming available in the building lifecycle (see figure 3.50 Appendix A). Central to the efficiency of the cycle a building development goes through is the effective transfer and use of data. As data rather than documents become the de facto standard of communication greater efficiencies can be achieved.

3.2.13 The Value of Data and Text in BIM models

Excessive BIM data represents a potential problem to create, use and maintain. Data takes an effort to create and if data exists, it requires attention irrespective of its value (Davenport & Beck, 2001) (Simon, 1971). Similar to the lean concepts of reducing inventory, excessive information results in time and effort being wasted. Inappropriate or wrong decisions maybe made because of excessive data. Incorrect decisions can be extremely costly for the client and all parties within the construction process. Effective BIM is not just about producing data, it is about making a difference by utilizing focused data. Ideally the user of the data should just receive or view the data sufficient for the tasks they need to perform. This has led to the concept of MVD (model view definitions). Defining information by its usefulness has been suggested to help in the development of lifecycle information (Hjelseth 2009) (see figure 3.51).

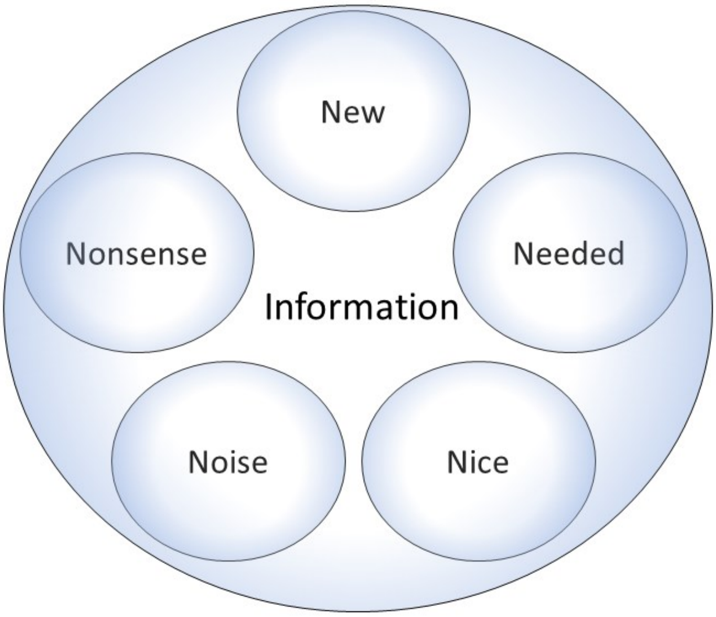


Figure 3.51: Distinguishing different types of information (Hjelseth 2009)

Guttman (2011) set out four principles relating to the value of the informational content of BIM.

Principle 1

- The effort cost of acquiring and maintaining quality information is proportional to the amount of information.

Principle 2

- The value of information is proportional to the cost and acquisition and maintenance of the relevant tangible building elements being modelled.

Principle 3

- The value of a BIM process is proportional to the acquisition and maintenance cost of the relevant tangible building elements being modelled and inversely proportional to the quantity – based cost of developing and maintaining the information.

Principle 4

- The quantity of information in a model based representation of a project is greater than a conventional representation by a factor of the number of building elements.

Some suggest that BIM and document management represent distinct entities (Tse 2009) in the construction process. Tse (2009) proposes the development of an IBDM (integrated BIM document model). This has the potential to add existing information in a searchable and usable form to the BIM domain.

Documents that traditionally been held in a paper based form include specifications. Building specifications can now be produced using NBS Create and be generated digitally over the web. NBS Create and eSpecs which is used in the USA have been designed to integrate with other BIM tools and systems. This linking of specification at object instance level has the potential to add additional intelligence and ease of development to the creation of integrated information. The question is then what information should be held in the BIM object and what should be held as text in the specification. This is a complex issue and it is important to ensure information is not duplicated. Figure 3.53 provides an indication of the issues.

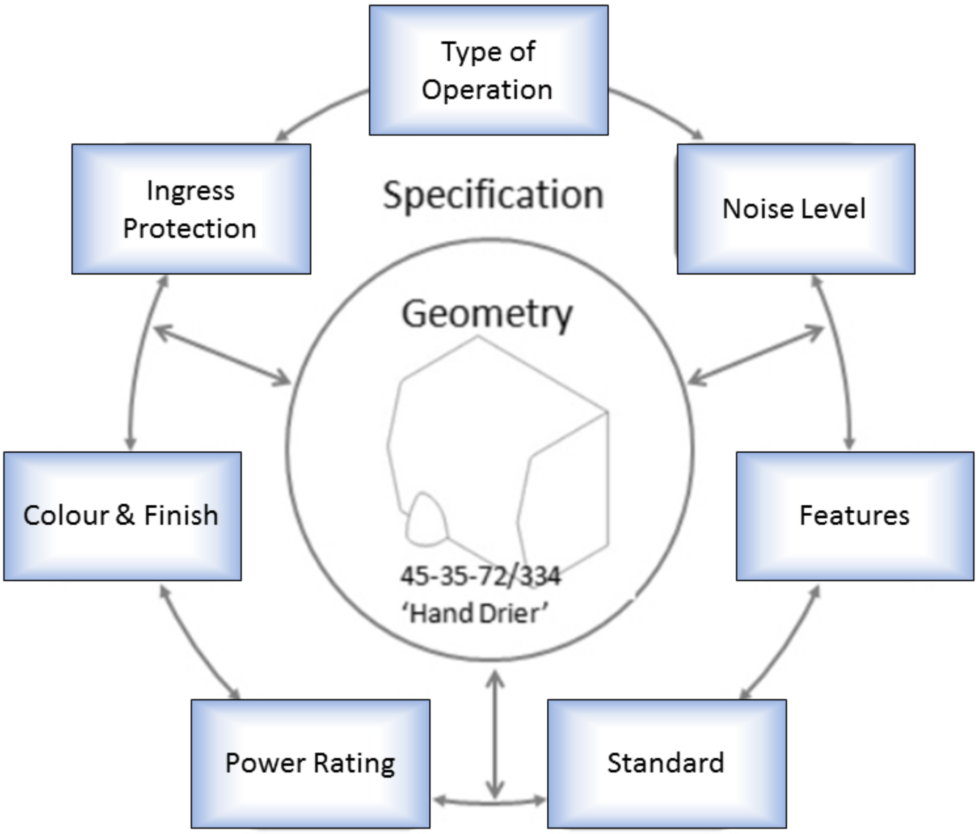


Figure 3.52: Appropriate location of information (Mordue 2013)

3.2.14 The Future of BIM

"Civilisation advances by extending the number of important operations we can perform without thinking about them"

Whitehead (1911)

Three business effects were identified by Fox (2006) as part of the BIM – VBE Measurement Framework (see figure 3.53). The sequence these effects are likely to occur in the order of automation change, informational change, then transformational change.

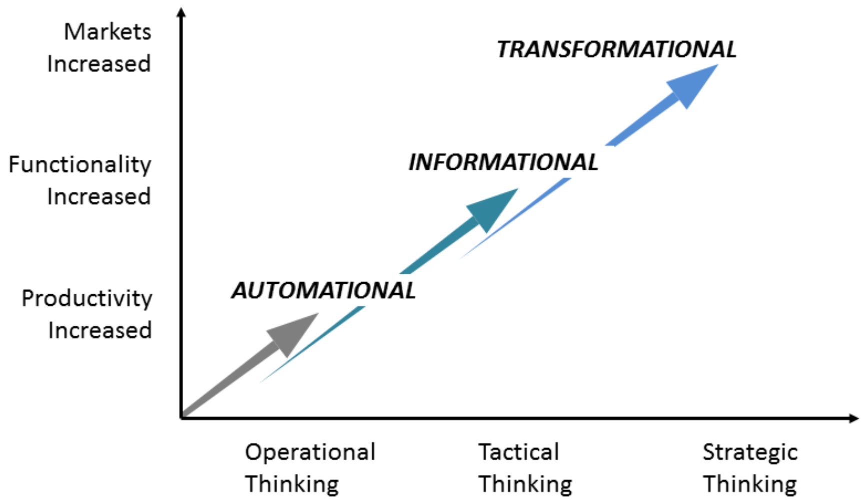


Figure 3.53: The changes brought about by BIM (Fox 2006)

The future development of BIM has been predicted by the Bew and Richards model (see figure 3.54). The capabilities of the IFC file format also are developing with proposals for any aspect of an IFC model to be "data driven".

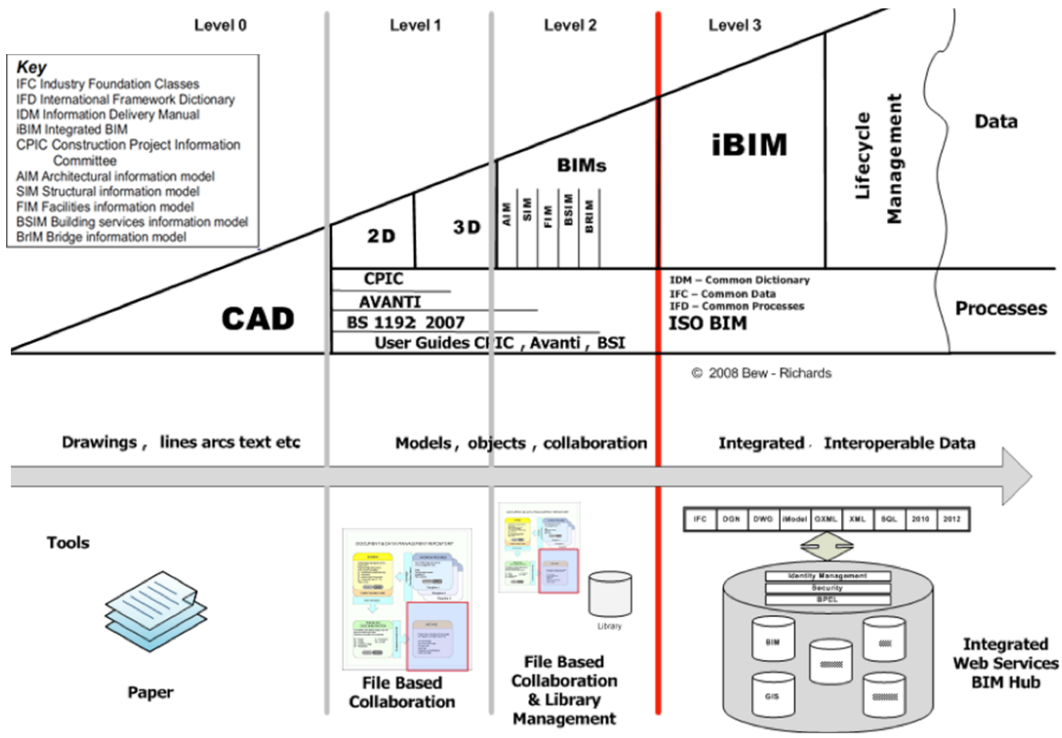


Figure. 3.54: The development of BIM Level 1, Level 2, Level 3

(Department of Business, Innovation and Skills 2011)

On this Bew and Richards model different levels of BIM development are indicated.

These are:

- Level 0 - Computer Aided Design (CAD) - Flat CAD with no 3D data. Only traditional drawings are produced often in the form of DWG.

- Level 1 - 2D and 3D - builds upon CAD but it is creating data that is only used for visualisation purposes. These models are not creating useful data that can be shared with other members of the team.

- Level 2 - BIM - Individual discipline models used to collaborate which contain intelligent data. The full potential of the data may not have been realised at Level 2. Data will be provided from these models in COBie format for UK Government projects over £5 million.

- Level 3 - iBIM or Integrated BIM - Shared and Integrated BIM models and shared data providing information including facilities management and lifecycle costing data.

The UK government has mandated that public projects should have reached Level 2 by 2016.

Reaching Level 3 or “IBIM” (intelligent BIM) the use of data management servers will be required. The further development of big data and use of multi media databases within the construction domain are also likely to be part of Level 3 IBIM.

A parallel view of BIM development was put forward by Consult Australia (2010) (see figure 3.55).

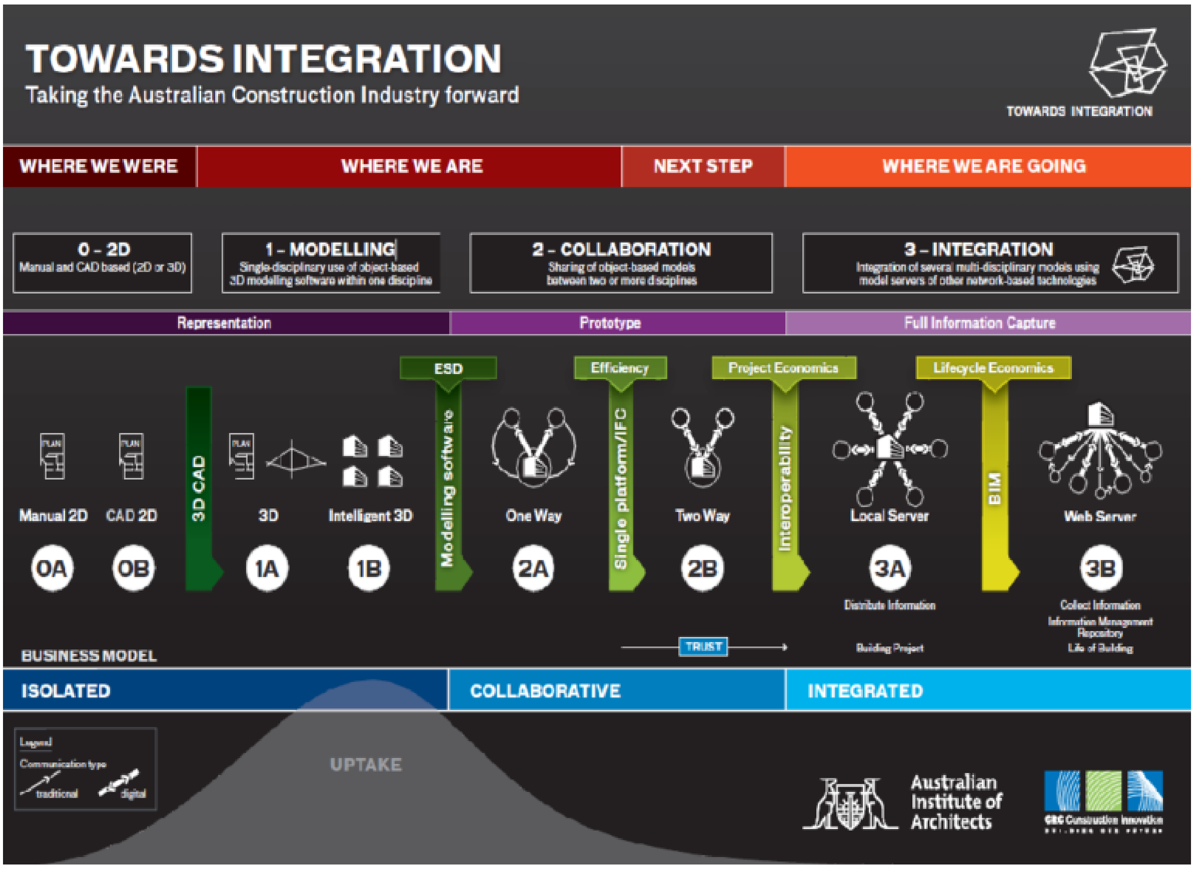


Figure 3.55: The Australian maturity index for BIM development

Linking of BIM objects with real world objects is likely to have a significant impact. The development of object tagging and specifically RFID (radio frequency tagging) linked to GUID is already taking place (see figure 3.56 and 3.57). Vela Systems a provider of such technologies has recently been purchased by Autodesk to be integrated into BIM 360 Field and Revit. Object tagging has a role to play during construction phases but also during the operations and commissioning stages of a project.

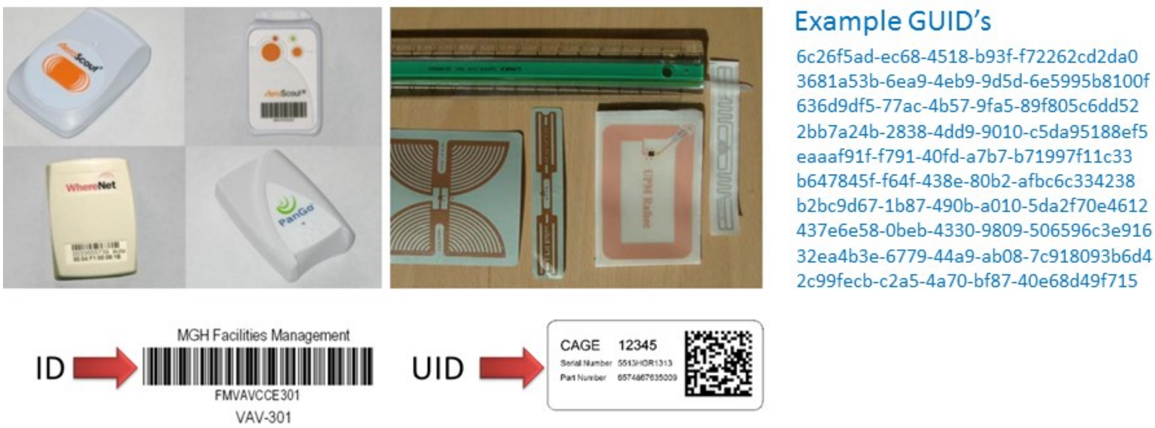


Figure 3.56: Examples of RFID Tags and GUID's

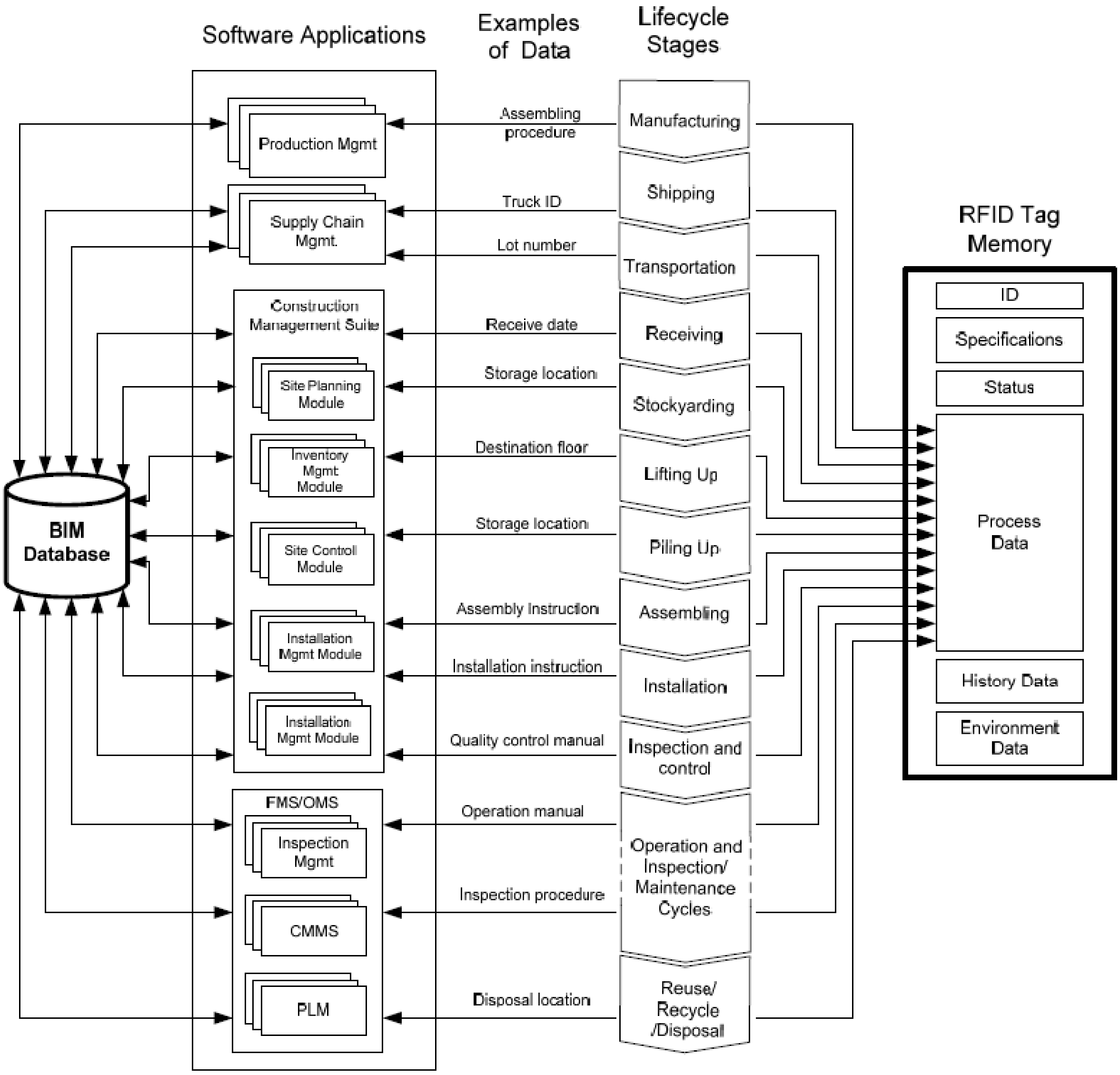


Figure 3.57: The use of RFID Tags in the project lifecycle (Motamedi 2011)

Currently the majority of BIM applications like the CAD systems they replace use a window, icon, mouse, pointer (WIMP) interface. The predicted progression interface technology is to a virtual reality (VR) interface (see figure 3.58). An increase in emphasis needs to be placed on the usability of the user interface (UI) (Chuang 2011) and the appropriateness of the models selected. This again will change the way BIM is worked with and perceived. Links between BIM and virtual environments such as “Second Life” are being developed (Pathmeswaran 2009). The use of virtual environments can be used for simulation and also virtual collaboration.

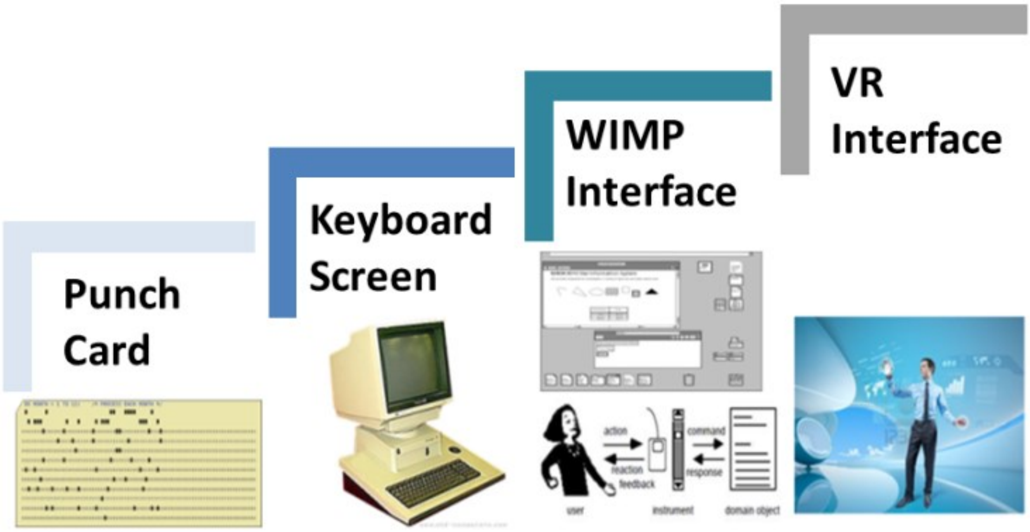


Figure 3.58: The evolution of the human computer interface (Fernando 2012)

An ability to develop contextual adaption visualization environments (CAVE) which respond to the problem, the knowledge operator and the purpose have the potential to provide better decision support utilizing BIM data (see figure 3.59).

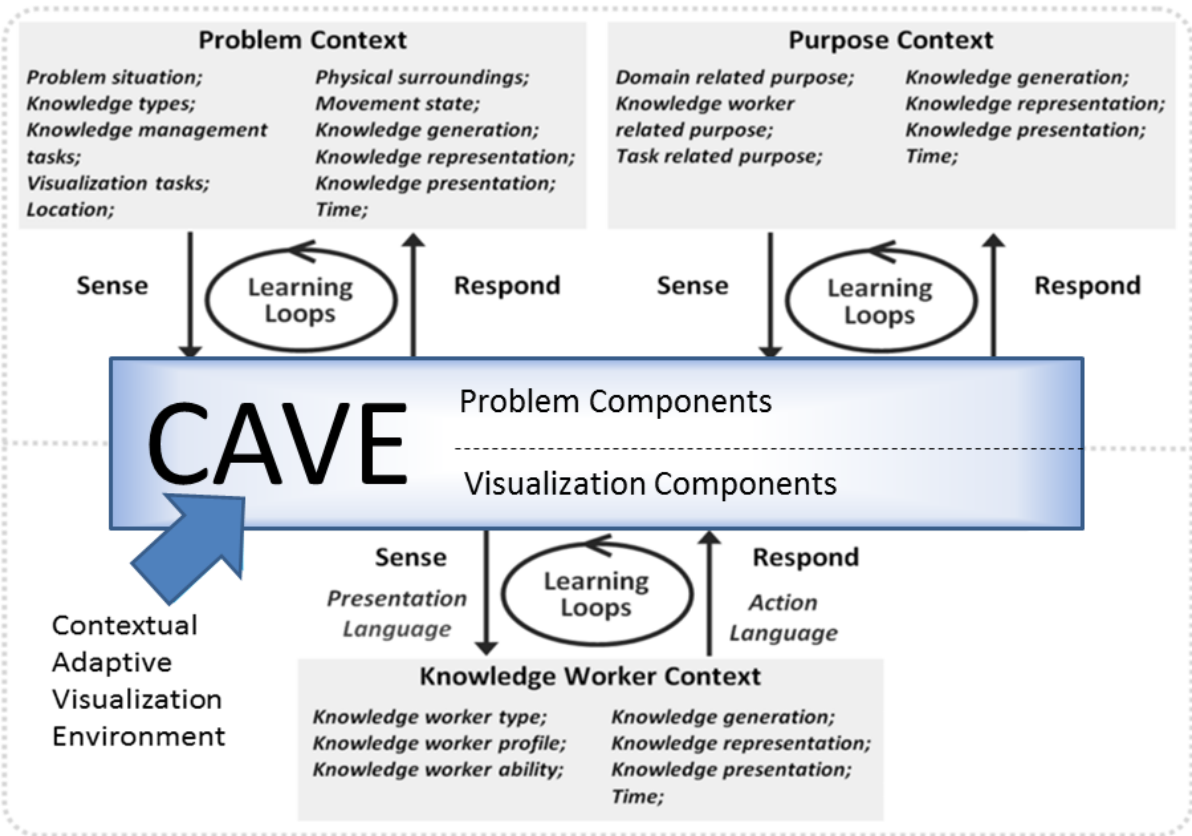


Figure 3.59: Development of contextual adaptive systems to aid decision support (Bai 2012)

Suggestions have also been made to link BIM models to case base reasoning systems (see figure 3.60) and evidence based design (Pati 2010). This has the ability to increase the capabilities of BIM in assisting in decision support.

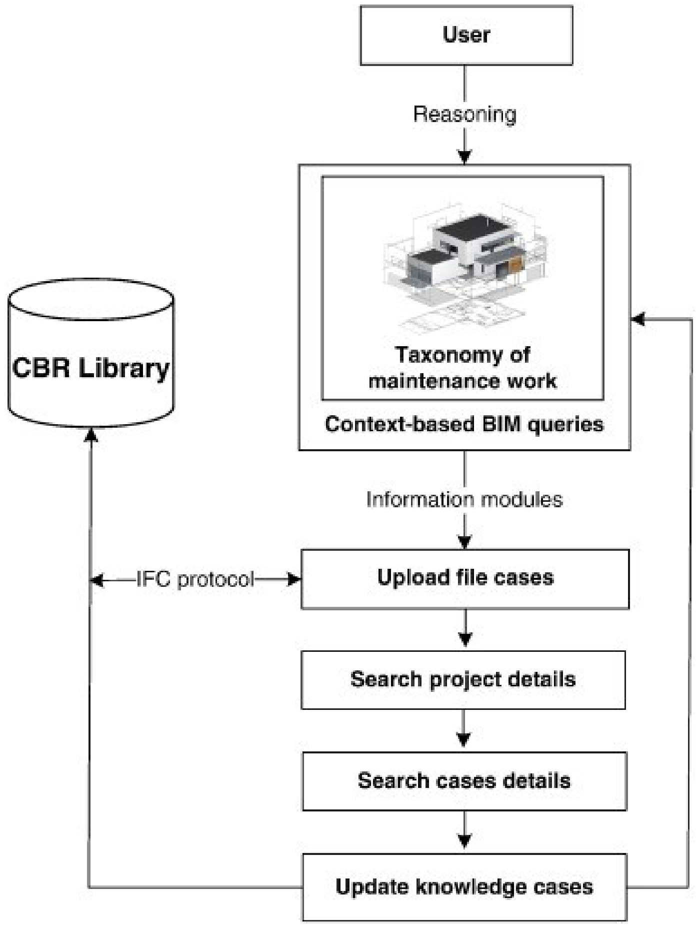


Figure 3.60: Developing BIM by linking it to a case base reasoning library (Motowa 2013)

Information changes how we experience the physical world. Working with information rich models will change architects capabilities and insight into the architectural domain. How data should most effectively be modelled depends on the type of the data and the decisions to be made from that data. Owen and Horvath (2002) classified five types of knowledge representation (see figure 3.61) which can be used as appropriate.

Pictorial	Symbolic	Linguistic	Virtual	Algorithmic
Sketches Detailed drawings Charts Photographs CAD model views	Decision tables Production rules Flow charts FMEA diagram Assembly tree Fishbone diagrams Ontologies	Customer Requirements Design Rules, constraints Analogies Customer feedback Verbal communication	CAD Models CAE Simulations Virtual Reality simulations Virtual prototypes Animations Multimedia	Mathematical Equations Parametrizations Constraint Solvers Computer Algorithms Design/ operational procedures

Figure 3.61: Classification of knowledge representations (Owen and Horvath 2002)

Further analysis has taken place as to when these forms are typically used in the development process (see figure 3.62).

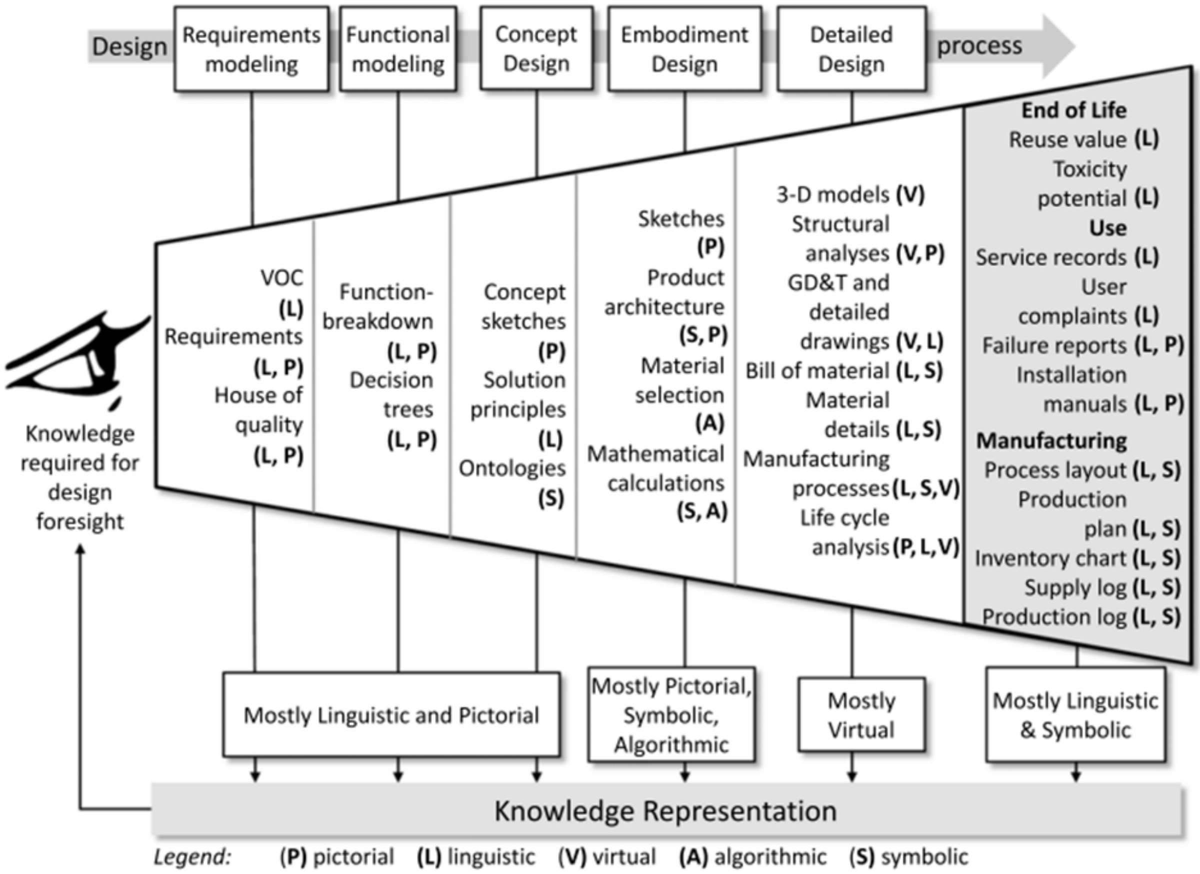


Figure 3.62: Types of Knowledge Representation traditionally used in the product development process (Chandrasegaran 2012)

The challenge of BIM will be to integrate all of these forms of knowledge representation into an effective process.

The amount of data particularly in digital form is increasing rapidly (see figure 3.63). In the UK the Open Data Institute has been set up to promote the UK governments Open Data Policy.

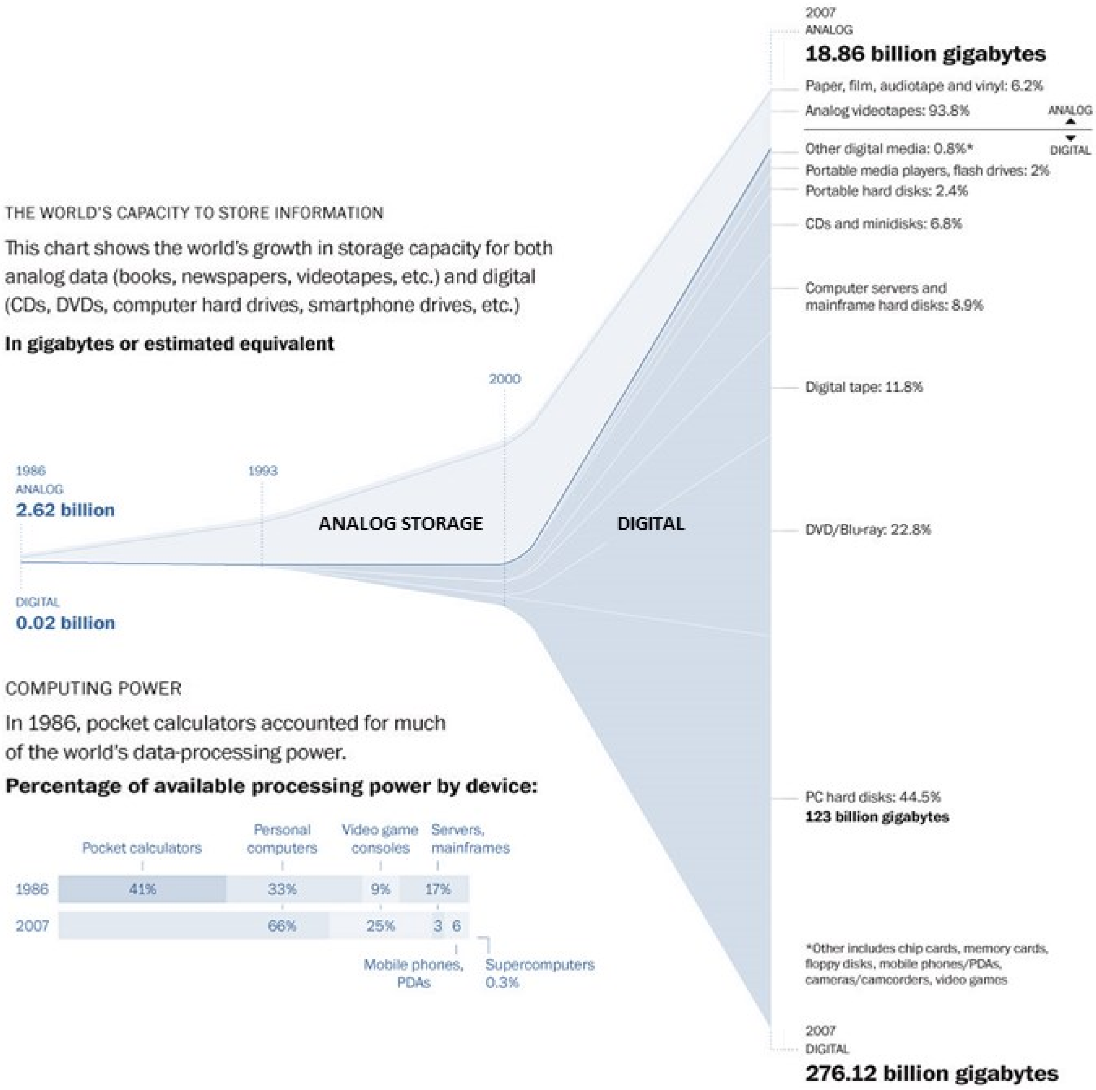


Figure 3.63: Rise of the digital information age (Vastag 2011)

The decrease in the cost of digital storage and the development of cloud computing has encouraged this rapid growth of data (see figure 3.64).

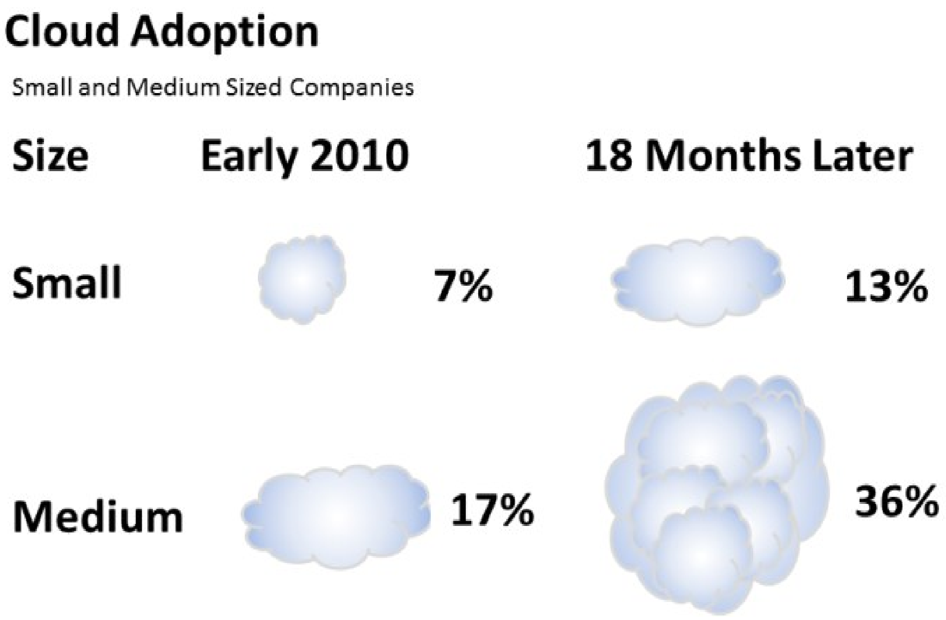


Figure 3.64: The growth in the percentage of data stored on the cloud by small and medium size companies (Pham 2011)

The implication of cloud computing on the development of BIM can be considered in several ways (see figure 6.65). Autodesk chief executive officer Carl Bass boldly describes his company's recent and radical expansion of cloud-based products and functionality as "the biggest thing to happen to computing since the invention of the PC" (Ijeh, 2012). Private BIM clouds have also been developed by BIM9.

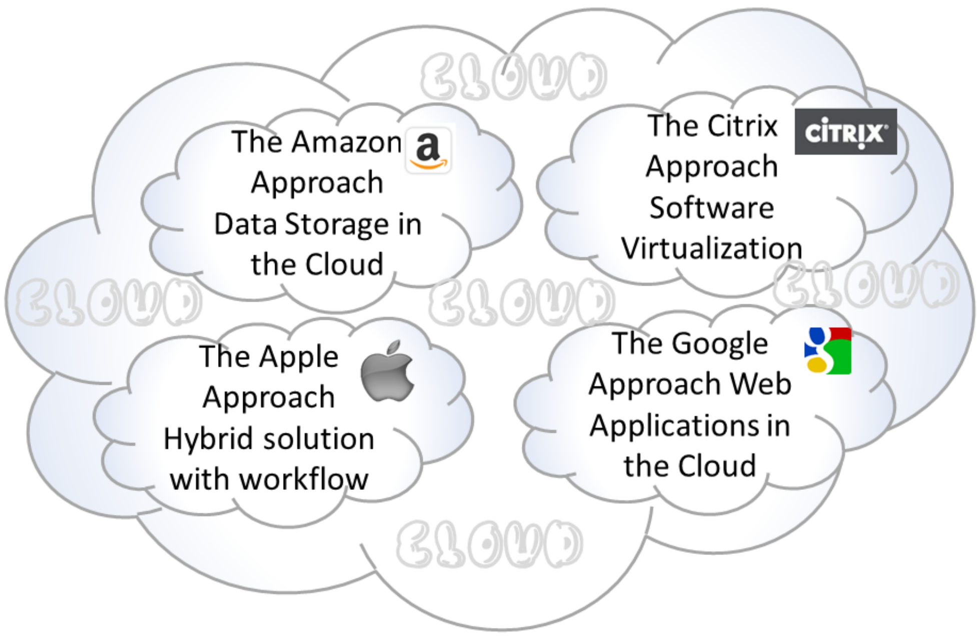


Figure 3.65: Approaches to cloud computing (based on Varkonyi 2011)

This explosion in data will be augmented by data captured through sensing devices which are now becoming part of our built environment. Cloud computing is already used for rendering and computational processes by the Revit BIM software. In the future cloud computing is likely to address processing speed and storage issues which have traditionally limited computerised systems being used for architectural design and PLM (Project Lifecycle Management) systems.

The variety of data available is increasing along with the velocity at which it can be accessed and the range of devices on which it can operate (see figure 3.66).

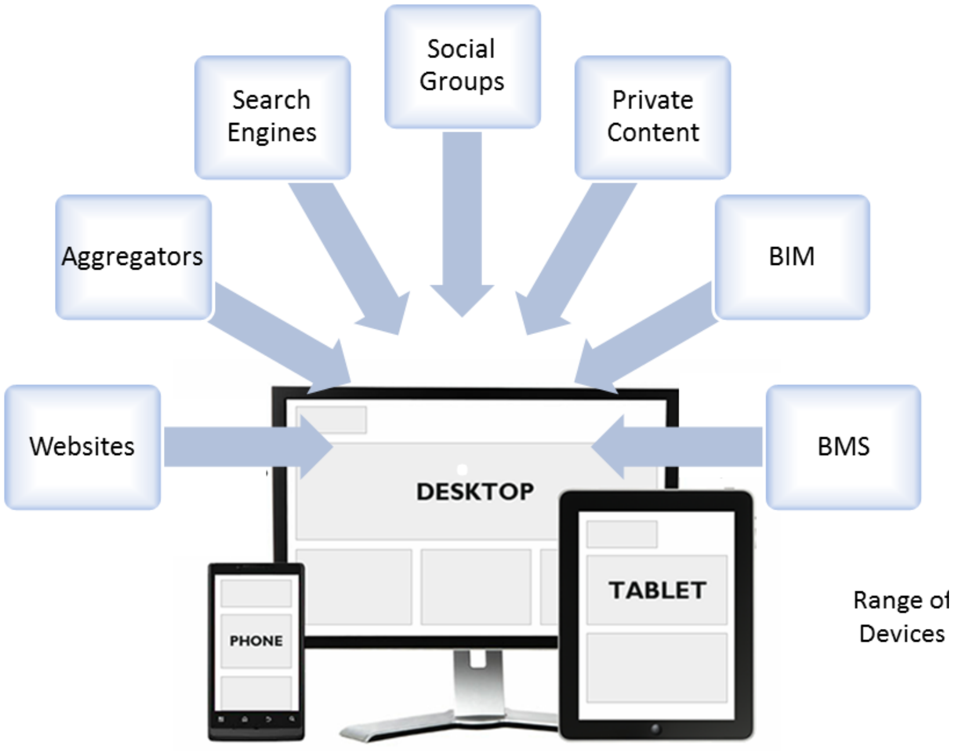


Figure 3.66: Data from multiple sources populating multiple interfaces

BIM represents one component in the explosion of digital data and the development of “the internet of things” (Ashton 2009). By using data rich BIM objects as a foundation, larger structured data stores can be potentially created. As BIM becomes more widely adopted there will develop an increased emphasis on the usability of such systems and the removal of the lean waste of processing unnecessary data.

A new-generation business analytics solutions comprising of agile business intelligence (BI) and analytical database technology that have the capacity to quickly, effectively and efficiently produce knowledge representations and actionable intelligence need to be developed using BIM data.

Data visualization and computer simulation can support strategic thinking, by reducing cognitive load, offloading short-term memory, allowing for easier comparisons, and generally facilitating inferences. Research has indicated data driven decision making increases productivity in organisations by 5-6% higher than would be expected given their other investments and information technology use (Brynjolfsson 2011).

Information visualization is already used in many areas of BIM. Examples include clash detection (see figure 3.67) and rule based design checking (see figure 3.68 and 3.69) both use visual forms to allow analysis.

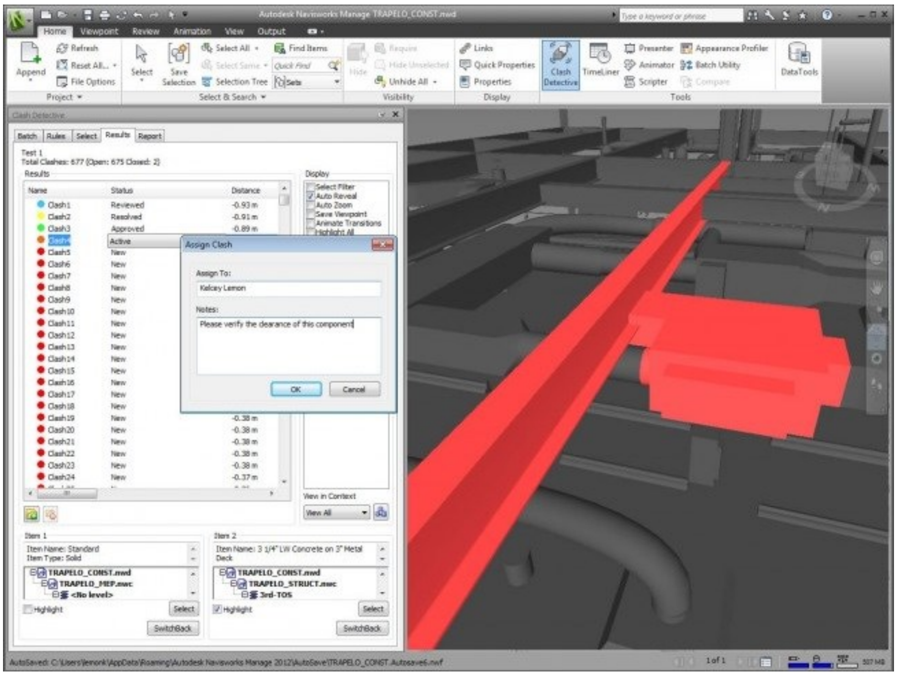


Figure 3.67: Navisworks BIM software being used to visualize clash detection

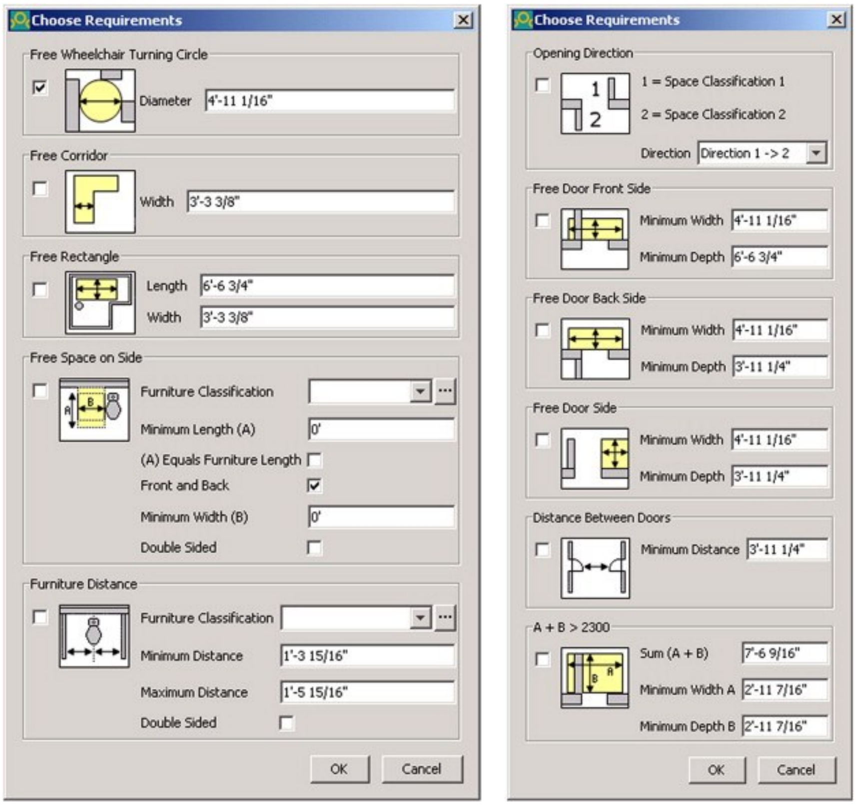


Figure 3.68: Setting up rule based checking for building access standards in Solibri Model Checker

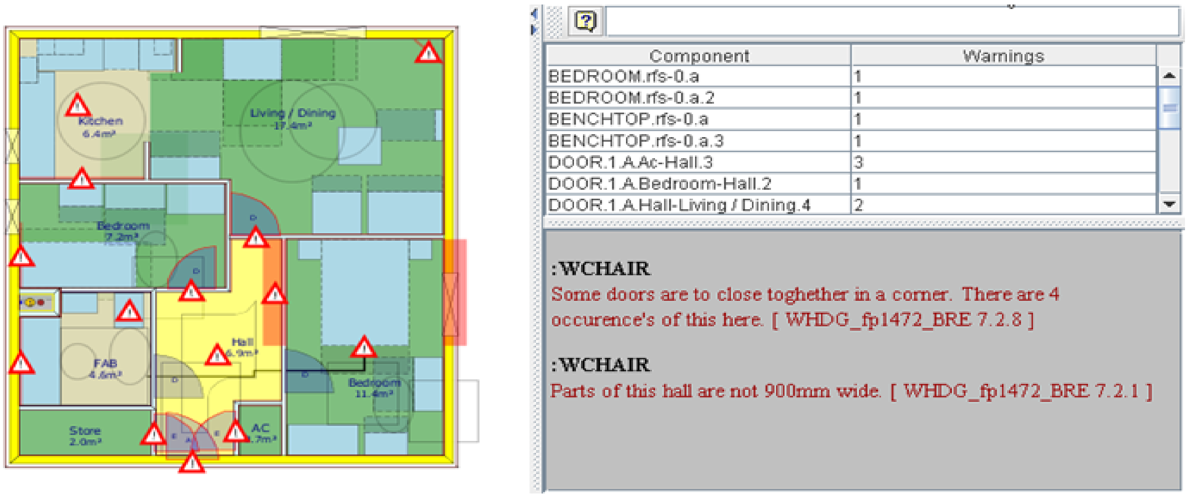


Figure 3.69: An example of rule based checking using Bluethink house designer (Khemlani 2009)

BIM using visual analytics is an emerging field of development. It combines the strengths from information analytics, geospatial analytics, scientific analytics, statistical analytics, knowledge discovery, data management and knowledge representation, presentation, production and dissemination, cognition, perception and interaction.

Some of the model forms that can be adopted to aid BIM decision making are illustrated (see figure 3.70 and 3.71). Models maybe form models, statistical models or process models. Using information visualization it will be possible to move from syntactic interoperability (data exchange) to semantic interoperability where the meaning is exchanged.

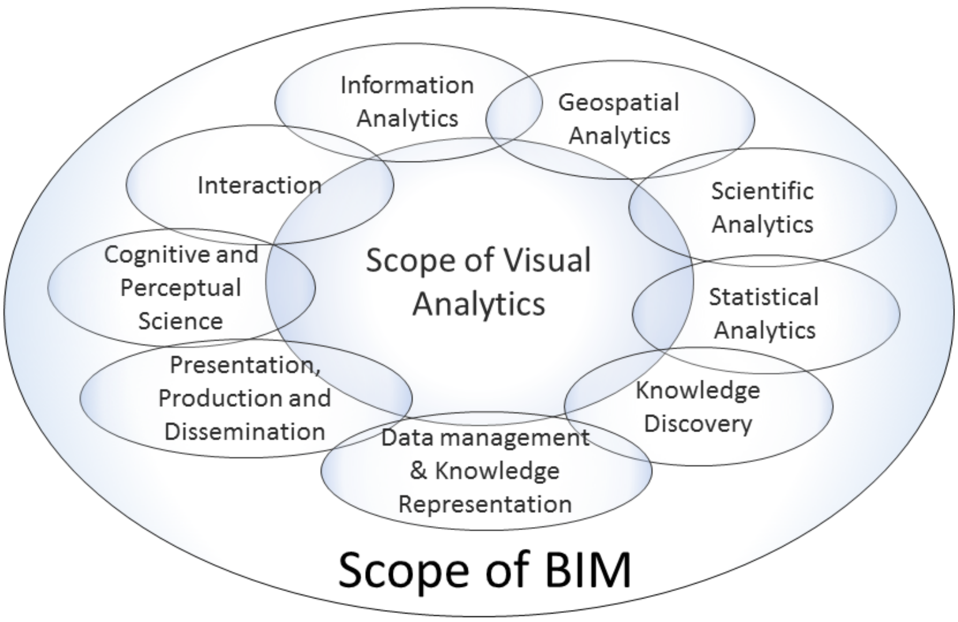


Figure 3.70: The scope of visual analytics related to BIM (adapted from Keim 2008)

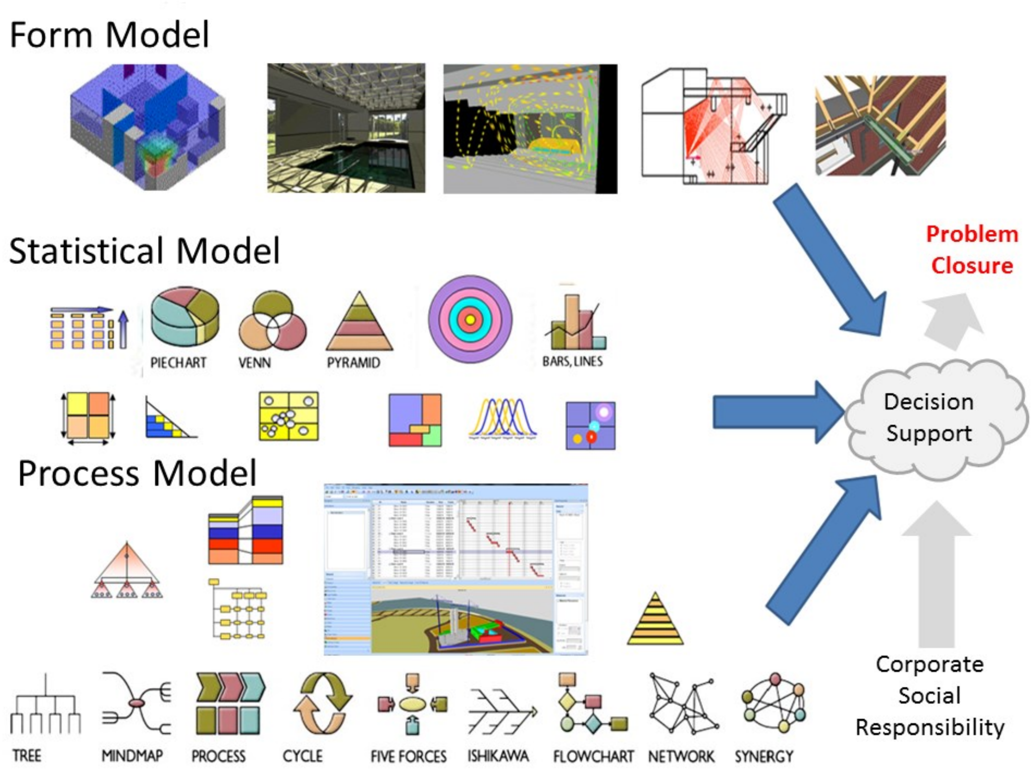


Figure 3.71: Form models, statistical models and process models all assisting in decision support (contains work by Eppler and Burkhart 2005)

What is required is a move form descriptive analytics to prescriptive analytics (Richardson 2013) (see figure 3.72).

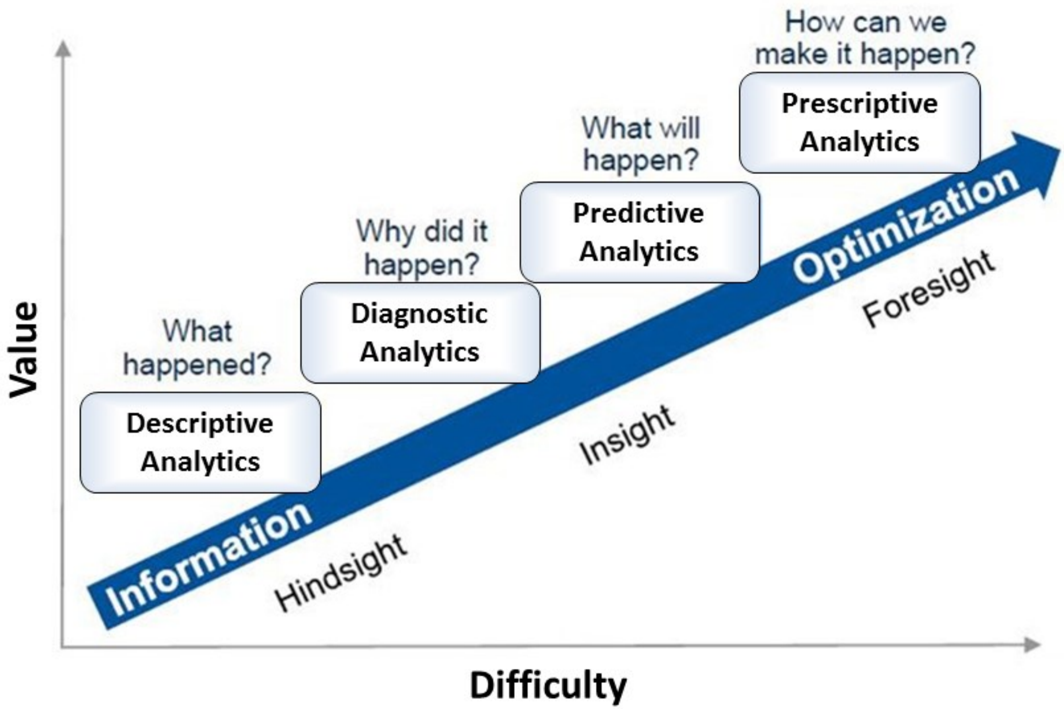


Figure 3.72: Increasing the value of information through analytics (Richardson 2013)

Running in parallel to BIM is the development of point cloud data from laser scanning (see figure 3.73). Products such as Autodesk Recap show the future potential of integrating point cloud data with BIM models.

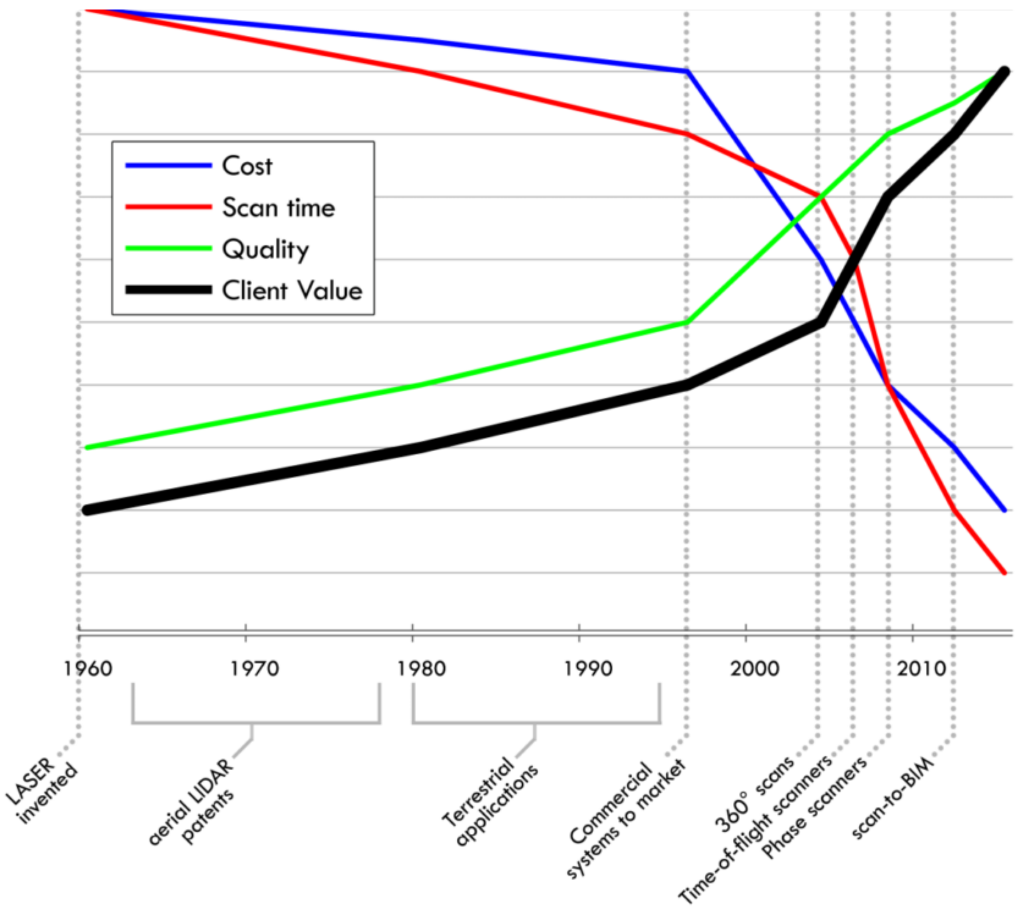


Figure 3.73: Timeline for laser scanning development (Randall 2013)

3.2.15 UK Government Documentation relevant to BIM and BIM Implementation

The UK government strategies reports that have brought together the construction industry in the UK to adopt BIM. The three major reports so far have been:

- BIM management for value, cost and carbon improvement - A report for the Government Construction Client Group Building Information Modelling (BIM) Working Party Strategy Paper March 2011
- Cabinet Office - Government Construction Strategy May 2011
- Building Information Modelling, Industry strategy: government and industry partnership HM Government URN 12/1327 2012

These reports may be found on the BIM Task Group Website. The BIM Task Group which brings together expertise from industry, government, public sector, institutes an academia. The website can currently be found at http://www.bimtaskgroup.org/.

3.2.16 Adoption of BIM from an International Perspective

The BIM policy stage by adoption of Europe, the Middle East and African countries is shown (see figure 3.74).

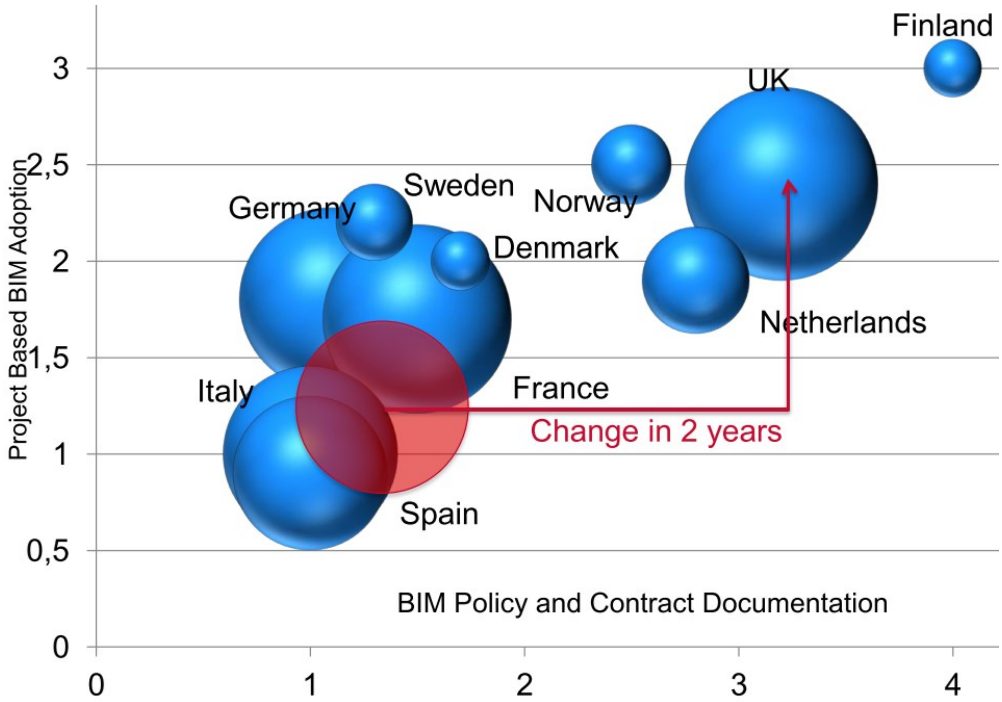


Figure 3.74: BIM Policy Stage by Adoption Rating – EMEA (Baxter 2012)

Efforts by the UK government can be compared with similar efforts in other countries. Senate Properties, a government owned enterprise responsible for managing and letting the property assets in Finland, required models meeting the IFC standard on its projects as of 1 October 2007 (Likländer 2011). The Danish government also chose the IFC format for its public works submittals in 2007 (Det Digitale Byggeri 2007).

In October 2006, the U.S. GSA the government agency that builds and manages federal facilities began requiring the delivery of BIMs for major federal building projects (Rundell 2007). This meant that the concept design must be submitted to the GSA in both the native format of the BIM authoring application and as an IFC (Industry Foundation Classes) file.

3.2.17 The Definition of BIM adopted as part of this Thesis

For this thesis an all-encompassing view of BIM is taken. Limiting the scope of the definition may result in benefits and opportunities being overlooked. Building information is regarded as all of the information created or collected relating to a building or development. Modelling is regarded as the process of making this information usable and of benefit. An important activity in structuring information is to develop relationships for unrelated parts. The aim of BIM implementation is to make the collection and creation of this information as easy as possible. The aim of modelling is to show this information so appropriate decisions can be made and understandings gained.

3.3 Implementing BIM – Introduction

There remains few documents address adequately the focus area of this research on the implementation of BIM (Crotty 2012). The areas of literature related to the BIM implementation can be subdivided as shown (see figure 3.75).

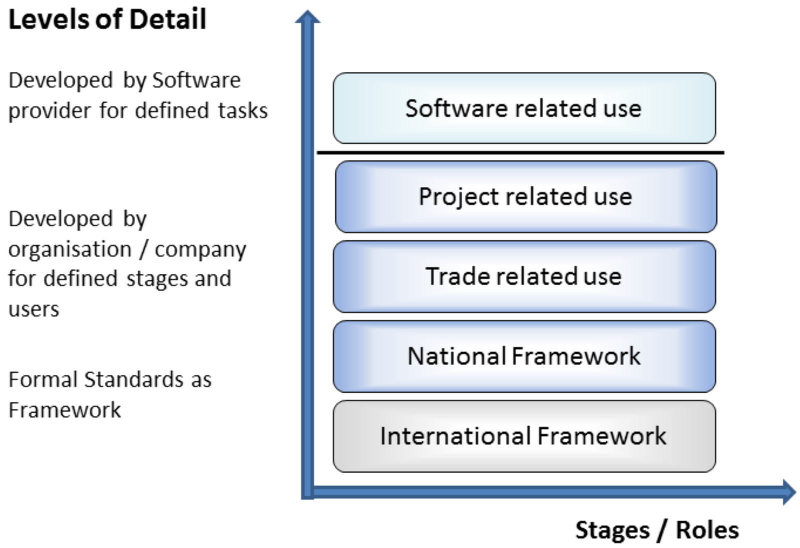


Figure 3.75: Literature related to BIM adoption (ISO/TS 12911:2011)

Some case studies also exist of BIM implementation in small architectural practices (Epstein 2012). But the content, guidance and contribution of these case studies is limited.

It is suggested that a socio-technical approach to information system development (ISD) should be used when implementing BIM (Arayici 2011) (Sackey 2013). Such an approach seeks to engage the user of the information in genuine participation to achieve an acceptable fit between people and technology rather than forcing one or both to change and adapt to the other (Vidgen 2003).

3.3.1 National and International documentation relevant to BIM and BIM implementation

Government Construction Strategy Report which was issued by the Cabinet Office in May 2011 and revised July 2012 can be seen as a reaction to the Latham and Egan reports. Item 7 of the strategic action plan was to introduce a progressive programme of mandatory use of fully collaborative Building Information Modelling for

Government projects by 2016 (see table 3.03 Appendix A). What is meant by "fully collaborative" BIM is open to interpretation.

The UK Governments Hypothesis was stated as follows in the Building Information Modelling (BIM) working paper 11 March 2011:

"Government as a client can derive significant improvements in cost, value and carbon performance through the use of open sharable asset information"

BIM and the utilization of the information it makes available also plays a central role in the drive to meet the other objectives within stated within the Government Reports (see Figure 3.76).

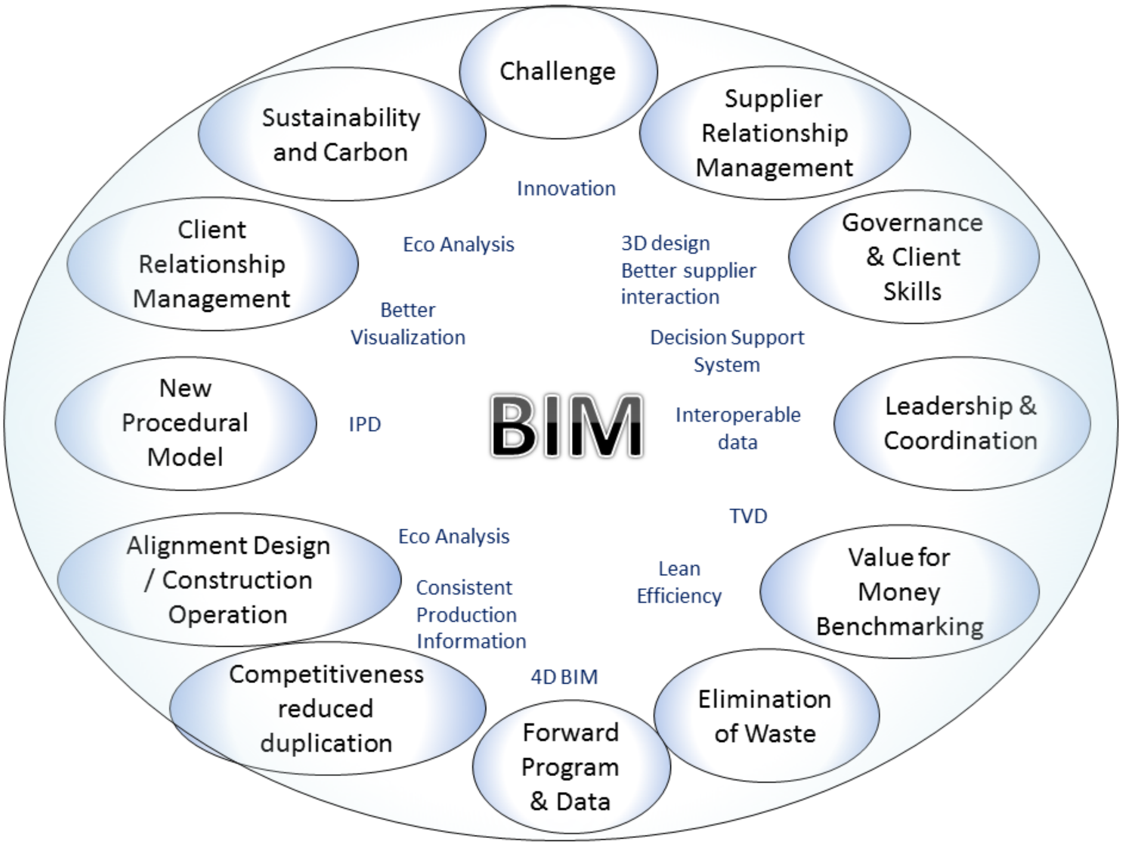


Figure 3.76: Issue arising from the government strategy report and their relationship to BIM (2011)

Several guides and formats exist on how BIM should be executed on a project (see figure 3.77). New guides are being produced all the time.

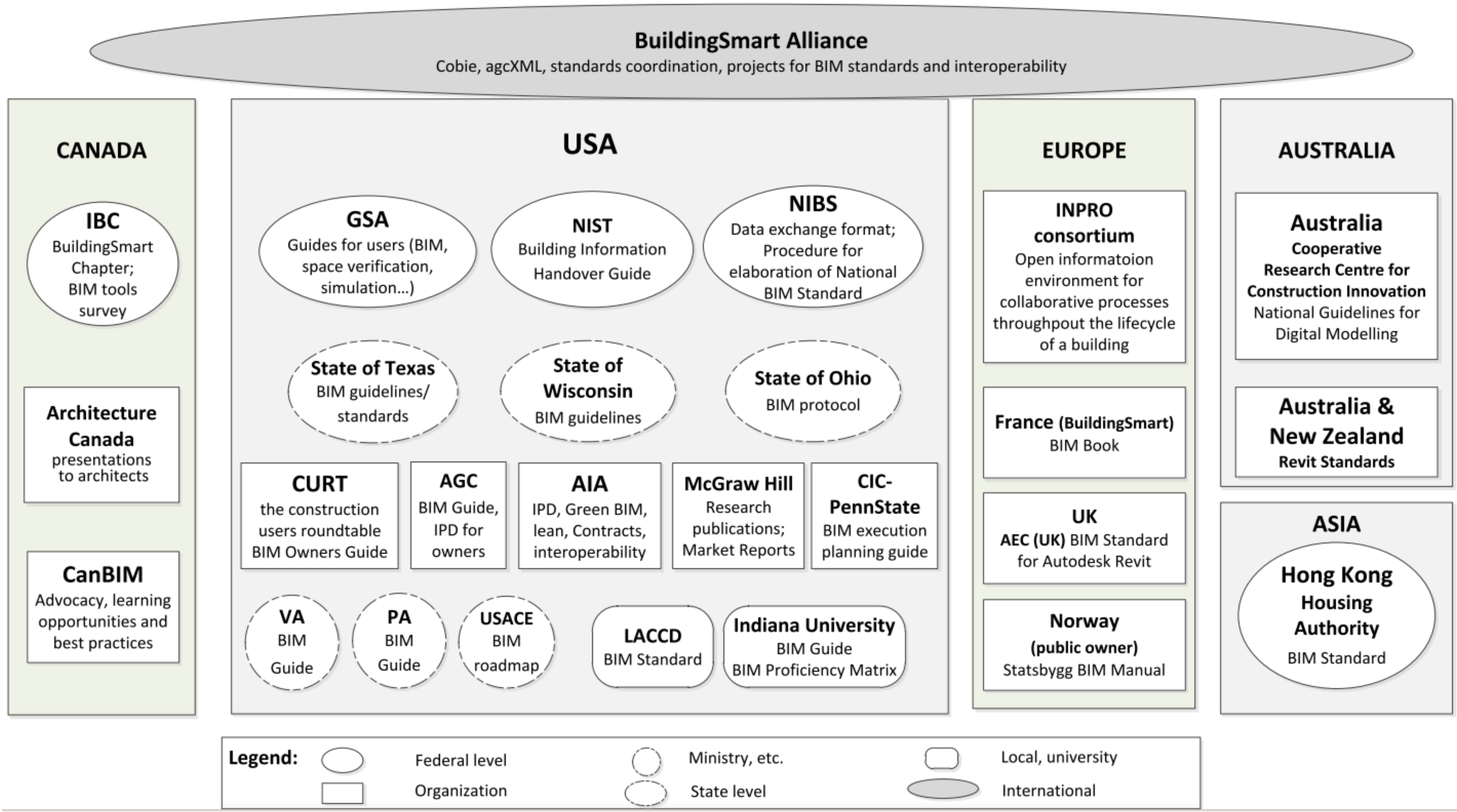


Figure 3.77: BIM guidelines and standards for different regions (Staub-French)

The guides currently available include the following:

Origin	Organization	Document	Date
Australia	CRC	National Guidelines for Digital Modeling - CRC Construction Innovation	
		Natspec National BIM guide version 1	
Canada	CAN BIM	AEC (CAN) BIM Protocol	2012
Denmark	BIPS	F103	2008
Finland	Senate Properties	BIM requirements 2007 - Volume 1: General part - Volume 2: Modelling of the starting situation - Volume 3: Architectural Design - Volume 4: MEP Design - Volume 5: Structural Design - Volume 6: Quality Assurance and merging of models - Volume 7: Quantity Takeoff - Volume 8: Using models for visualization - Volume 9: Use of models in MEP analysis COBIM 2012	2007
Germany	buildingSMART Deutschland	Anwenderhandbuch Datenaustausch BIM/IFC	
Hong Kong	Housing Authority	BIM Standard	2009
United States		The Associated general Contractors of America - The Contractors Guide to BIM Version 1	
	AIA	AIA E201- 2007 Digital Data Protocol Exhibit	
		AIA E202- 2008 BIM Protocol Exhibit	
	CURT	BIM implementation: An owners guide to getting started UP-1203 April 2010	2007
	Georgia Tech	BIM requirements and Guidelines for Architects, Engineers and Contractors version 1	2010

	GSA	Series 01 – 3D-4D-BIM Overview	2011
		Series 02 – Spatial Program Validation	
		Series 03 - 3D Laser Scanning	
		Series 04 - 4D Phasing	
		Series 05 - Energy Performance and Operations	
		BIM Guide for Facilities management	
	USACE	BIM - A roadmap to implementation	
	University of Houston	Facilities Planning and Construction Department UHS BIM Protocol	
	Indiana University	Building Information Modeling (BIM) guidelines and standards for Architects, Engineers and Contractors	
	Los Angeles Community College District	LACCD Building Information Modeling Standards LACCD BIMS version 3 June 2 2010	
	NIST	National BIM Standards 1.0 Version 1.0 Part 1 Overview, Principles and methodologies, National Institute of Building science 2007	
	Penn State	Project Execution and planning guide version 2 – The computer integrated construction research program	2010
	State of Ohio	Building Information Modeling protocol	
	State of Wisconsin	Building Information Modeling (BIM) guidelines and standards for Architects, Engineers and Contractors	
	Triton College	Building Information Modeling BIM Standards manual	
	USCG	BIM User Guides	
Singapore	Building Construction Authority	BIM Guide	2012
Sweden	Standards Institute	Bygghandlingar 90	
Norway	STATSBYGG	BIM manual	

These documents are either project focused or audience focused and are targeted at different audiences within the AEC industries (see figure 3.78). They also tend to focus on what is required and fail to address how it should be achieved. This is partly to do with the fact that how the objectives are to be achieved is to some extent determined by the software selected.

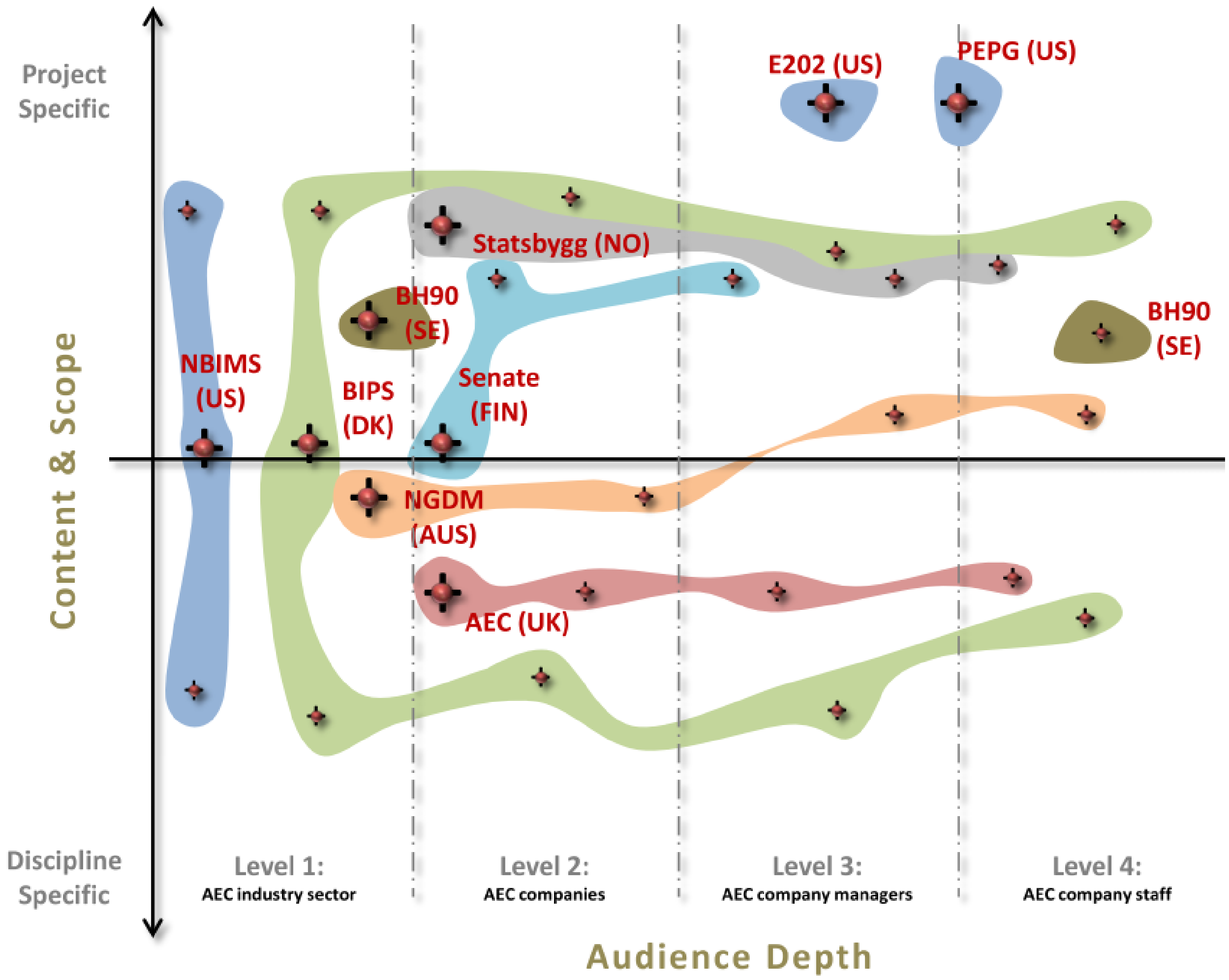


Figure 3.78: BIM Guidelines Positioning (Hooper 2010)

BIM standards also exist in the UK developed by AEC (UK).

Table 3.04 further analyses the content of these guides. Both the Natspec from Australia and the VA guide from the US are particularly good in the range of subjects they cover.

		USA										Europe				Au
		GSA	NIBS	NIST	CIC - PennState - BIM Execution Guide	VA - Veteran Affairs BIM Guide	PA - Port Authority of NY&NJ BIM Standard	Wisconsin BIM standard & Guide for arch & eng	Texas guidelines - standards for professionals	CURT - BIM Implementation owners Guide	AIA etc IPD for owners	Inpro - Europe	UK	Norway	France	Australia
		Federal					State			Asso			Countries			
General																
	BIM Theory		x									x				
	BIM Benefits	x		x	x			x	x	x				x	x	x
	Point of view(owner, professionals, builder)	opb	inst								p					
Process																
BIM Management																
	BIM adotion process in company	x	x	x	x	x				x					x	x
	BIM maturity (matrix, measure, certification)						x									
	BIM Management (execution plan)				x	x	x			x			x			x
	Planning & Impl of Guide			x	x											x
	Risk Management											x				
	Experience Feed-back											x				
	Legal Aspects						x					x				x
Project	Process (Project, batiment)	x		x	x	x	x	x	x	x	ear	x		x		x
	Project Delivery Mode			x	x	x	ipd				ipd	x				
	Collaboration				x		x				x	x	x			x
	Project team	x			x	x						x	x			
Process of creation of the standard			x										x			
Model																
Contents of the model by building aspect																
	Architecture	x			x	x						x		x		x
	Structure				x	x						x		x		x
	Spatial program	x				x			x			x		x		x
	Visualisation	x				x								x		x
	Building Code				x							x		x		x
	4D phasing	x			x	x						x		x		x
	Energy Performance	x			x	x					x	x		x		x
	Sustainability										x				x	
	Clash Detection				x	x	x					x		x		x
	5d estimating													x		x
	circulation, safety	x												x		x
Contents by disciplines + landscape, interior, acoustic								x						x		
Content by phases, prelim, concept, dev,exec, oper																x
	Construction					x			x		lear	x		x		x
	Subcontractors, fabricator					x										
	Operation (As built)											x		x		x
Technology																
	Technology (Software, infrastructure)	x			x	x	x	x								x
Requirements																
	Modeling requirements	x			x	x	x	x				x	x	x		x
	BIM application hierarchy objects + prop													x		x
	Deliverables	x			x	x	x					x	x	x		
	Quality controls & performance measure	x			x		x					x				
Data																
	data exchange	x	x	x	x							x	x			x
	File names, folder structure					x	x					x	x	x		
	Metadata			x												
	data interoperability		x	x	x		x					ifc	x			x
	Sharing, storing data		x		x	x						x	x			x

Table 3.04: Analysis of BIM Guidelines (Staub-French 2011)

3.3.2 BIM Project Execution Guidance

Currently the most comprehensive BIM execution guidance is the Pennsylvania State University BIM execution plan (CIC research group 2010). This execution plan is design to enable a multi-disciplinary project to be undertaken effectively. The problem with this execution plan is that it assumes effective interoperability. Effective interoperability may only be achieved if the tools selected are capable of achieving the interoperability required. BIM execution plans are also available from AEC (UK), Indiana University and the US Army.

Project execution assumes that practices and organisations have already an operation BIM system. These guides provide little on how practices are to move from legacy systems to having the ability to use BIM.

3.3.3 BIM Organisation Implementation Guidance

As documented in the review of national standards there is some information on BIM adoption in many of these standards. But the information provided is not comprehensive or sector focused.

Autodesk Inc. with revenue of US $1,951.8 million (Source Form 10-K 2011) the vendors of Revit software, the largest software vendor in the BIM domain, have written the Autodesk BIM deployment plan. This deployment plan is particularly useful as it sets out the differences that occur when using BIM under different forms of construction contract.

3.3.4 Software tool Guidance

There are many BIM tools, some of these tools are applicable at various stages of the building life cycle where as some tools relate to specific stages of the building life cycle.

Several books have been written explaining how to use Revit. Books are also available on how to use ArchiCad (Good 2009). Online manuals are also available for download for other BIM authoring tools. These explain at a mouse and keyboard level how to operate the respective BIM tools. These guides tend to show how to produce traditional deliverables as opposed to data rich BIM deliverables suitable for multiple disciplines. The problem that practices face is one of transition from a legacy system to a new system and embedding practice knowledge into methods of operation. The literature available does not address these issues and problems.

3.3.5 General Guidance in Books and Journals

Several critical books have been published covering BIM and BIM adoption. These have shaped the general view of BIM and therefore are mentioned here. These are:

BIM Handbook: A guide to BIM for Owners (Eastman et al 2008)

Note: This is perhaps the most comprehensive book covering many aspects and case studies related to BIM.

Building Information Modelling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers (Smith et al 2009)

Note: A multi-disciplinary viewpoint of BIM implementation

The impact of Building Information Modelling Transforming Construction (Crotty 2012)

Note: Provides an interesting view on the effects of BIM in the wider UK construction industry.

BIM and integrated design: strategies for architectural practice (Deutsch 2011)

Note: this book focuses on how BIM affects individuals and organizations working with BIM.

BIM Demystified Steve Race

Note: Provides a short, practical introduction to BIM with forms and tables.

Implementing successful building information modelling (Erika Epstein 2012)

Note: This book covers the topics necessary for BIM implementation but not in particular depth. One chapter is dedicated to implementing BIM. Also included in the book is a range of case studies but unfortunately none of these is from the UK.

These books consider BIM more form the aspect of total transition rather than the more likely and problematic integration of BIM in a single discipline and with legacy systems and disruption mitigation in the transition process. Also there are many issues specific to architectural practices that are not dealt with in these books.

Several of the books contain numerous case studies. Where case studies are recorded mostly through vicarious experience a certain filtering is inevitable. Effective BIM implementation requires both a overall and detailed understanding. The devil is in the details (Mies Van der Rohe). Though engaging in direct experience through action research it is hoped this thesis will provide a greater insight into BIM adoption.

What also seems to be missing from the BIM literature is integration of BIM within current management, change management theory and current information systems. Historically it is unlikely that people will have been trained with the full range of skills necessary to holistically understand and document BIM and BIM implementation. In architectural training at least the focus is on how to design and develop building and less on business development. This is reflected in the literature produced. Little discussion is given to the field of modelling and knowledge representation. Certain pockets of knowledge exist within organisations but this knowledge represents a competitive advantage and therefore is not published.

Much of the literature reviewed as part of this research was in the form of academic papers. Such papers it can be argued represent to forefront of BIM development. There is a question with these papers how the knowledge and insight they contain should be integrated into a more general and comprehensive body of knowledge. The structuring of chapters 2,3 and 4 of this thesis have to some extent placed the finding of these numerous investigation into a relational context.

Table 3.05 documents the significant journal papers written concerning BIM.

Dimension	Category	Variable	Constituent	Chinowsky & Reinschmidt (1995)	McKinney & Fischer (1998)	Jung & Gibson (1999)	Caldas & Solbelman (2003)	Dawood et al (2003)	Jung & Kang (2007)	Kim & Grobler (2007)	Spearpoint (2007)	Jung et al (2008)	Tobin (2008)	Succar (2009)	Taylor & Bernstein (2009)
BIM Technology	D0 Data Property	D01. Parametric	D.01.1 Geometric	x	x			X		x			x		
			D0.1.2 Non Geometric		x		x	X							
		D02. Level	D0.2.1 Knowledge	x	x				X					x	
			D0.2.2 Information											x	
			D0.2.3 Row Data											x	
		D03. Facet *	D0.3.1 Commodity*					x	X						
			D0.3.2 Locator*					x	X						
	R0 Relation	R01. Composition	R0.1.1 Link	x	x		x								
			R0.1.2 Group												
			R0.1.3 Layer												
		R02. Ontology	R0.2.1 Reasoning**	X	x					X				x	
			R0.2.2 Hierarchy												
			R0.2.3 Object							x			x		
	S0Standards	S01. Process	S01.1 Modelling						x						
			S01.2 Exchange				X								
		S02. Product	S0.2.1 Modeling								X				
			S02.2 Exchange				x			x	X		x		
	U0. Utilization	U01. Maturity ***	U0.1.1 SC Integration***											x	X
			U0.1.2 Analysis***		X						X				X
			U0.1.3 Coordination***											x	X
			U0.1.4 Visualization***											x	X
		U02. Morphology	U0.2.1 Distributed							x			X		
			U0.2.2 Concentrated										X		
		U03. Implementation	U03.1 Strategy			X			x			X			
			U03.2 Policy			X									
			U03.3 Procedure			x			x			X			
			U03.4 Manual			x			x						
	P0	P0. Perspective	P01. Industry									x			
			P02. Organisation			x									
			P03. Project									x			
	F0	F0. Contr. Biz Function	F01 Planning ****			X									
						X									
			F14 R & D ****			X									

* Facet defined by Jung & Kang (2007)

** Reasoning defined by Chinowsky & Reinshmidt (1995)

*** Maturity defining Taylor & Bernstein (2009)

**** Biz Function by Jung & Gibson (1999)

x Covered
X Focused

Table 3.05: Showing the academic papers written addressing the major areas affecting BIM adoption. The relevance of several more recent papers will be documented in due course. (Youngsoo Jung 2010)

BIM Execution Planning Guide	AIA BIM Protocol Ex.	Autodesk Comm. Spec.	Consensus Docs BIM Addendum	USACE BIM Roadmaps
Project Reference Information				
Project Overview Information		X		
BIM Contractual Requirements			X	
Key project Contacts		X	X	X
BIM Goals/BIM Objectives				
Purpose of BIM Implementation		X		X
Why Key BIM use decisions		X		X
BIM Process Design				
Process Map for BIM Project Activities		X		
Define Information Exchanges		X		X
Delivery Strategy / Contract				
Definition of delivery Structure		X	X	
Definition of Selection				
Definition of Contracting			X	
BIM Scope Definitions				
Model Elements by Discipline	X			
Level of Detail	X	X	X	X
Specific Model Attributes	X	X	X	X
Organisational Roles and Responsibilities				
Roles and responsibilities of each organisation	X	X		X
Define Contracting Strategies for			X	
Communication Procedure				
Electronic Communication Procedure		X		
Meeting Communication Procedure				
Technology Needs				
Hardware		X		X
Software		X	X	X
Space			X	
Networking Requirements		X		X
Model Quality Control Procedures				
Methods to ensure model accuracy	X	X	X	X
Glossary of terms	X	X	X	X

Table 3.06: BIM Project execution guides as listed in the Pennsylvania State University BIM execution guide (Appendix H)

BIM adoption is one aspect of organisational change, reengineering and business improvement. As such current practices in change management and organisational re-engineering are considered and how they should be applied in the case of implementing BIM.

3.3.6 Review of BIM Implementation Strategy Frameworks and identification of their Limitations

Frameworks should ideally provide an understanding of difficult concepts. A framework should go beyond merely identifying problems with current approaches; it should offer new ways of looking at and perceiving phenomena and offers information on which to base sound, pragmatic decision making.

Developing such a framework for BIM adoption in architectural practice is difficult for the following reasons:

- Each architectural practice tends to work in a way which is most efficient to itself. As such one approach to BIM will not be suitable to all architectural practices. Therefore a framework for BIM implementation should allow for a contingency approach as put forward by Woodward (1958).

- The technology of BIM is continually changing

- Historically architectural companies may only need to go through such radical change every 20 years. (The change from manual to CAD production occurred for many architectural practices in about 1990, over twenty years ago.)

- Adoption of BIM is often to give competitive advantage therefore companies do not share instigation methods

Although partial guidance on BIM adoption exists no fully functional BIM implementation strategy frameworks exist. Several authors have developed parts of such frameworks. The most prolific author in this area is Succar (2010) (see figure 3.79). The main focus of Succar's framework focuses on what is required and what is to be achieved as part of a BIM implementation. This approach links the BIM maturity levels required with the competence levels to be achieved. This research endeavours to build on this work and integrate it into a business process reengineering framework. The element that is missing from this work is the integration of change management theory to explain how BIM should be adopted.

BIM ADOPTION - Steps requiring deliverables

Process	Policy	Technology
Leadership:	**Contractual:**	**Software:**
Management Decisions:	Responsibilities	Delivery Modes
Vision	Rewards	Software Prerequisites
Culture	Risk Allocation:	Semantic Connectivity
Organisational Processes:	Insurance	Main Deliverables
Programme Management	**Regulatory:**	Modelling & Visualisation Levels
Communication Activities:	Building Regulations:	Clash Detection between drawings files or models
Internal	Codes & Standards	Code Checking & Compliance (Accessibility; Fire...)
External	Performance	Plant Design & Construction Sequencing (4th Dimension)
Infrastructure:	Sustainability	Product Quantities & Project Costing (5th Dimension)
Physical Infrastructure:	Project Guidelines:	Construction & Fabrication Prototyping
Spaces	Best practices	Engineering Analyses (Thermal; Acoustic...)
Equipment (non-I.T.)	Bench marks	Interoperability (Proprietary, Open and Non-Proprietary)
Technological Preperations (activities)	Classification Systems	Discipline Specific Steps
Knowledge Assets (non-human)	**Preparatory:**	**Hardware:**
Human Resources:	Research	Computer Hardware (Minimum Requirements):
Knowledge Resources	Educational Programmes	Processing Power
Skills Resources		Storage Capacities
Products & Services:		Display Properties
Products:		Office Equipment
Structured Output:		Site Equipment (If different from above):
Physical Components		Mobility
Virtual Components		Connectivity
Non-Structured Output		**Network:**
Services:		Network Prerequisites:
Modes of Delivery		Bandwidth
		Access Control
		Security
		Information Direction
		Web Technologies

Figure 3.79: BIM competency sets (adapted from Succar 2010)

3.3.7 The Barriers to BIM Adoption

The reason why business change projects fail was investigated by KPMG (2010) (see figure 3.80).

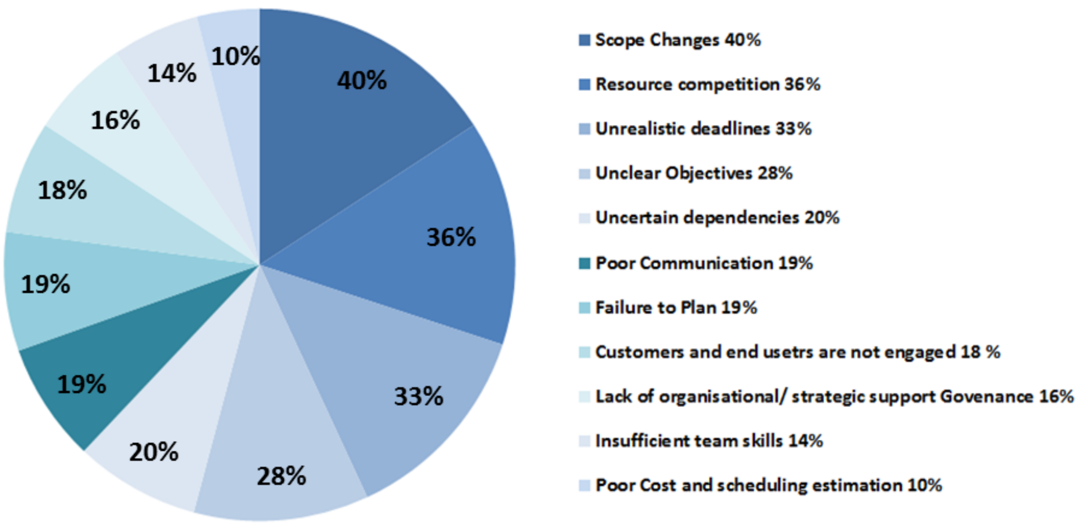


Figure 3.80: The Reasons why projects fail (KPMG 2010)

The range of projects and the types of constructions where BIM is being used is increasing (McGraw-Hill Construction 2012). Yet there are those who stress that BIM is not appropriate for all projects (Latham 2012). In the case of Latham, ecclesiastical refurbishment projects where the complex forms often adopted by historic architectural designs are difficult to represent in BIM were being referred to. These issues are likely to be resolved overtime. As previously mentioned BIM projects carry an overhead which in particular cases may be inappropriate in light of the benefits currently may be gained.

BIM forces architects to produce designs that are counterintuitive to how architects have been trained and how they think (Graves 2012). Certainly there is a change in concept from drawing to modelling. According to Leecalisti (2012) the BIM way of working wants precision and information too early in the design process. Training in colleges and Universities will provide graduate architects with BIM related skills. As BIM becomes more widely used and the BIM tools become more and more sophisticated the range of projects were BIM is not appropriate will become less and less.

An important element in developing a successful BIM adoption strategy is to understand the barriers which normally imped the adoption of BIM. Various diffusion models have been developed which can be applied to BIM (Rogers 1962, Moore 1999, Bass 1969, Collan 2007). The “lazy user model” (Collan 2007) (see figure 3.81) suggests that selection is based on the amount of effort required by the user. So if this is correct greater adoption will occur if it is made as easy as possible for the user to understand and use BIM.

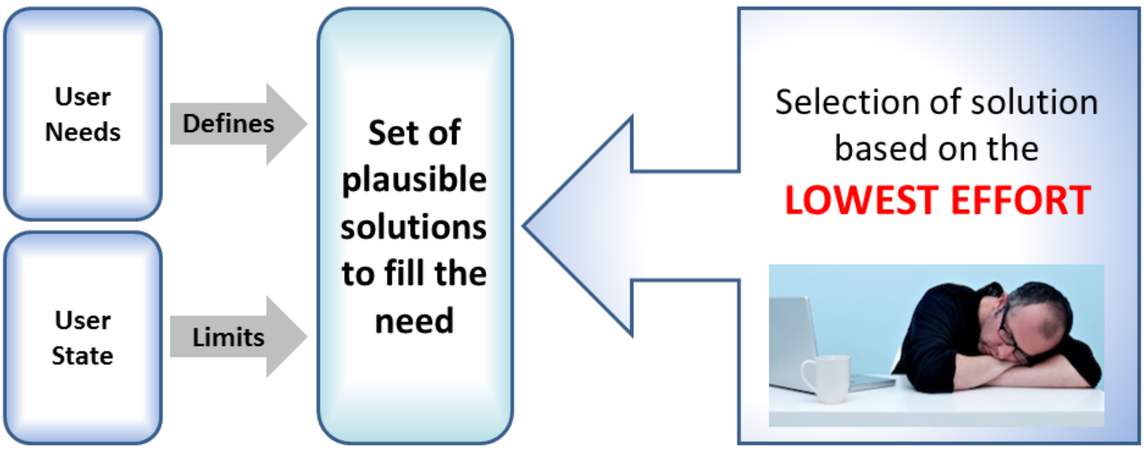


Figure 3.81: The Lazy User Model or concept of product diffusion (Collan 2007)

The Singapore Building Construction Authority (2011) identified the challenges and strategies to BIM adoption across the construction industries (see figure 3.82).

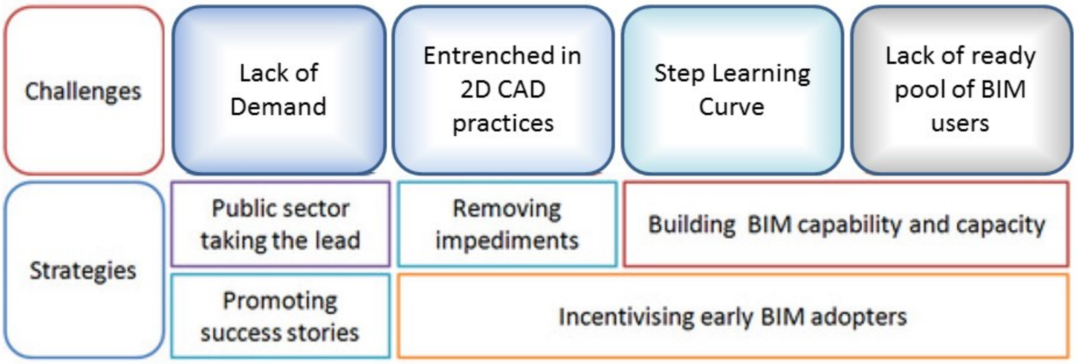


Figure 3.82: Identification of the challenges and strategies to adopt BIM by the Singapore Building Construction Authority (Kam 2011)

The challenges in Singapore are similar to the challenges faced in the UK.

The adoption of BIM may not give an immediate increase in productivity (see figure 3.83). According Aedas (a large international architectural practice) the time spend on producing stage D information is significantly reduced on repeat projects (see figure 3.84).

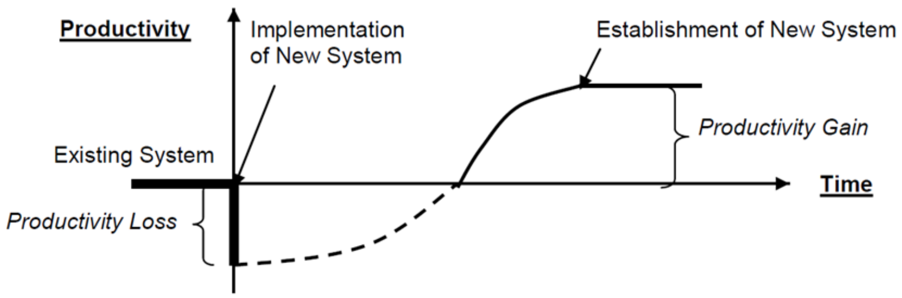


Figure 3.83: The New Software Effect on Productivity (Autodesk Inc, 2007)

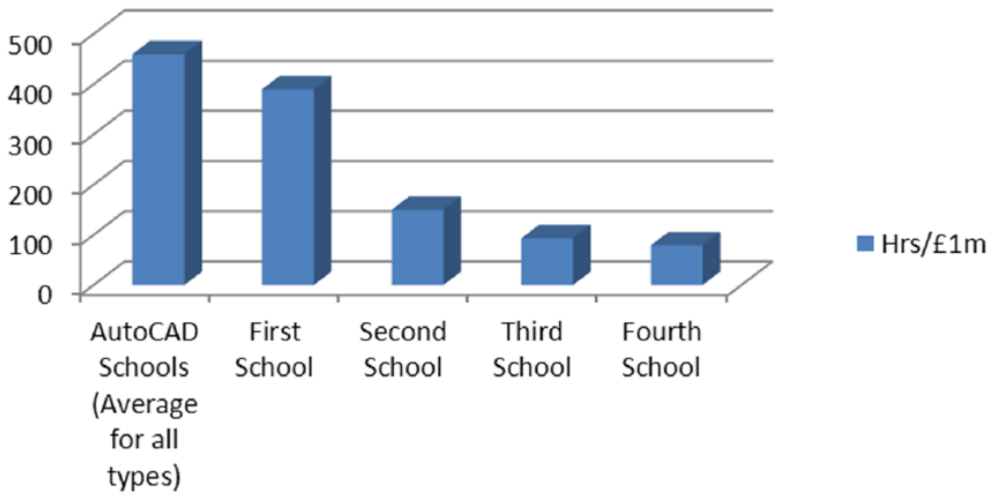


Figure 3.84: Reduction in time spent to produce stage D information on schools (Robinson 2010)

The first barrier to BIM adoption identified by Jernigan (2011) is that BIM adopters do not understand that many of the problems that the industry faces are "wicked problems" that cannot be resolved with linear solutions. Also Jernigan suggests that members of the construction industries focus on 'What's in it for me?' or focusing on one's niche to the exclusion of others.

BIM requires a more holistic or comprehensive view. A realization is required, that traditional specialization are no longer the only and most ideal approach to adopt. This requires practitioners to move away from the traditional or silo thinking by adopting a curiosity for broader interests and also take a longer term view. The barriers to BIM adoption can be broken down into three areas. The element of this curiosity should focus on the following:

- Process concerns / barriers
- People concerns / barriers
- Technology concerns / barriers

3.3.7.1 Process Concerns

There is a need for well-defined transactional business process models. These have rarely been used in the construction industry at a data level. There is a need for practical strategies for purposeful exchange of meaningful information between many tools applied to industry processes today (Bernstein et al 2004). This transactional process model should take account of the capability of the BIM tools used and the skill of the BIM operators.

Jernigan (2011) identified several process problems:

- Not understanding the difference between cooperation and collaboration, while focusing on the wrong social and organizational structures.

- Lack of system thinking and lack of strategic vision.

- Approaching BIM and integrated processes as technology and focusing on 3D not on Integrated Decision Making.

- Reliance on and fear of changing legacy systems and processes.

- Not understanding of the power of Open Standards and interoperability.

- Requiring systems that are more complex, more finished and more difficult than necessary.

3.3.7.2 People Barriers to Adoption

Gu (2008) identified human inhibitors of BIM adoption as follows:

- Lack of work practice and business models

- Lack of defined roles and responsibilities

- Lack of BIM awareness and support

- Lack of BIM training

A person or subunit may resist BIM adoption because of factors unique to the individual or common to the entire group. Eliminating this resistance may require a change in personnel involved with the system implementation, educating the individual, coercing the resistor with edicts or policies, persuading the resistor, and/or by increasing user participation in order to earn their commitment to the project. Markus (1983) suggests education and participation are far more preferable than coercion. Eccles, (1994) by cited Buchanan and Badham (1999) highlight the possible issues people may have coming to terms with change in general (see table 3.07).

Ignorance	Failure to understand the problem
Comparison	The solution is disliked and an alternative preferred
Disbelief	The feeling that the proposed solution will not work
Loss	The personal costs are unacceptable
Inadequacy	The rewards are not sufficient
Anxiety	Fear of being unable to cope with the new situation
Demolition	Change will destroy existing networks
Power Cut	Sources of influence and power will be weakened
Contamination	New ways of doing things are not acceptable
Inhibition	Low willingness to change
Mistrust	Motives for change are not trusted
Alienation	Alternative interests valued above the new interests or state
Frustration	Change will reduce power and career opportunities

Table 3.07: Sources of resistance to change (Eccles, 1994, cited in Buchanan and Badham, 1999, p.199)

Markus (1983) offers three theories of why resistance may occur to the adoption of innovative systems such as BIM.

The first theory involves internal factors while the second theory focuses on external factors. Both can be held simultaneously. An individual may have a tendency to resist a system – but, with all other factors being equal, this individual would be less likely to resist a well-designed system. This is an important element addressed in the later chapters of this thesis.

Markus' third theory addresses the combination of system and person: resistance can be the result of the interaction between characteristics of the people being asked to adopt the system and characteristics of the system itself.

Resistance may be a response to factors inherent in the system being implemented. People resist technically inadequate systems, systems of poor ergonomic design and "user-unfriendly" systems. If resistance is system-related, correcting the problems associated with the system should reduce or eliminate the resistance. To proactively address system-based resistance, use skilled designers, pay attention to ergonomic features, modify the system to better conform to organizational procedures, and involve users during the design phase.

3.3.7.3 Technology Barriers to Adoption

There is a requirement that digital data be computable (Bernstein et al 2004).

Gu (2008) identified technological inhibitors of BIM adoption as follows:

- Version management
- Model validation
- Data integrity
- Data organisation
- Communication and information exchange
- Standards and interoperability
- Data security

Surveys documenting the hurdles to BIM adoption

The FMI/CMAA undertook as survey of the hurdles to BIM adoption. The findings to this survey are documented (Table 3.08). What is clear is that lack of expertise is regarded as the primary hurdle to BIM adoption. A survey was also under taken by RICS (2011) (table 3.09). This survey indicated that the lack of client demand was a major barrier to BIM adoption.

BIM Hurdles						
	All Responses		**Non BIM Users**		**BIM Users**	
	Score	Rank	Score	Rank	Score	Rank
Lack of expertise	4.09	1	4.29	1	3.82	1
Greater System Complexity	3.92	2	4.01	3	3.81	2
Lack of industry Standards	3.92	3	4.07	2	3.74	3
Poor integration with existing systems	3.79	4	3.91	4	3.67	4
Different needs across stakeholders	3.72	5	3.79	8	3.63	5
Training Burden	3.66	6	3.82	6	3.46	6
Unclear Business Value and ROI	3.62	7	3.82	7	3.38	7
Lack of Executive Buy - in	3.57	8	3.88	5	3.20	8
Vague Cost Estimates	3.32	9	3.43	10	3.20	9
Legal / Contractual Concerns	3.23	10	3.43	9	3.02	10
Security Risk	3.03	11	3.20	11	2.84	11

Rate hurdles that slow or prevent adoption of BIM solutions on capital construction projects

1=Strongly disagree

5=Strongly agree

Table 3.08: BIM Hurdles (FMI/CMAA 2007)

Table 14. Building Surveyors' scoring of relative importance of barriers to take up of BIM

Response options ►	**Very important or important**		**Relevant**		**Little or no importance**		**Balances**		**Response**	
Potential barriers ▼	All %	BIM %	All %	BIM %	All %	BIM %	All %	BIM %	All Nr	BIM Nr
Lack of application interfaces between BIM systems and 3rd party applications of choice	65	63	29	21	4	16	61	47	69	18
Lack of IT infrastructure	45	47	42	47	9	5	36	42	71	20
Lack of standards	41	53	37	37	15	11	26	42	70	20
Lack of client demand	63	38	35	62	1	-	62	38	71	13
Current professional indemnity insurance terms	50	37	37	42	9	21	41	16	70	19
Lack of government lead/direction	46	42	26	32	20	26	26	16	70	19
Current conditions of engagement	38	47	32	42	21	11	17	16	71	20
Lack of new and/or amended forms of construction contracts	42	32	45	47	9	21	33	11	69	20
Uncertainties over ownership of data and responsibilities	42	32	41	47	12	21	30	11	69	19
Lack of training/education	29	32	44	47	18	21	11	11	68	19

Table 3.09 Building Surveyor's scoring of the relative importance of barriers to take up BIM

3.4 The financial barrier to adopting BIM

Practices need a continual cash flow and new projects to remain in business. However the older the business is the longer and larger the investment in legacy systems that are needed to keep the "lights on".

According to an NBS survey (NBS 2013) 36% of the respondents did not use CAD (see figure 3.85). Of these it is reasonable to assume a percentage of these were small architectural practices.

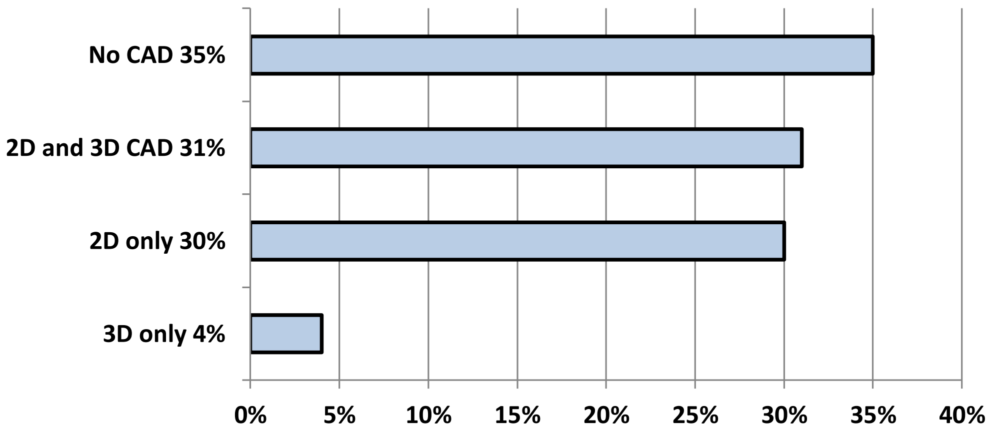


Figure 3.85: Survey of how drawing work is done (NBS BIM survey 2012)

The issue in relation to the potential benefits to be achieved via BIM adoption is that the benefits often do not directly assist the parties that need to make the upfront investment. It is those parties involved in BIM authoring, which is in most cases architectural practices that need to make the largest investment both financially and in terms of cultural change but many of the benefits from BIM are accrued later in the development process. BIM provides efficiencies but at a cost. Papers and reports have been written by software vendors to justify how BIM provides a return on investment (Autodesk 2007) (McGraw Hill Construction 2012). Why many small architectural practices have not adopted BIM is a question of cost and return.

The expenditure on IT has seen a steady fall; if this trend continues then there is a very real danger that the profession will fall behind in both software and hardware, just at the time when new, integrated design packages (BIM) are becoming a requirement in many sectors of work (RIBA 2010).

The purchase of a licence for many of the popular BIM authoring tools is over £3000 and the hardware and operating system costs may be approaching £1000. The estimated cost including training to provide a operational BIM user is £10,000.

If an architectural technician is paid £20,000 per year the investment in BIM represents 6 months' salary. Therefore if the architectural practice wishes to breakeven over the period of a year a technical technician needs to double their output and be working on the BIM tools continuously.

But in small architectural practices it is usual for the staff to cover a wide range of roles and not be restricted to just using production tools such as CAD or BIM. If through the adopting of BIM the number of staff that are required is reduced this can reduce office overheads but also the collective knowledge within the company may be reduced.

To address this fundamental issue several approaches can be adopted:

- The more economical BIM tools can be selected
- Maximum usage can be arranged out of the BIM tools that are selected
- Methods can be found to reduce the cost of training and BIM implementation
- More profitable projects and work streams can be found and undertake using BIM
- Partnering arrangements can be setup where by the BIM author benefits from the downstream benefits of using BIM
- The BIM tools can be setup and used in particular ways to gain maximum efficiency and effectiveness

Once the BIM software is purchased an annual service and upgrade fee may be required which adds to the costs incurred.

3.5 Summary of Chapter 3

In this chapter the complex nature and the many facets of BIM have been indicated. An attempt has been made to provide a working definition for BIM. The barriers to BIM implementation have also been documented. The existing information available on BIM implementation frameworks both nationally and internationally has also been researched and recorded.

Chapter 4

Chapter 4: This explains the potential benefits of BIM as a new way of working for architectural practices. Thus the research objective C is addressed.

CHAPTER 4 Benefits of BIM

4.1 Introduction

The benefits of BIM come mainly from using the information and data from BIM while the main focus of this thesis is creating an operational BIM system (see figure 4.01).

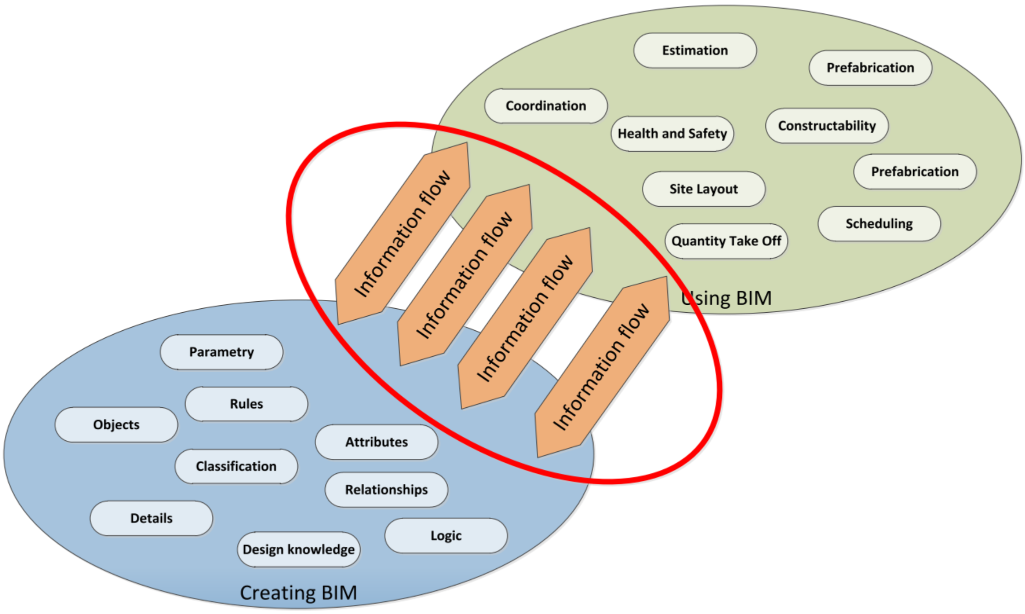


Figure 4.01: The difference between creating a BIM system and using BIM to achieve benefits (Berard 2012)

BIM may also be considered in terms of adding value to the process or adding value to the product (see figure 4.02).

	Design	Construction	Use / Operations	End of Lifecycle
	VALUE FROM PROCESS		VALUE FROM PRODUCT	
For Stakeholders directly involved: architects, builders, owners	- *Collaboration* - *Trust* - *Efficiency* - *Ability to deliver on time and budget*	- *Collaboration* - *Efficiency* - *Ability to deliver on time and budget* - *Easiness to build*	- *Easiness to maintain* - *Easiness to adapt* - *Improvement to owner's business*	- *Easiness to re-use / recycle* - *Market valorisation*
For Stakeholders not directly involved: Users, Community Environment	- *Inclusive*	- *Job opportunities* - *Less carbon emission* - *Less accidents* - *Less disturbance during construction*	- *User experience* - *Activity improvement* - *Crime reduction* - *Land valorization (neighborhood)*	- *Less environmental impact*

Figure 4.02: Different ways to perceive value across the lifecycle of a construction project (Tillmann 2012)

Literature related to BIM can be trisected into literature making the business case, literature making the technology case and literature making the human case (Deutsch 2011) (see figure 4.03). The major focus of all of these types is how potential benefits can be gained. Mooney (1996) identified the business value of IT (BIM) as automation, more effective information management and transformational effects supporting innovation.

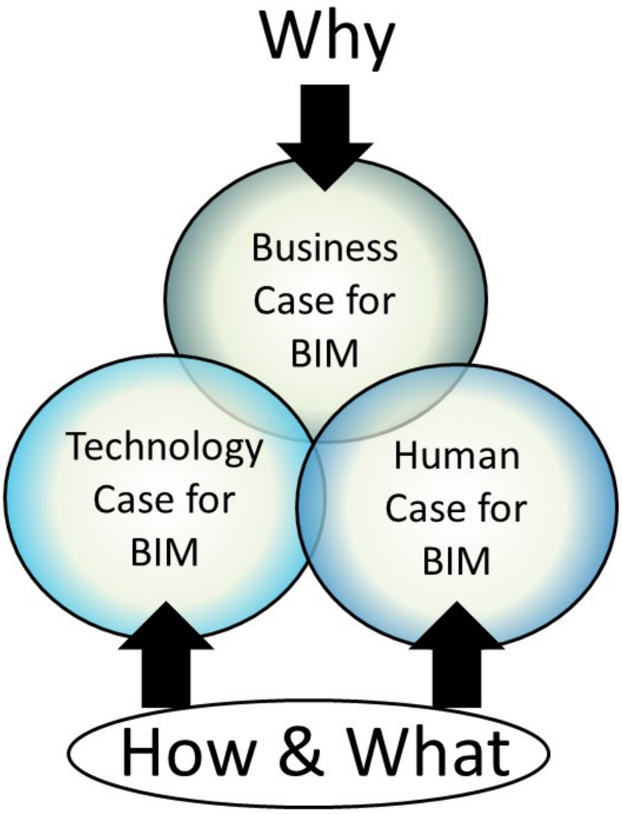


Figure 4.03: The different cases in relation to BIM

In this section the benefits of BIM are seen predominantly from a lean perspective. This is because lean is a philosophy focus on business, process and product improvement.

4.2 Using Lean Concepts to define BIM Benefits

When adopting BIM, architectural practices should focus on achieving a more effective and efficient methods of operation. One way to understand these efficiencies is to consider architectural practice in "lean" terms.

Lean production and lean methodology were originally developed on the Toyota car assembly lines in Japan (Womack et al 1990). Fundamental differences exist between the automotive industries and the construction industries (see figure 4.04) and these should be consider when adopting lean. The production wastes that occur are to some extent context specific (Koskela 2013) (Pasquire 2013).

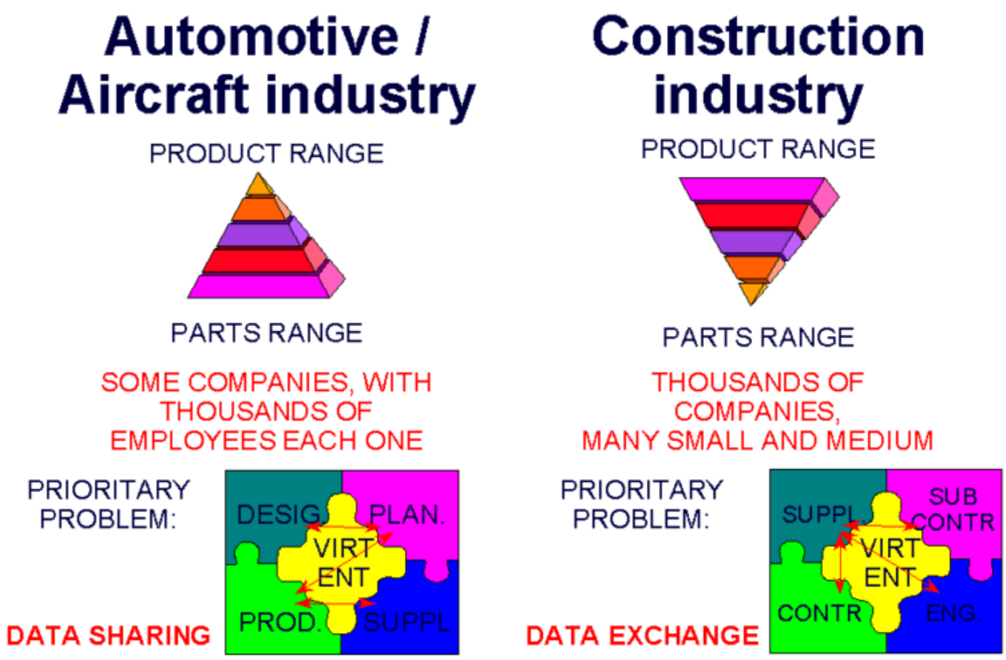


Figure 4.04: Comparison of the automotive and aircraft industry with the construction industry (Grassi and Zorgno 1999)

According to Rubrich (2013) lean implementation has four components (see figure 4.05).

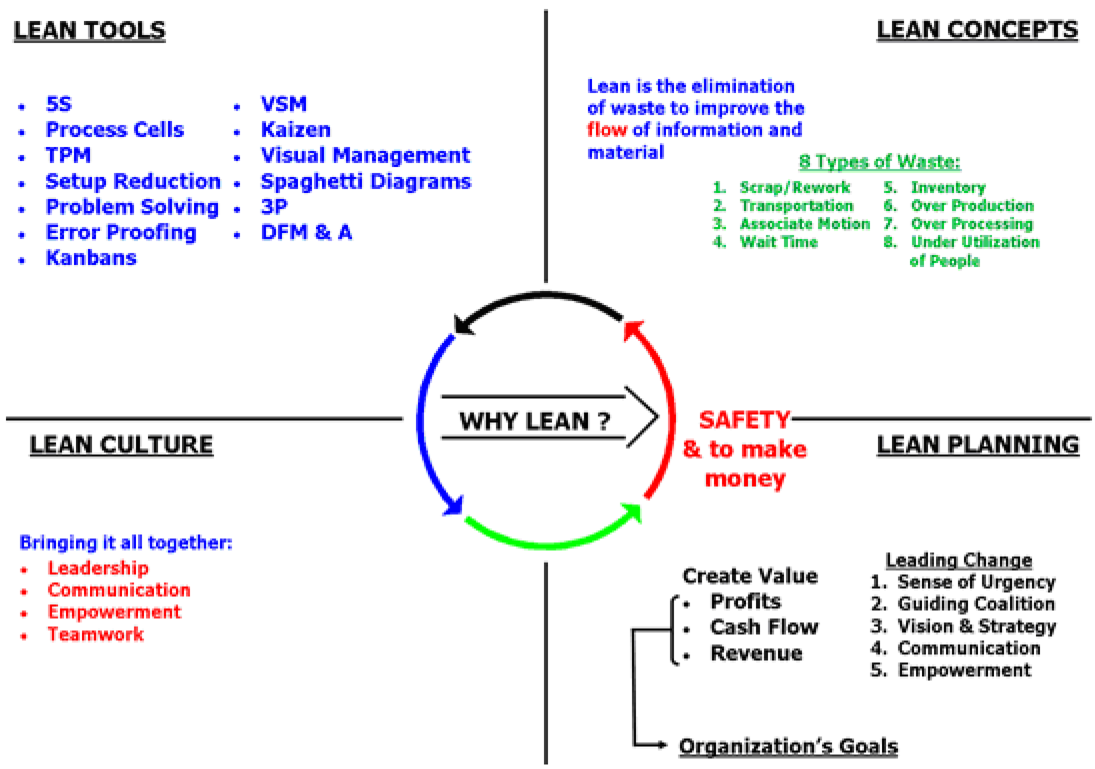


Figure 4.05: The Four Components of Lean Implementation (Rubrick 2013)

Fundamental to the Lean approach is the removal of wastes. There are a number of sources of waste such as:

i) the waste of overproduction
ii) the waste of waiting
iii) the waste of transportation
iv) the waste of inappropriate processing
v) the waste of unnecessary inventory
vi) the waste of unnecessary movement
vii) the waste of defects

(Shingo -1998)

A further waste of "making do" has been identified; this is where a task is started without all the necessary inputs or information (Koskela, 2004). Ballard (2000) also identified negative iteration is an important source of waste in design. Macomber and Howell (2004) also identified failure to use people's talents and skills and the failure to speak and the failure to listen as lean wastes. Latency, the lag from asking a question and receiving a good enough answer can also be considered as a waste (Chachere et al 2009).

Womack and Jones (2003) set out five lean principles:

- i) to specify value by product,
- ii) to make value flow without interruptions,
- iii) let the customer pull value from the producer
- iv) to pursue perfection
- v) to identify all steps along the process chain.

The complete analysis of processes and information flows within the value stream differentiates lean thinking from a simple process analysis.

Three major concepts of production exist, transformation, flow and value (Koskela 2000). In order to evaluate how effectively an organisation operates we need to review an organisation against all these independent angles of production (see table 4.01).

Many of the advantages of BIM can be seen in a Lean context (Sacks et al 2009) (see table 4.01) and BIM has been identified as a Lean Tool (Ningappa 2010) (Gerber et al 2010). Attempts have also been undertaken to integrate last planner techniques with BIM (Bhatla and Leite 2012) and with the BIM capability maturity model (Hamdi and Leite 2012).

BIM Functionality

Lean Principle		Visualization of from	Rapid generation of design alternatives	Reuse of predictive data for model analysis			Maintenance of information and design model integrity		Automated generation of dwgs and docs	Collaboration in design and construction		Rapid generation and evaluation of multiple construction plan alternatives			Online electronic object based communication				
Reduced variability	Get quality right first time	x	x	x		x	x	x	x		x	x		x		x	x		
	Focus on improving upstream flow variability			x	x	x	x	x					x	x	x			x	x
Reduced Cycle Time	Reduce production cycle duration		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	Reduce inventory								0			0	0	0	x	x			x
	Reduce batch sizes (for single piece flow)														x	x			x
Increase Flexibility	Reduce Change over time			x								x					x		
	Use multi skilled teams										x								
Select an appropriate production control approach	Use pull systems														x	x		x	x
	Level the production												x						
	Standardize													x		x			
	Institute continous improvement																		x
Visual Management	Visualize production methods		x											x		x			
	Visualize production process		x										0	x	x	x			
Design the production system for flow and value	Simplify	x																	
	Use paprallel processing		x											x					
	Use only reliable technology								x			x			x	x		x	x
	Ensure the capability of the production system								x										
	Ensure comprehensive requirement capture	x		x		x					x								
	Focus on concept selection			x	x	x							x						
	Ensure requirement flow down	x				x	x				x					x			
	Verify and Validate	x		x	x	x		x			x		x	x	x				x
	Go see for yourself	x													x				x
	Decide by concensus, consider all option	x									x			x		x			
	Create an esstablished network of partners																	x	

Table 4.01: Synergies between BIM and Lean Construction (Sacks et al 2010)

4.3 The Benefits of using BIM in a Small Architectural Practice

The key benefits of BIM were defined by Tizani (2007):

- To avoid repetitive manual re-entry of data and the move to an integrated practice
- To increase automation of the building process. A key element of this being machine readable data
- To accommodate design experimentation and awareness through virtual analysis
- To facilitate a more agile methodology
- To create data consistency across all forms of building representation over the building lifecycle
- To provide greater understanding particularly through visualization
- To create a more effective collaborative working environment
- To create a knowledge driven object orientated process

Three factors play major roles in the effectiveness of BIM, the provision of accurate measurements, the ability to visualise information and the ability to transfer information without distortion or loss of integrity.

Different disciplines within the construction perceive the benefits from BIM in different ways (see figure 4.06). If clients and owners perceive a benefit it is they who are likely to demand its use from the design and construction teams. It has been indicated that owners see improved multi-party communication as the major benefit but benefits that directly enhance their ROI are likely to carry the most weight.

	Improved Site Safety	Postive Impact on Sustainability	Postive Impact on Staff Recrutment / Retention	Faster Plan Approval and Permits	Increased Prefabrication	Lower Project Cost	Reduce cycle time for Project Activities and delivery	Better Multi Party Communication	Improved Project Process Outcomes	Improved Personnel Productivity
Architect	13%	47%	46%	35%	19%	62%	68%	74%	74%	79%
Engineer	13%	20%	28%	28%	22%	41%	50%	65%	59%	59%
Contractor	57%	36%	37%	48%	81%	78%	79%	71%	81%	85%
Owner	33%	67%	17%	50%	50%	83%	50%	100%	100%	50%
Total	33%	37%	37%	40%	48%	65%	68%	71%	74%	77%

Figure 4.06: Elements that improve ROI for BIM users by discipline type (McGraw Hill Construction 2012)

The major benefits perceived by architects is improved productivity followed by improved process outcomes and multiparty communications. Work is often repeated in architectural practice where it is unnecessary to do so. Using standard templates and object libraries in BIM can help reduce potential wastes of effort. An example of the time savings using BIM are shown below (see table 4.02)

Task	CAD (Hours)	BIM (Hours)	Hours Saved	Time Saving
Schematic Design	190	90	100	53%
Design Development	436	220	216	50%
Construction Documents	1023	815	208	20%
Checking and Coordination	175	15	159	91%
Totals:	1824	1141	683	

Table 4.02: BIM enables Lott + Barber to Save Time and increase productivity (Autodesk 2007)

It has also been suggested that the number of staff can be halved on any large project if all parties are efficient in a BIM tools used in a collaborative way (Smith 2012). These advantages are borne out by figures from Ayers / Saint / Gross (see figure 4.07).

Pre BIM									
Week Number	1	2	3	4	5	6	7	8	Total
Principal	4	4	4	4	4	4	4	4	32
Project Manager	16	16	16	16	16	16	16	16	128
Project Architect	24	24	24	24	24	24	24	24	192
Architect 1	40	40	40	40	40	40	40	40	320
Intern Architect	40	40	40	40	40	40	40	40	320
Total Hours	124	124	124	124	124	124	124	124	992
Average Rate									$92.25
Fee Required									$91,520

Post BIM									
Week Number	1	2	3	4	5	6	7	8	Total
Principal	4	4	4	4	4	4	4	4	32
Project Manager	24	24	24	24	24	24	24	24	192
Project Architect	40	40	40	40	40	40	40	40	320
Architect 1	24	24	24	24	24	24	24	24	192
Intern Architect	0	0	0	0	24	24	24	24	96
Total Hours	92	92	92	92	116	116	116	116	832
Average Rate									$110.25
Fee Required									$91,520

Figures 4.07: Manpower savings at Ayers / Saint / Gross by using BIM (Brix 2005)

In other practices a marked improvement has been show of the second or third repeat projects undertaken using BIM (see figure 4.08).

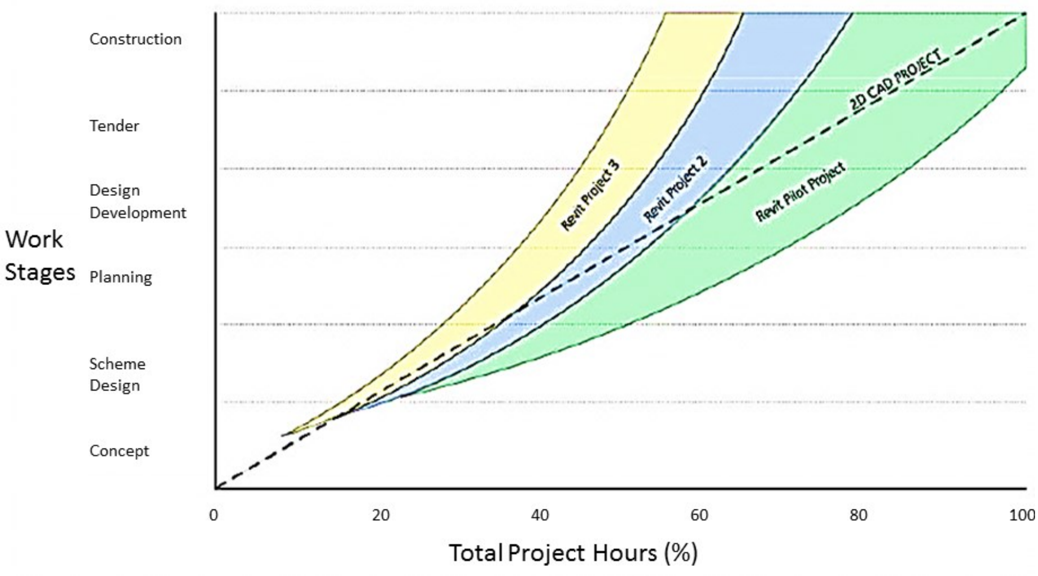


Figure 4.08: Benefits in terms of project hours comparing the first, the second and third BIM projects undertaken using Revit (Aedas 2011)

There are two key areas where BIM brings about benefits to architects. The first area of benefit is through the ability to share and reuse data/information. This benefit of reuse of data may manifest itself over the design and documentation on multiple projects. The second area is the advantages that are bought about by being able to use that data for modelling and simulation (see figure 4.09).

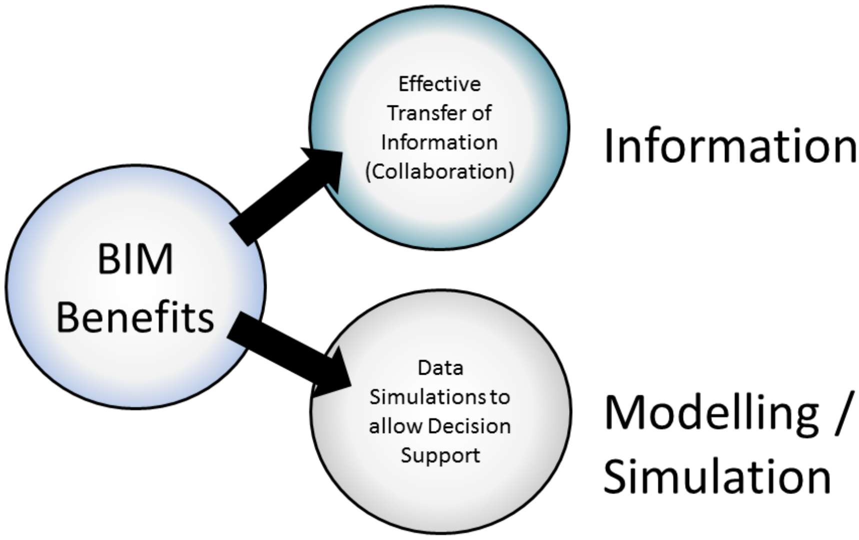


Figure 4.09: The key benefits of Building Information modelling

But the greatest benefits in terms of reducing risk by using BIM is skewed towards contractors not architects (see figure 4.10). The closer the stakeholder is to the construction works, the more benefit they derive from the improved planning and coordination through the use of BIM.

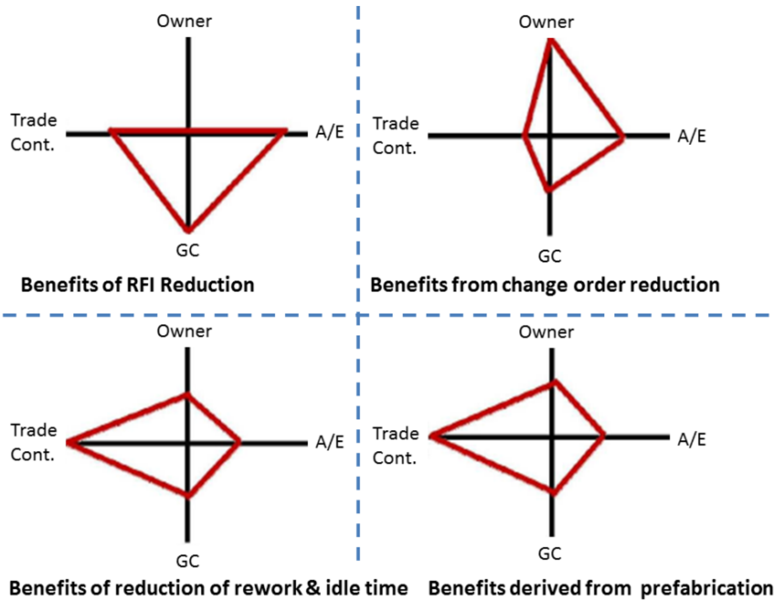


Figure 4.10: The benefits of BIM from the perspective of different stakeholders (Chelson 2010)

The table 4.02 shows the types of analysis that can take place when the data required is incorporated into BIM objects. This development of this table was based on the work of the Veterans Affairs Department, Object Element Matrix (2010).

BIM Object Information Category	Primary Analysis	Compliance with Clients Brief	Review of health and Saftey Issues	Review of Enviromental Issues	Functionality Re4view	Operability and maintainability	Engineering Principles	Value for money	Interface Between Disciplines	Standardisation	Security	Constructability	Life Cycle Facility Management	Life Cycle Operations Management
Building Program & Project Meta Data	Portfolio management	■							■				■	■
Physical Properties of BIM Objects & Elements	Space Analysis / Clash detection	■	■			■	■	■	■	■	■		■	■
GeoSpatial & Spatial Location Objects & Elements	Locational Constraints	■	■		■	■			■		■			
Costing Requirements	Cost Analysis Value Engineering	■						■	■					
Energy Analysis Requirements	Energy Performance Analysis			■					■					
Sustainable Material BREEAM or Other Req.	Eco Analysis			■					■					
Phases Time Sequencing & Schedule Req.	Buildablity Analysis		■						■					
Manufacturer Specific Information Requirements	Supply chain management		■						■	■		■		
Program/Space Compliance or Validation	Brief Validation				■				■			■		
Code Compliance / Occupant Safety Requirements	Egress and Safety Analysis		■			■			■			■		
Specifications	Life Cycle Analysis		■	■	■				■			■	■	
Facilities / Asset Management	Facilities Management Analysis		■	■	■	■		■	■	■	■		■	■

Table 4.03: BIM Object Information Categories and the uses that information

For any client, design or construction team member, what is important is to define what are the primary benefits and goals which are to be aimed for through BIM adoption. Defining the desired future state will provide focus for the BIM and the data, tools and approaches to be used. Where possible, project objectives should be confirmed with all the stakeholders directly involved. Effective use of BIM can be considered as achieving a balance of business, operational and technical capabilities (see figure 4.11).

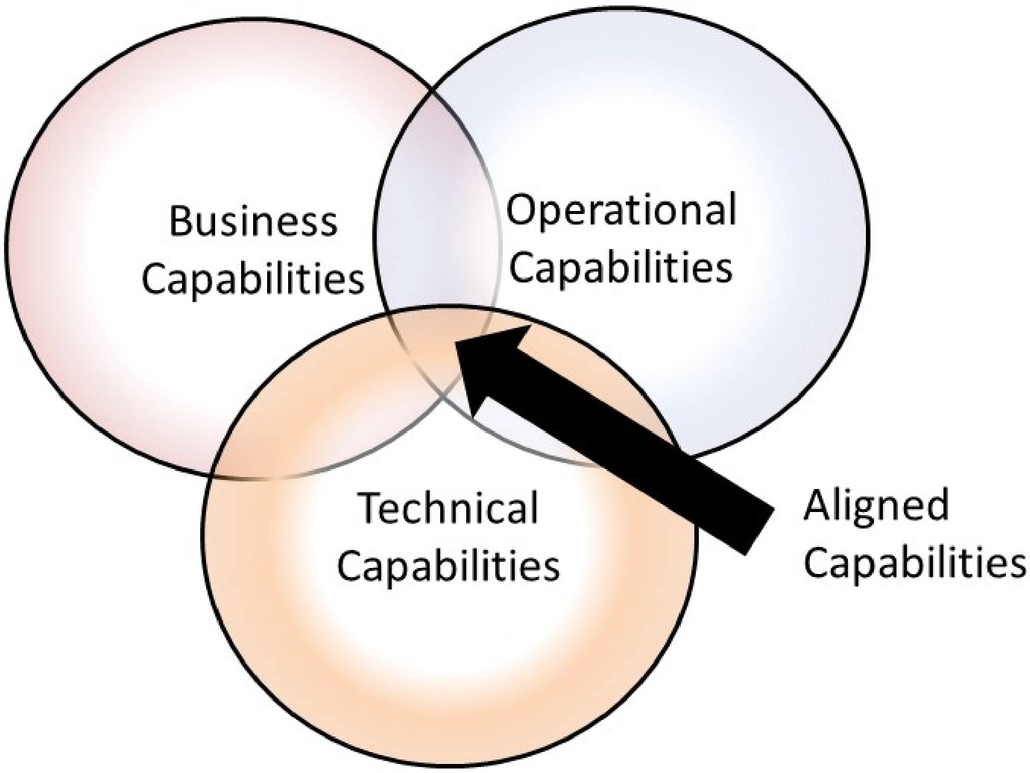


Figure 4.11: Capabilities affected by BIM adoption

The outcomes by using BIM can be considered in terms of technical capabilities, operational capabilities and business capabilities. Following are examples of some of the outcomes that could be considered and expected when using BIM (see table 4.03). These findings were borne out by the action research undertaken as part of this research.

Technical capability	Operational capability	Business Capability
Ability to produce (effective instructions necessary to achieve "building" objectives) the necessary drawings, documentation or model representations and visualizations or instruction sets from the BIM model. (It is estimated that 90% of people who are presented with 2d drawings are unable to visualize the intended physical result. Therefore 3d representations can have a distinct advantage).	Ability to undertake concurrent design in a 3D environment throughout the entire design process and undertake rapid prototyping as required. (Visual management)	Ability to complete larger more complex design projects with greater efficiency than at present
	Ability to use BIM to support controlled filtered process focused collaboration and information exchange with parties as required	Improved design outcomes through better understanding of design alternatives (rapid prototyping) by clients, designers, contractors, operators and stakeholders.
	Ability to reduce error in (documentation / work instructions) as a result of single source data and through better coordination between all parties. (Error Proofing)	Better Cost control and eco analysis through model quantification
Ability to accurately exchange information (BIM models) with consultants (structural, building services, and quantity surveyor etc.). This will allow interoperability, functionality, less likelihood of error through rework and the reduction of work duplication.	Ability to undertake faster process completion through the use of parametric objects and object libraries. The development of a more agile development process allowing a more flexible process.	Better quality control through more effective model validation using software tools, virtual preconstruction, virtual operation analysis and design review / validation.
	Ability to undertake faster process completion through the use of parametric objects and object libraries. The development of a more agile development process allowing a more flexible process.	Using BIM should achieve less data atrophy during the building lifecycle with particular benefits during the asset management stage. (Where it is possible to link this with RFID additional benefits may be achieved).
	Reduction in the resources required (people, finance, materials etc.) to undertake development predominantly through the use of single data input and subsequent reutilization.	Reduced risks associated with information-related errors associated with information consistency through model generation and errors introduced during information exchanges, etc.
	Development of a more transparent process. (Visible audit trails)	
	Ability to integrate better with the supply chain though anytime accurate quantity takeoff (allowing sequential just in time ordering and supply of products). Also accurate quantities potential will reduce the amount of waste produced on site and during operation	
	Ability to adopt more effective contractual forms, develop Integrated Project Delivery and other innovative contractual arrangements	
	Adoption of enhanced flow. (When a project stops and starts	
	Better alignment with design for manufacture and a prefabrication approach if required. (Model to manufacture)	
	Better site and overall logistics	
	Deceases time to project completion, through reduced time within all the project related activities.	
	Avoidance of operational and physical clashes	
	The ability to demonstrate the adding of value throughout the project development	

Table 4.04: Analysis of the technical, operational and business capabilities of BIM (adapted from Aranda-Mena 2008)

4.4 The Benefits of a Small Architectural Practice adopting BIM to the wider Construction Industry

The major benefit provided by BIM models and the information systems that they can populate is that they enable “what if” analysis or optioneering to take place. It is this ability to test out in a virtual form where major savings can be made and new approaches developed.

Small architectural practices are often the first of many actors in the construction process and as such have an important role to play initiating and developing a more efficient and effective information flows as part of the building lifecycle process. The benefits of BIM were documented by the FMA/CMAA in 2007 (see Table 4.04).

BIM Benefits						
	All Responses		**Non BIM Users**		**BIM Users**	
	Score	Rank	Score	Rank	Score	Rank
Improved Communication and Collaboration Among project Participants	4.22	1	4.02	1	4.42	1
Higher Quality Project Execution and Decision - Making	4.09	2	3.97	2	4.19	2
Greater Assurance of Project Archival	3.98	3	3.87	3	4.08	4
More Comprehensive Planning and Scheduling	3.97	4	3.83	4	4.09	3
Higher Quality Construction Results	3.90	5	3.79	5	4.00	6
Easier to Achieve Process Standardization	3.89	6	3.71	6	4.06	5
More reliable compliance with specification and regulations	3.73	7	3.60	8	3.85	7
Greater Productivity from labour Assets	3.71	8	3.62	7	3.79	10
More consistent performance against project budgets	3.68	9	3.62	10	3.84	9
Significantly reduced change order claims	3.64	10	3.56	9	3.71	11
Broader Strategic perspective and Innovation	3.63	11	3.38	13	3.85	8
Decreased Labour Costs	3.52	12	3.41	12	3.62	12
Measurably Reduced Contingencies	3.49	13	3.44	11	3.52	13
Improved Safety Performance	3.27	14	3.22	14	3.32	14
Competitive Advantage in Recruiting and Staffing	3.21	15	3.13	15	3.27	15

Rate benefits that BIM solutions provide on capital construction projects

1= Strongly disagree
5= Strongly agree

Table 4.05: BIM benefits (FMA/CMAA 2007)

The key benefits to the construction industry and small architectural practices of adopting BIM are illustrated (see figure 4.12).

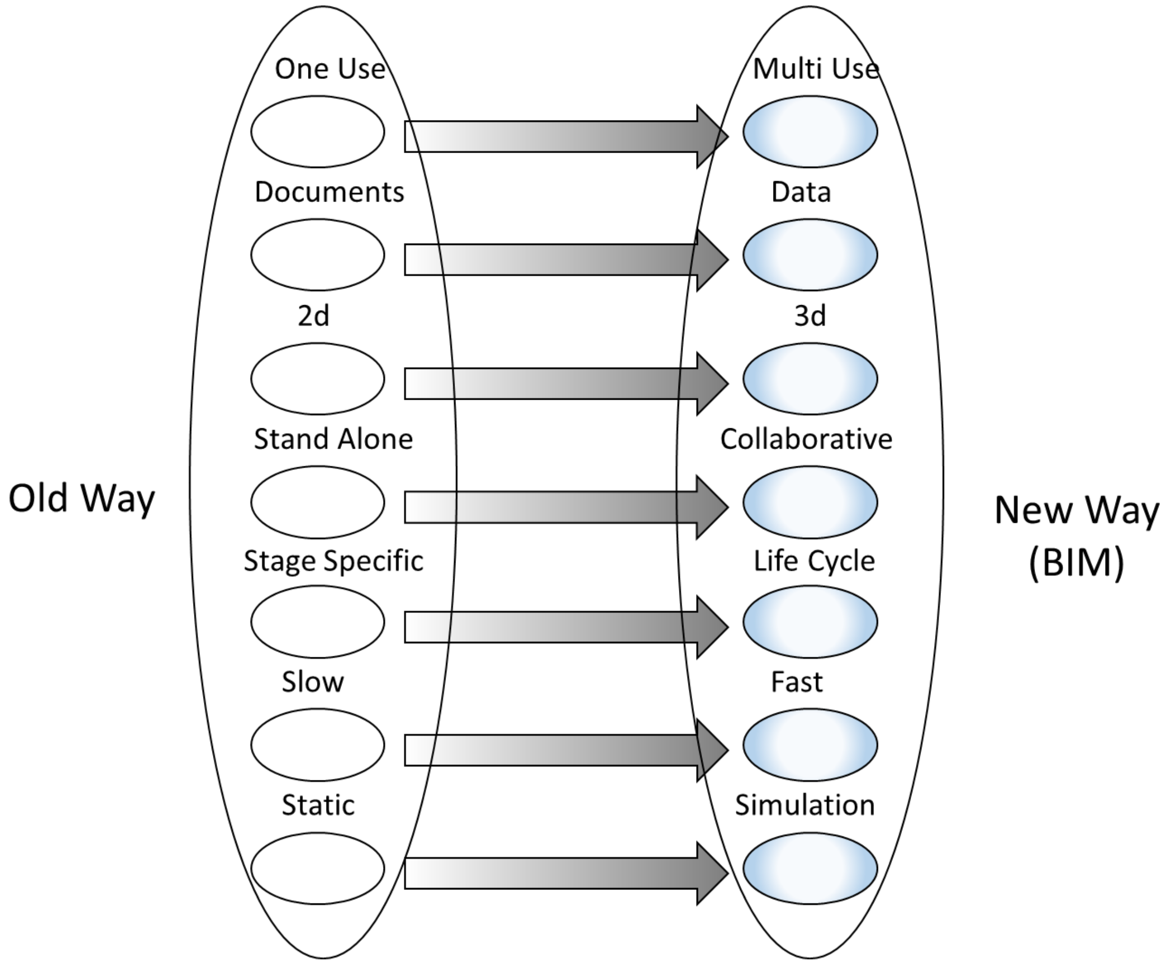


Figure 4.12: Change that can occur with the adoption of BIM

The major competitive advantage architectural firms can develop is to adopt enhanced business processes.

"The whole incentive for companies to improve and redesign their business processes is to become more competitive … the greater satisfaction of clients and customers is only the means to the ends of beating the competition … in industries like construction, where firms do not possess strategic assets such as sunk costs, locational advantages, or patents, nor where they can compete through cost leadership obtained by capital investment, process capabilities are all they can offer to clients: the ability to design better structures, the ability to better manage supply chains, and the ability to motivate labour"

Winch and Carr (2001)

So what is the advantage of using BIM over using CAD? BIM authoring tools have been designed to provide data across the whole building lifecycle process (Wix

1997). While CAD tools such as AutoCAD and Microstation where originally designed for the manufacturing / mechanical industries. So using BIM, the tools are better aligned to the tasks being undertaken in architectural practice. The advantages gained by building professionals will depend on the particular user's business model. But the key advantages are consistent, transferable, information rich information which can be used in multiple modelling and analysis applications. Establishing the relative importance of these benefits to the specific architectural practice is an important part of the BIM adoption process.

Construction Industry Problem	How BIM addresses the problem
Problems in Design and Creation	
Need to be able to deal with complex "wicked" problems (Cutler 2009) (a problem that is difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize)	BIM can be considered as a method of augmenting human intellect in line with the work of Engelbart (1962).
Too much rework of information	Using a shared model problems associated with coordination of information should be reduced as should the checking time required.
Difficulty of altering designs, hindering rapid prototyping	As BIM uses parametric objects rapid prototyping is facilitated
Problems in Coordination	
Lack of understanding of issues (Pelosi 2007)	As BIM uses 3d objects the visualization of building related issues becomes easier and model validation against user briefs can be undertaken.
Inability to link related information	In BIM it is expected that information / data will be attached to objects. In this way the model becomes a repository of information which can also be linked to external data sources.
Lack of synchronous information	The fundamental change when moving from computer aided design (CAD) and associated documents to BIM is that the information in the BIM scenario should be in sync with the central model.
Problems in Validation	
Lack of automated checking	User requirements, building codes, construction rules and regulations imply constraints on a building design. Additional constraints can be introduced by the different participants of the collaborative planning process through the individual body of knowledge representing their particular domain. Checking digital building models for

	compliance with these constraints allows detecting design errors and conflicts in an early stage.
Lack of automated clash detection	When BIM objects are created the working areas and kinematic envelopes can be defined. Using visibility setting in BIM software tools these can either be made visible or hidden. When these areas are made visible it is easy to check that sufficient space has been allocated around specific objects.
Lack of ability to test different scenarios	Once BIM objects have been created and the information attached to them they can be loaded into BIM analytical engines. Using these tools various facets of the building can be investigated.
The need to move away from non-intelligent deliverables to deliverables that can be interrogated.	What BIM enables is the transition from the use of artifacts (drawings, specification documents etc.) to the use of objects and ultimately data. This view of BIM is described as “atomic BIM” (Tobin 2008).
Problems in sharing information	
Lack of multi functionality of data produced	BIM is synonymous with nD modeling the parallel utilization of building information for different analyses and evaluations assisting across the building lifecycle. For reference 2d to 6d are listed below: (this list can be extended incorporating many different facets and capabilities) 2D - Something with 2 dimensions (flat) 3D - Something seen in 3 dimensions e.g. width, length and height. 4D - Adding the aspect of Time to a project (phasing/sequencing) 5D - Adding the aspect of Cost to a project (cost estimating) 6D - The aspect of Life Cycle Management (owner/FM)
	Using a shared project model simplifies the communication process. The uses the industrial foundation classes (IFC) as an exchange intermediary between disciplines and software tools. Thus reducing the need to develop additional exchange protocols.
Lack of link to real world objects	A BIM object is an information container

	(repository) that holds all critical information about a building product designed and manufactured by a company or brand.
Problem Utilizing Information	
Inability to document functional information	BIM objects can also define functional elements such as zones of operation, grid and turning circles. It is through the attached information objects can serve different functions.
Material Waste	On site materials are often cut to size resulting in material wastage. Automating how elements are cut and used can reduce wastes (particularly in elements such as timber frames).
Knowledge Waste	Knowledge that is acquired is not applied or used in subsequent circumstances where it is applicable. Reusing BIM objects means knowledge is not wasted
Carbon Waste	BIM allows for more and more accurate sustainability analysis
Control of Costs	BIM offers the opportunity to develop target value design and continuous value optimization (Reed et al 2009)

Table 4.06: Construction Industry Problems and BIM solutions

Listed below are the benefits found by an analysis undertaken at Stanford University Centre for Integrated Facilities Engineering (CIFE). The figures are based on 32 major projects using BIM (CIFE, 2007):

- Up to 40% elimination of unbudgeted change.
- Cost estimation accuracy within 3%.
- Up to 80% reduction in time taken to generate a cost estimate.
- A savings of up to 10% of the contract value through clash detections.
- Up to 7% reduction in project time

4.5 BIM to address sustainability issues

With the use of BIM models a more predictive approach to building performance is developing. Using BIM models it is potentially possible to evaluate more options against more criteria (see figure 4.13) and therefore achieve more sustainable buildings and a more sustainable built environment.

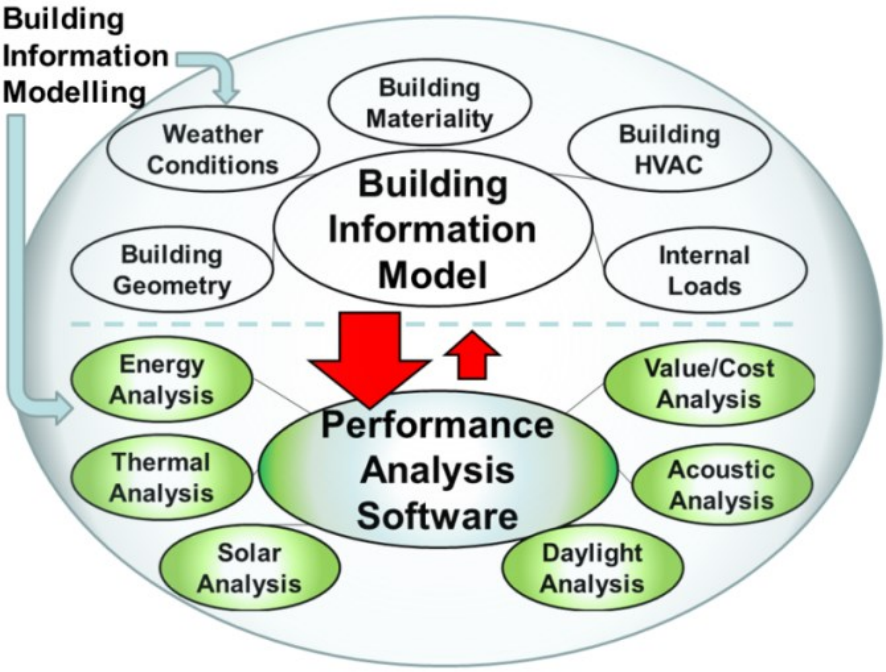


Figure 4.13: The use of BIM for Sustainability analysis (adapted from Azhar 2009)

Such analysis can take place at any of the stages of the building lifecycle process (see figure 4.14).

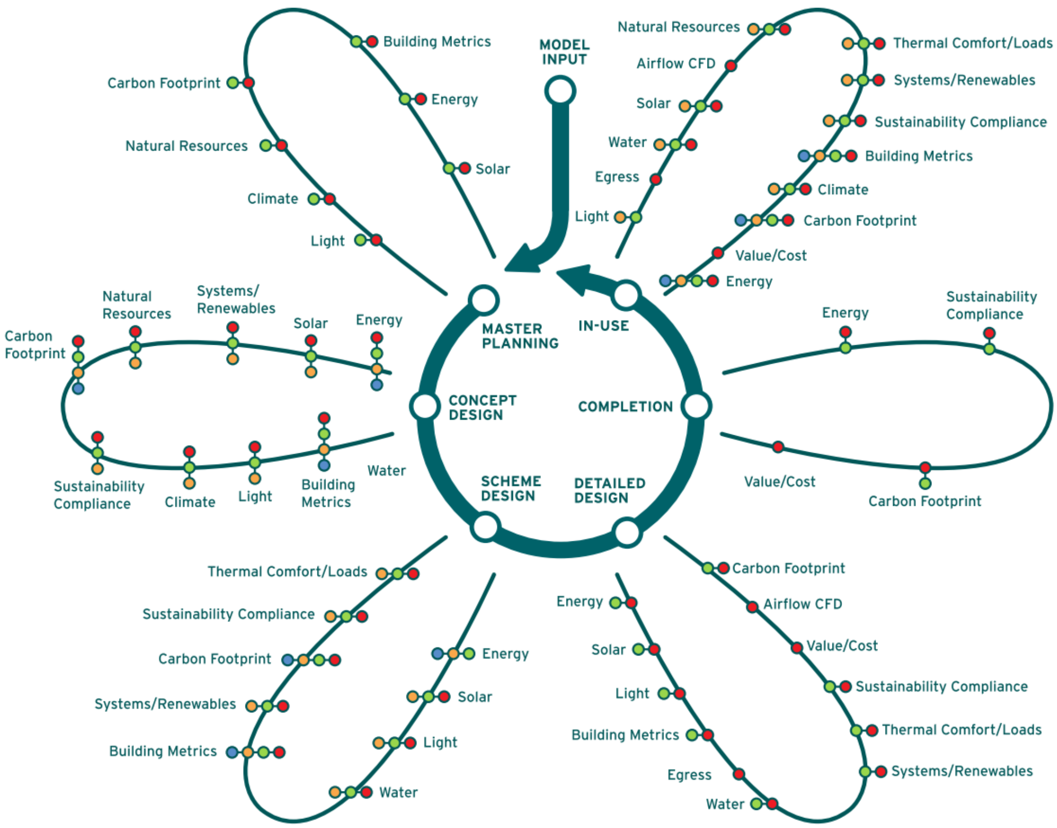


Figure 4.14: Use of BIM tools for eco analysis throughout the building lifecycle (IES 2010)

The GLITNE project in Norway (2006 – 2009) set out to establish links using BIM models between building costs and environmental costs (see figure 4.15).

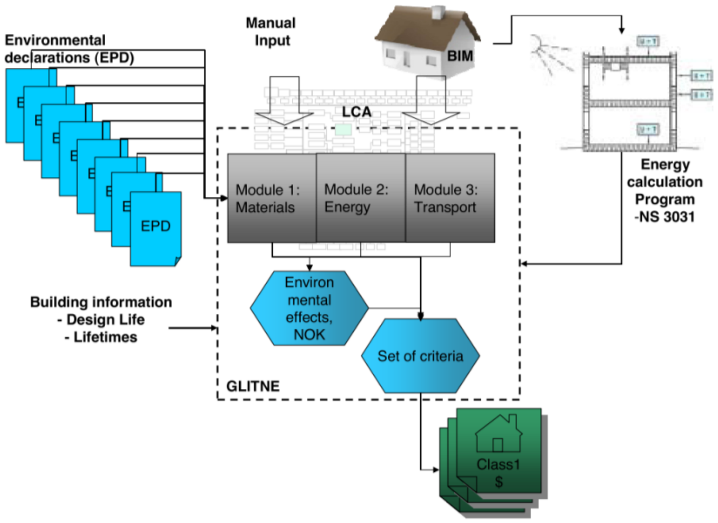


Figure 4.15: The GLITNE methodology (Strand-Hanssen 2008)

A range of eco BIM tools and lists there specific capabilities is shown (see figure 4.16). BIM tools such as Ecotect, Radiance, Daysim, 3ds Max can assist when undertaking daylight analysis.There are infact hundreds of eco BIM tools. Assisting in eco analysis is a major benefit of using the BIM approach. The U.S. Department of Energy provides a directory of building energy software tools.

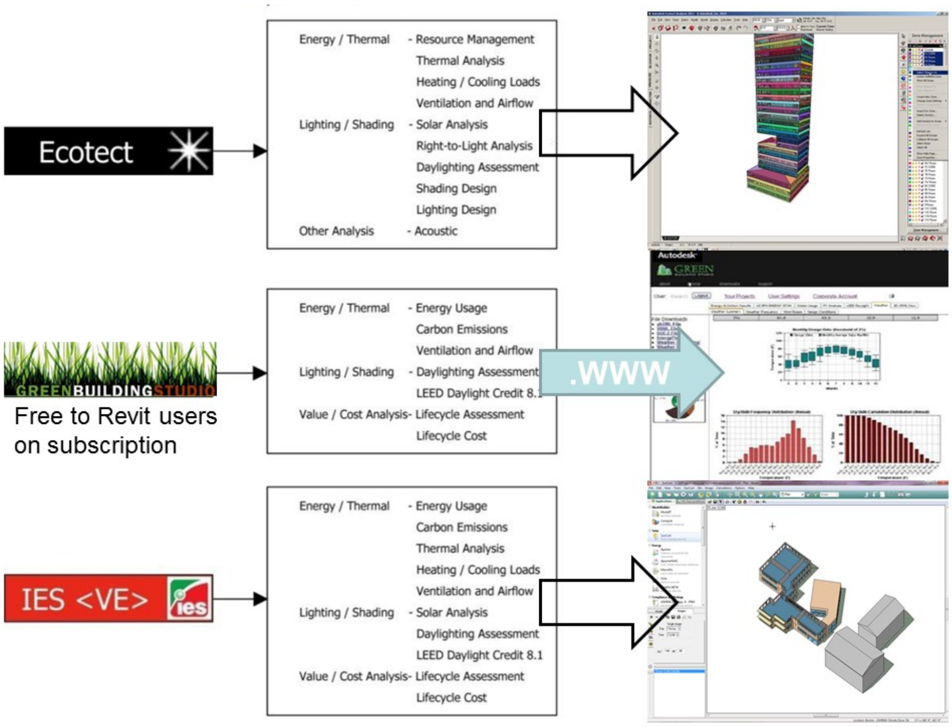


Figure 4.16: A range of Eco tools used with BIM models (Azhar 2009)

Dashboards are now often used as the output from eco analysis (see figure 4.17).

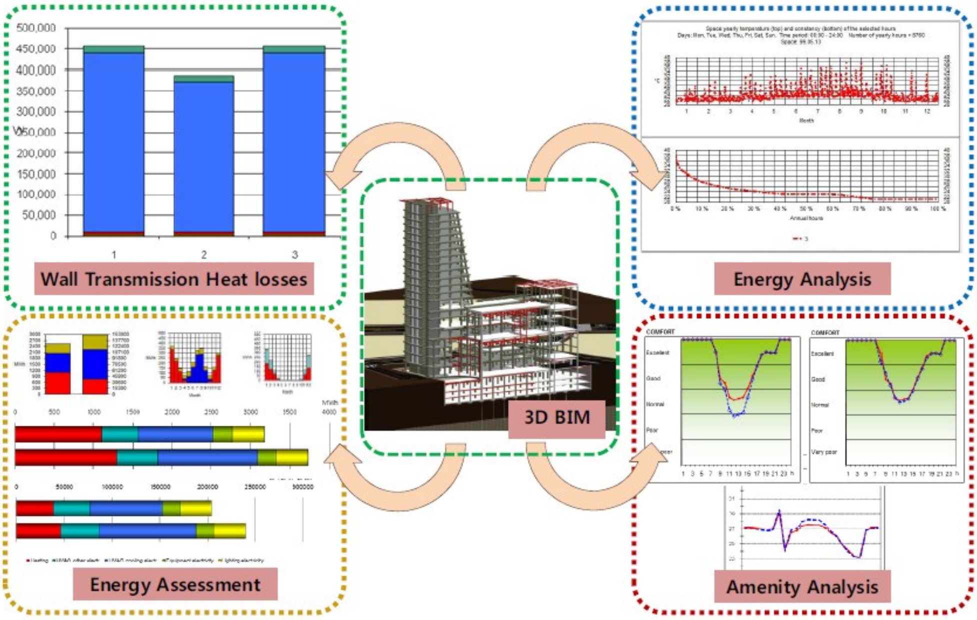


Figure 4.17: Digital Broadcasting Contents Centre energy assessment (Kim 2011)

4.6 BIM and Health and Safety

New York City department of building has now decided to accept 3d site safety plans (Bloomberg 2013). A range of accidents can occur and these can be identified and modelled using BIM (see figure 4.18). The colours used to identify the objects related to risk assessment and method statement. Potentially this could be linked to a return on health and safety and environmental investment system (ROHSEI).

Figure 4.18: System in development by the author to use BIM for warning of health and safety issues

Guidance has been written on BIM based safety management (Kiviniemi et al 2011). BIM based safety modelling requires the consideration of both the building elements and the temporary elements that are required to make the building. Through the use of BIM modelling it is possible to simulate in a virtual environment many of the safety risks in a building and risk that occur during construction and demolition (Azhar 2013). Strategies for BIM based checking systems have also been developed (see figure 4.19) (Zhang 2013) (Sulankivi 2009).

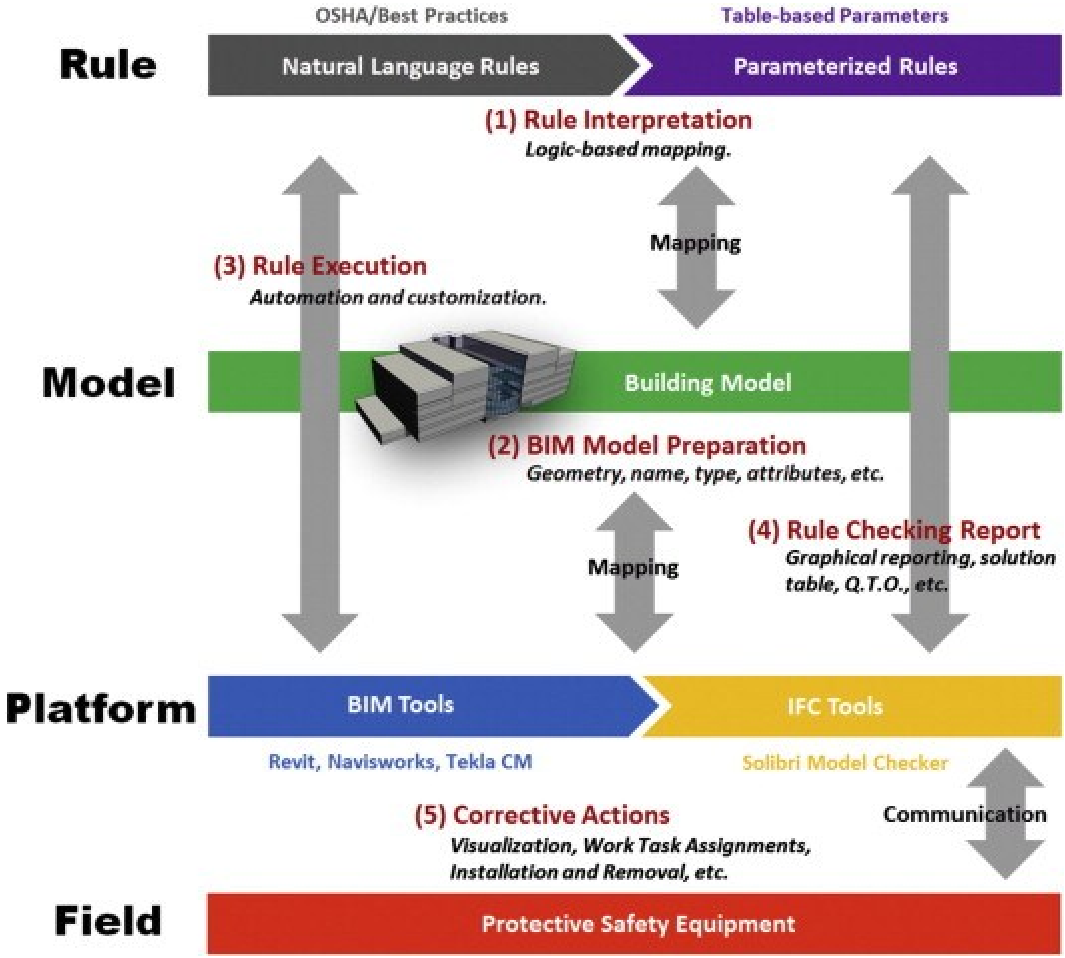


Figure 4.19: The development of a BIM based safety checking system (Zhang 2013)

4.7 Project Integration, Clash detection and reduced rework

Historically a duality of written and graphical information has been produced where conflicting information may be produced. The integration between written specification and graphical BIM systems is developing and may eventually offer some level of solution to such problems (Chapman 2011). NBS Create is one such tool that starts to address this problem (see figure 4.20).

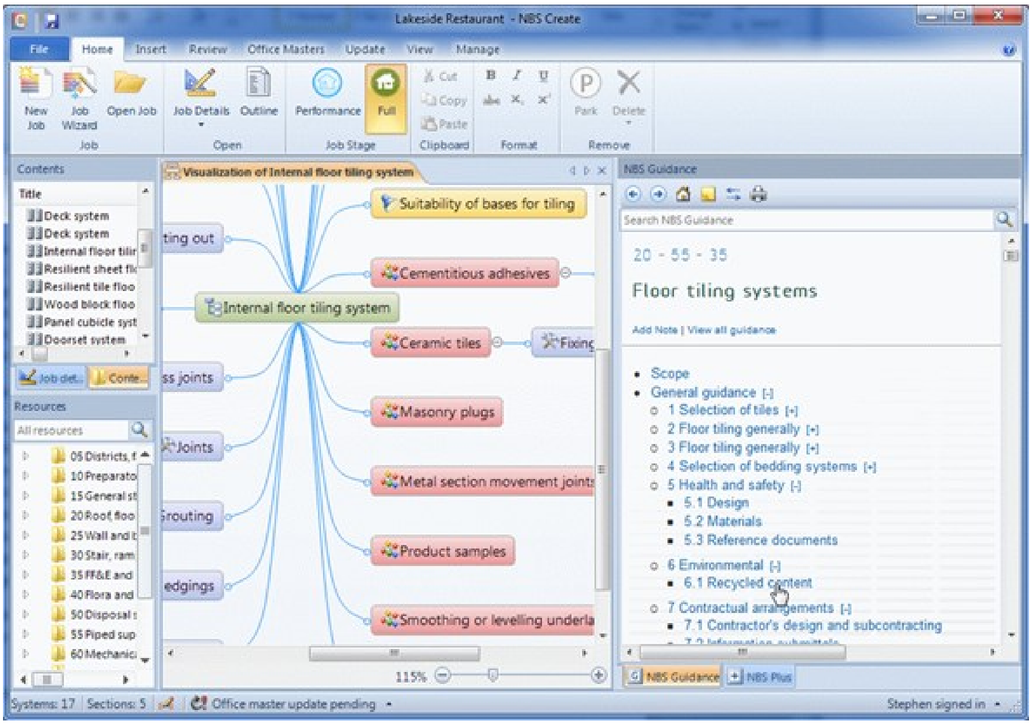


Figure 4.20: Screen shot of the NBS Create Interface

Through virtual preconstruction using BIM rework can be drastically reduced (Azhar 2008). BIM also has the potential to develop virtual pre operation models to address the major cost that are incurred in facilities management (Ioannidis 2012).

Clash detection undertaken using BIM models, has been shown to significantly reduce rework on site (WRAP 2013). Using BIM models consistency across plans, sections and elevations is easier to achieve and therefore less errors occur on site. Clash detection of the models produced by different disciplines also can facilitate 3D coordination. BIM models files can also be used to show what has changed and what has been inserted as the design progresses (see figure 4.21)

Figure 4.21: Overlaying BIM models to show what has been inserted and what has changed

4.8 Designing Better Buildings

Models can facilitate active reflection by illuminating what is. This assists the designer by taking some of the cognitive load away, allowing them to focus on the problems and issues at hand.

BIM models also allow prototypes to be shared thus facilitating a collective design process. Efforts have also been made to integrate BIM with set based design (Bavafa 2012). Using BIM quantities and areas can instantaneously be generated. Potentially this has can help in the decision process as part of rapid prototyping.

The range of complex forms that have recently developed providing iconic architecture can be directly attributed to the functionality provided by new parametric and generative computerized tools (Roudavski 2007).

Strategies of benefit realization management (BRM) and choosing by advantages (CBA) Suhur (1999) can also be linked to the BIM approach.

BIM is driving the further use of prefabrication for construction (McGraw Hill Construction 2011). Optimal component sizes can be integrated into a BIM system through the introduction of standard object libraries. Constructability reviews and sequence models using BIM models can also help develop better construction strategies and thus reduce the labour and time spent on site (see figure 4.22).

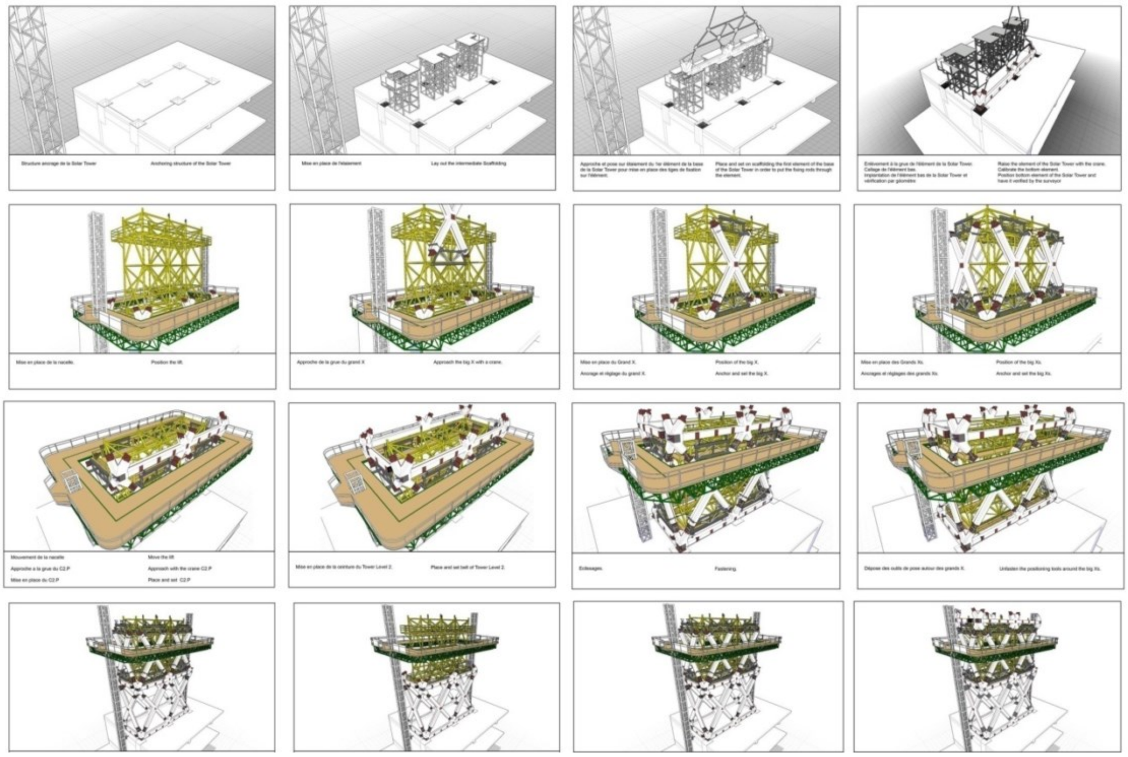


Figure 4.22: The Kaust Solar Chimney construction sequence (Courtesy of OGER International and Gehry Technologies)

Using BIM models integrated with structural analysis software it is possible to predict building performance in multiple situations and events. Using BIM simulation tools both the effects of fire and the effectiveness of occupant evacuation can be tested.

BIM through automated space validation has the ability to assist in ensuring space standards are met but not exceeded. Computerised routines and CNC (computer numerical control) can also be used to ensure the maximum use of the material available. The future challenge is to link of the architect's digital design to digital manufacture thus creating a more efficient and less wasteful process.

Rule based checking of BIM models can provide a rapid way to check for code compliance. Currently BIM is not utilized to assist the authorities in the tasks that they perform. In Singapore the Construction and Real Estate Network (CORENET) e-submission system use BIM facilitates rapid approvals. Recently the BIM4Regs group has been setup to advise the UK government BIM Task Group in these areas. Figure 4.23 shows some of the BIM based rule checking systems used internationally. While figure 4.24 shows a possible structure for a BIM based rule checking system.

	Development agency, project	Singapore, CORENET	Norway, Statsbygg	Australia, CRC for CI	USA, ICC	USA, GSA
	Target rules	Buildingcode	Accessibility	Accessibility	Building code	Circulationandsecurity
	Rule checking platform	FORNAX	SMC	EDM	DA's SMARTcodes for SMC, Xabio	SMC
A. Rule interpretation: Translates a written rule-base into a computer implementable one						
A.1. Method of translation of written rules to computer code	A.1.1. *By programmer*	Yes	Yes	Yes		Yes
	A.1.2. *Employs predicate logic or similar derivation process*	Yes		Object-oriented interpretation of code; Graph application; Express Rule Schema	Yes	
A.2. Has developed an ontology of names and properties			Space name based ontology	Yes. Covers AS1428. 1, Design for Access and mobility, and BCA D3	Yes	Space name based ontology
A.3. *Rules coded in:*	A.3.1. Directly in computer code A.3.2. Parametrictables A.3.3. Rule-basedlanguage	Computer code	Parametric tables	Rule-based language: Express Rule Schema, Express-X	SMARTcode builder	Parametric tables
B. Building model preparation: extracts and derives model view for checking						
B.1. Supports *model view* approach to processing rules	B.1.1. Derive new properties Using enhanced objects	Yes–called FORNAX	SMC library	Internal model schema to define objects and additional properties	DA's SMARTcodes for SMC and Xabio	SMC provides limited API for deriving properties
	B.1.2. Derive new models		Adds geometry for additional checking[a]	Sub-model schema to derive domain-specific view	SMC supports derived circulation graph	SMC supports derived circulation graph
	B.1.3. Performance model view and integrated analysis			Performance model view using intermediate and results model schema		
B.2. Uses *dictionary* of standard properties and relations for defining access		Implemented in FORNAX	Space names	Uses IFC model properties and relations and the internal model for defining acess	Dictionary in SMARTcodes	Only for space names
B.3. *Visibility of layout rule parameters*						
C. Rule execution: rule processing and checking						
C1. Building *model validation* to verify minimum. model requirements for checking.			Yes	Runs the chosen rule set against the model to identify areas with insufficient information	Yes	Implemented in SMC
C.2. *Manages view submissions for completeness*	C2.1. Checks consistency. of view submissions					
D. Rule check reporting						
D.1. Rule instance graphical reporting		Yes	Yes	Graphic display of the check results; 3D visualization not linked	Yes	Yes
D.2. Textual reference to source rule text		Yes	No	Yes	DA's SMARTcodes for SMC, XABIO	Reference to section, paragraph, line

Figure 4.23: Automatic rule-based checking of building designs (Eastman 2009)

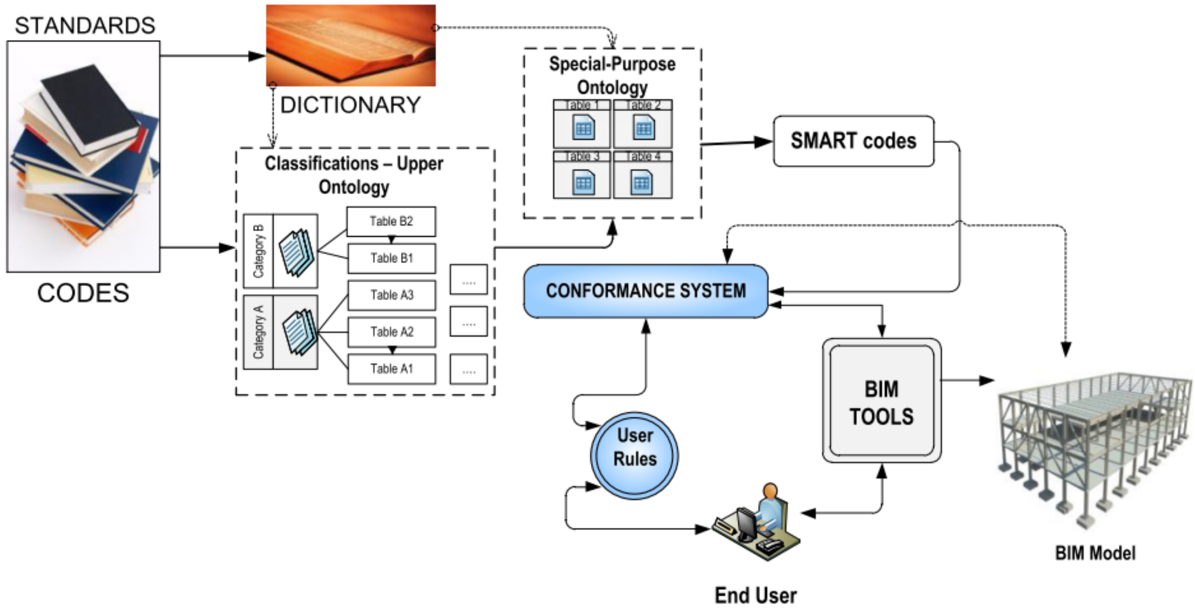


Figure 4.24: Structure of a BIM base rule checking system (Nawari 2012)

4.9 Better Cost Control

BIM through its ability to provide accurate quantity take off has an enhanced ability to contribute to real time project cost awareness. Using BIM it should be easier for contractors to estimate the fees necessary to undertake a contract. Using these methods different design options can be rapidly evaluated in terms of approximate costs. In the future new more efficient costing mechanisms are likely to be developed based on BIM. New processes such as target value design (TVD) which use BIM are now being adopted to reduce costs (Macomber 2013).

SMM7 (the standard method of measurement) and the new rules of measurement commonly used by quantity surveyors are not aligned to the output from BIM models. Further research is needed to optimize the BIM costing process.

4.10 Better Data and Information Transfer

Overcoming information transfer problems internally and externally is a critical element for architectural practice. It is these challenges that the interoperability provided by BIM sets out to address. BIM may not replace all hardcopy but BIM can operate as a totally electronic system. BIM has the ability to structure data making it possible to store, maintain and share without undue processing or effort. As more participants in the building development process use interoperable technologies the principles of Metcalf’s Law are likely to apply (see figure 4.25).

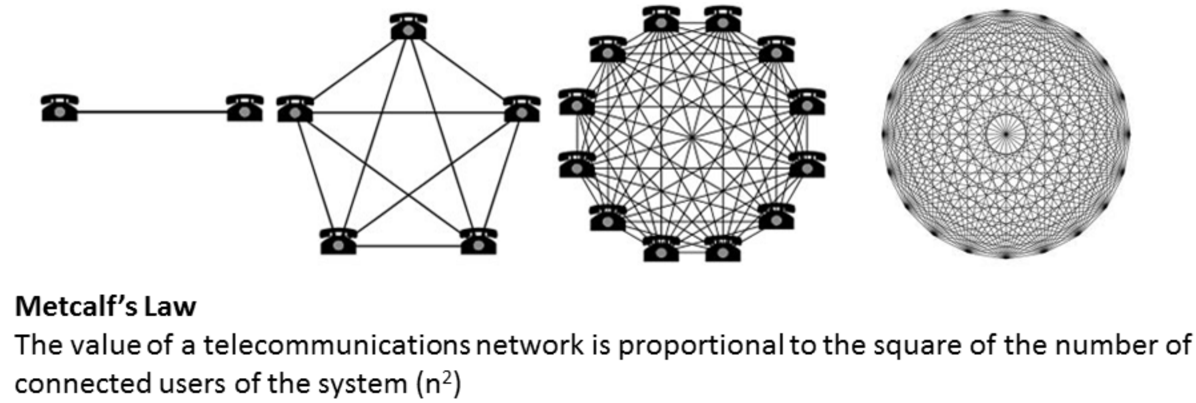


Figure 4.25: Metcalf's Law

4.11 Better Life Cycle Management

ISO 15686 is the ISO standard dealing with service life planning. Using BIM related data it is possible to manage and maximize the life cycle of both new and existing buildings. To develop a lifecycle information model (LIM) it has been suggested objects should be classified as proposed, decided, built or replaced (Hjelseth 2009). Existing buildings can be converted into BIM models with the assistance of laser scanning. Point clouds can now be taken into some BIM tools. This can then form part of the BIM information and BIM process.

Using BIM automation infrastructure lifecycle management can be assisted (see figure 4.26).

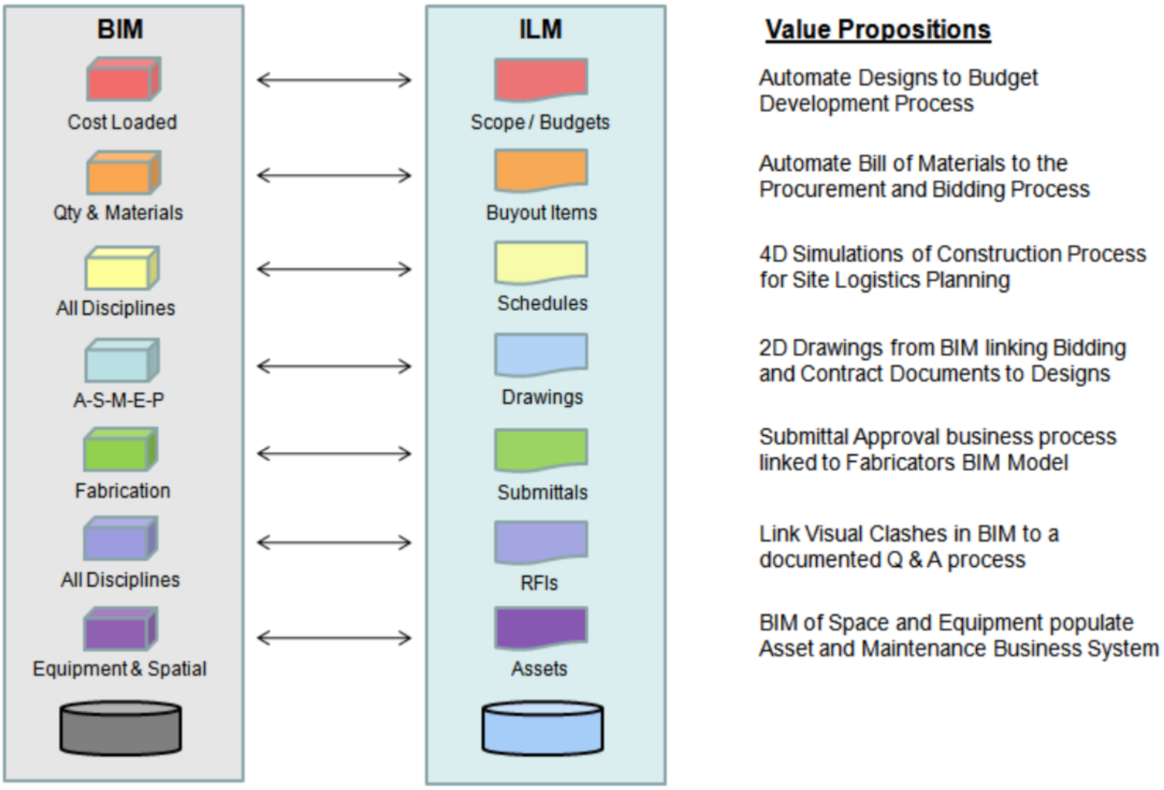


Figure 4.26: Using BIM automation to assist in the infrastructure lifecycle process (Meridian Systems 2008).

One approach is to store the lifecycle data in a separate database connected to the graphical database through and API (see figure 4.27).

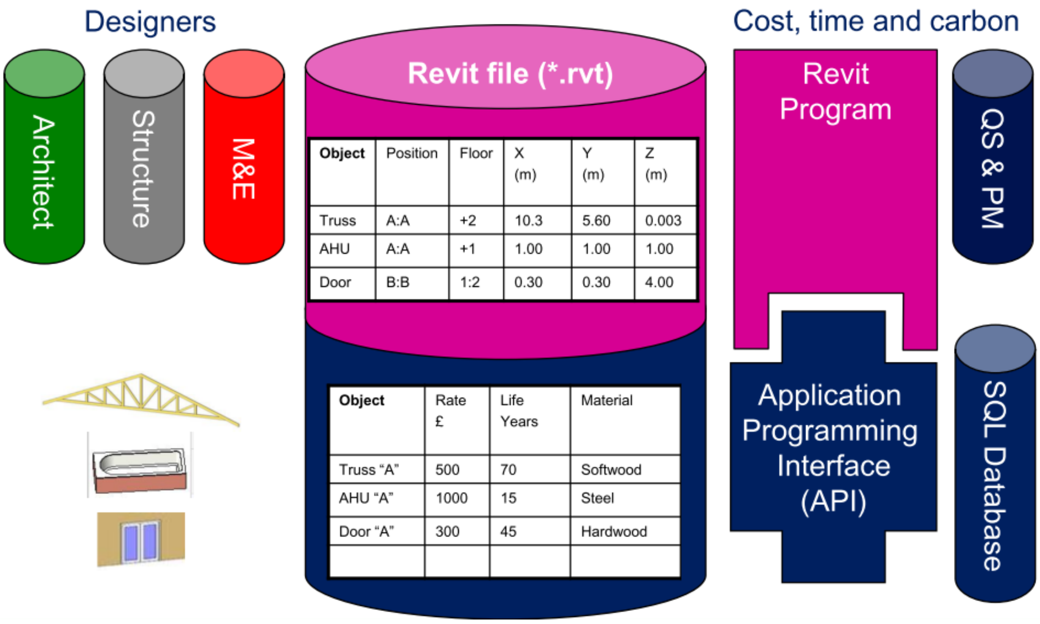


Figure 4.27: A BIM lifecycle costing system developed by Rider Levett Bucknall (Patchell 2012)

To address this problem and provide predicted and actual feedback from buildings development of a BIM mashup dashboard aggregating data from static and live sources has been suggested by the author (see figure 4.28).

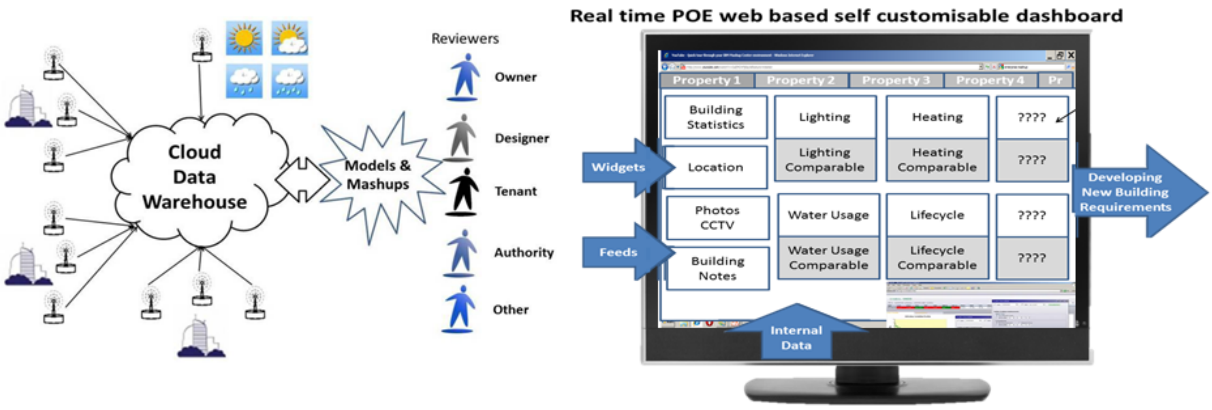


Figure 4.28: Provision of a predicted and actual feedback analysis dashboard (Coates 2010)

4.12 Summary of Chapter 4

In this chapter has set out to indicate some of the benefits of BIM. This text has not been exhaustive many other benefits can be achieved. But when implementing BIM the potential benefits should be considered and where possible a strategy should be set out to achieve those benefits.

Chapter 5

Chapter 5: This presents the research philosophy, approach, design and methods used to address the research aim and objectives outlined in Chapter 1. It explains the research methodology in detail and gives more information about the action research strategy used as a basis for developing this thesis.

CHAPTER 5 Research Methodology

5.1 Introduction

Research can be defined as the process of seeking, via varied methodological enquiries, solutions to problems, to add to the body of knowledge through significant insights (Herbert 1990). To achieve this, several of research methodologies are available. According to Collis and Hussey (2003) and Sridhar (2008) a research methodology is a systematic and orderly approach taken to the collection and analysis of data. Kerlinger (1979) states that research methodology represents the logical development of the research process to generate a theory. It will be shown that within the terms defined by Hussey and Hussey (1997) this research project sought to analyse, explain and create new knowledge, through mainly qualitative methods. Inductive reasoning was used to develop a new “improved” approach.

Saunders et al, (2007), describe the research process within a concept of a ‘Research Onion’ (see figure 5.01) that comprises different layers where each layer of the onion refers to a research approach which finally formulate the research process. The first layer considers the research philosophy, the second considers the research approach, the third examines the research strategy, and the fourth refers to the time horizon and the fifth raises questions of the data collection methods.

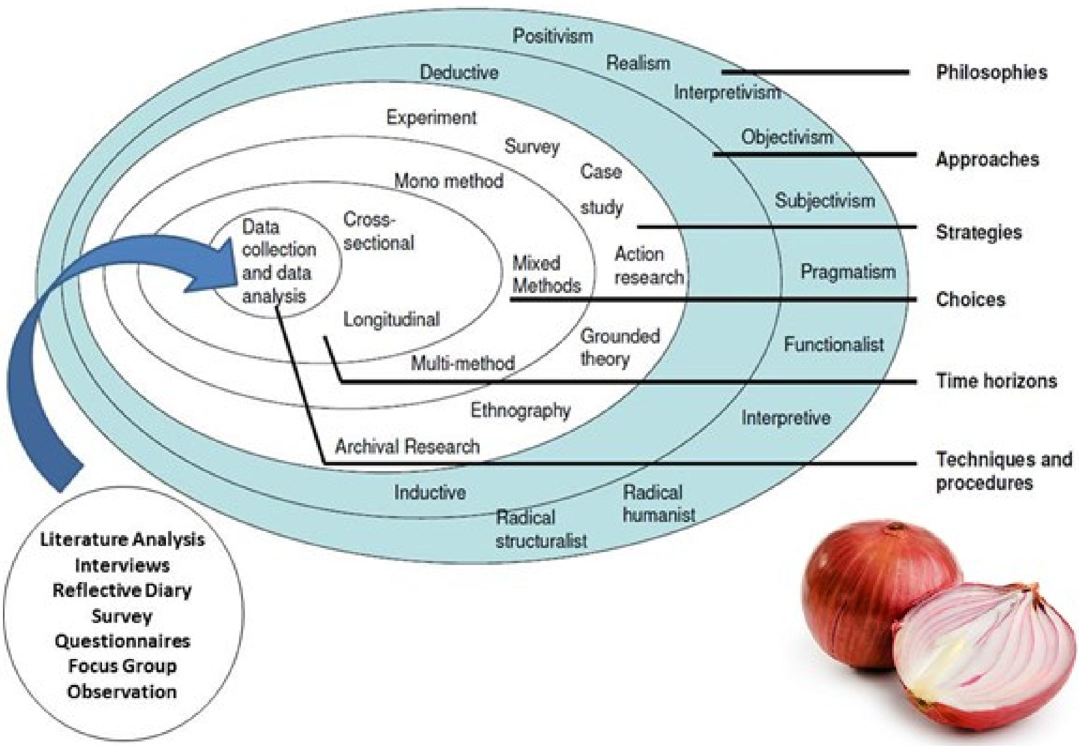


Figure 5.01: Research Onion (adapted from Saunders et al, 2006).

Research methodology in this study will be discussed in the axis of research onion. Other approaches were considered such as Crotty (1998), but the research onion approach seemed to provide for a wider range of considerations. Thus in the view of the author the research onion provides a better method of determining the approach to adopt. The choices made within this research in relation to the “Research Onion” are shown (see figure 5.02).

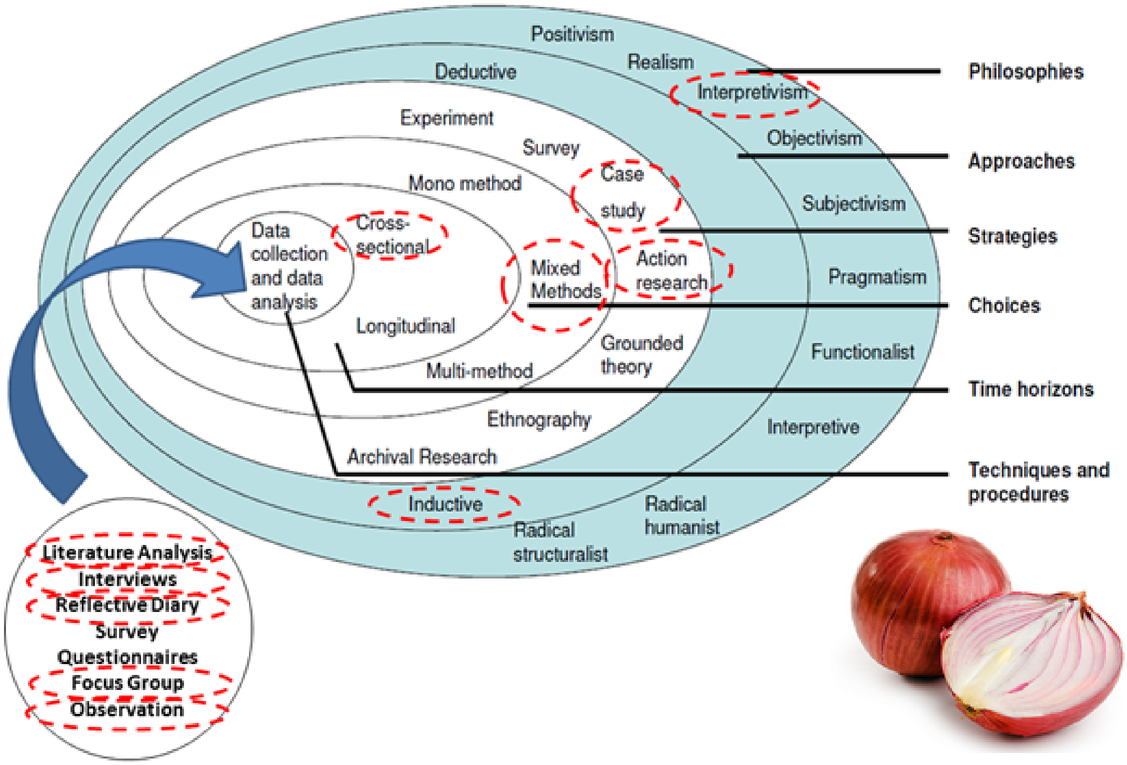


Figure 5.02: Research process for this study -Research Onion (adapted from Saunders et al, 2006).

The reasons and background for making such choices are set out in the following sections of this chapter.

5.2 Research Philosophy

The concept of research philosophy refers to the progress of scientific practice based on people’s views and assumptions. Philosophy can be defined as "the critical examination of the grounds for fundamental beliefs and an analysis of the basic concepts employed in the expression of such beliefs" (Encyclopaedia Britannica 2002). Saunders (2006) sets out the philosophies as positivism, realism, interpretivism, objectivism, subjectivism, pragmatism, functionalist, interpretive, radical humanist and radical structuralism (see figure 5.03).

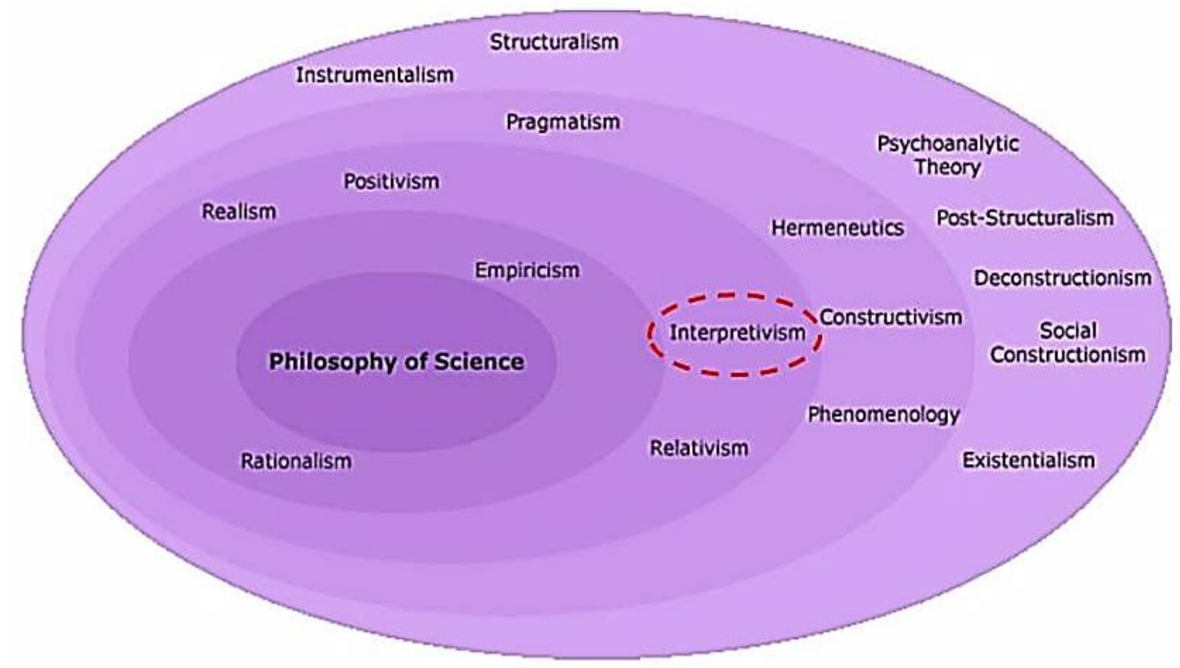


Figure 5.03 Philosophical choices for research (Lähdesmäki et al, 2010)

Positivism asserts that the only authentic knowledge is that which is based on sense, experience and positive verification. For this reason positivism is usually based on quantitative research. Positivism applies scientific reasoning and law-like generalisations in the process of knowledge construction (Remenyi 1998)

Realists tend to believe that whatever we believe now is only an approximation of reality and that every new observation brings us closer to understanding reality. The primary focus for the realist is first, to identify the underlying objects of research, which then helps to define the approaches that should be adopted; the approach is secondary. For the realist it is implied that, once we know what we are looking for, any number of approaches can be adopted and applied in different, novel ways; the target being to unearth the real structures and mechanisms within a particular research situation.

Objectivism is the notion that an objective reality exists and can be increasingly known through the accumulation of more complete information.

Subjectivism dominates qualitative methodology. It construes interactions between researcher and subjects (through interviews in particular) and the active interpretation of data -- which are central features of qualitative research -- as a license for the free exercise of subjective processes. The subject is free to express whatever subjective idea he or she desires, and the researcher is free to subjectively interpret data.

Pragmatism is founded, roughly, on the following hypotheses: that knowledge is a social phenomenon rather than introspective; that an object of knowledge must consider the conceivable effects upon our actions in order to conceive of the object in its entirety; that truth can only be found through on-going investigation, in which we check our experiences against one another; that truth is never complete, as the future is always uncertain and may alter a current truth; that all knowledge is primarily a call to action, wherein we recheck it, build upon it, or use it to shape our society; that all learning changes the world, for part of its effect will be causing us to act differently than had we not learned.

Structural functionalism is a broad perspective in sociology and anthropology which sets out to interpret society as a structure with interrelated parts. Functionalism addresses society as a whole in terms of the function of its constituent elements; namely norms, customs, traditions and institutions.

An interpretive paradigm is based on the view that people socially and symbolically construct their own organisational realities (Berger & Luckman, 1967). The Interpretive paradigm is based on two concepts a relativist ontology and a transactional or subjectivist epistemology. A relativist ontology assumes that reality as we know it is constructed inter subjectively through the meanings and understandings developed socially and experientially. Transactional or subjectivist epistemology - assumes that we cannot separate ourselves from what we know. The investigator and the object of investigation are linked such that who we are and how we understand the world is a central part of how we understand ourselves, others and the world.

In the radical humanist paradigm theorist are mainly concerned with releasing social constraints that limit human potential. They see the current dominant ideologies as separating people from their "true selves". They use this paradigm to justify desire for revolutionary change. It's largely anti-organization in scope.

In the radical structuralist paradigm, theorists see inherent structural conflicts within society that generate constant change through political and economic crises. This has been the fundamental paradigm of Marx, Engles, and Lenin.

The research philosophy adopted for this thesis is one of an interpretive paradigm and a paradigm of praxis. People have free will, purposes, goals, and intentions, so people should be studied as active agents. This implies a subjective epistemology and an ontological belief that reality is socially constructed. The central concept of “The Social Construction of Reality” is that persons and groups interacting in a social system form, over time, concepts or mental representations of each other's actions, and that these concepts eventually become habituated into reciprocal roles played by the actors in relation to each other. As such the social system can be seen as an enabler or impediment when new approaches such as BIM are being adopted.

5.3 Research Approach

The research approach is also referred to in the literature as research strategy (Jankowicz, 2000) or research method (Yin, 1994). According to Cresswell (2003) the selection of the research approach is critically important in allowing the researcher to meet stated objectives. Trauth (2001) suggests that the research problem should suggest the research approach.

"what one wants to learn suggests how one should go about it" (Trauth, 2001)

From an interpretivist perspective Trauth (2001) discusses the important factors in selecting research approaches and considers the important factors that affect researcher decisions regarding the research approach to adopt. She suggests these are as follows:

- The research problem
- The researcher's theoretical lens
- The degree of uncertainty surrounding the phenomena
- The researcher's skills
- Academic politics

Yin (1994) suggests that the following considerations should be taken into account when selecting the research approach.

- The nature of the enquiry and the type of question being posed
- The extent of the investigator’s control over actual behavioural events
- The degree of focus on contemporary events.

Holme, et al. (1996) identify three different, but overlapping, research approaches (Holme 1996): the analytical approach, the systems approach and the actors approach. To determine the research approach the work of Trauth (2001), Yin (1994) and Holme (1996) have been combined (see figure 5.04)

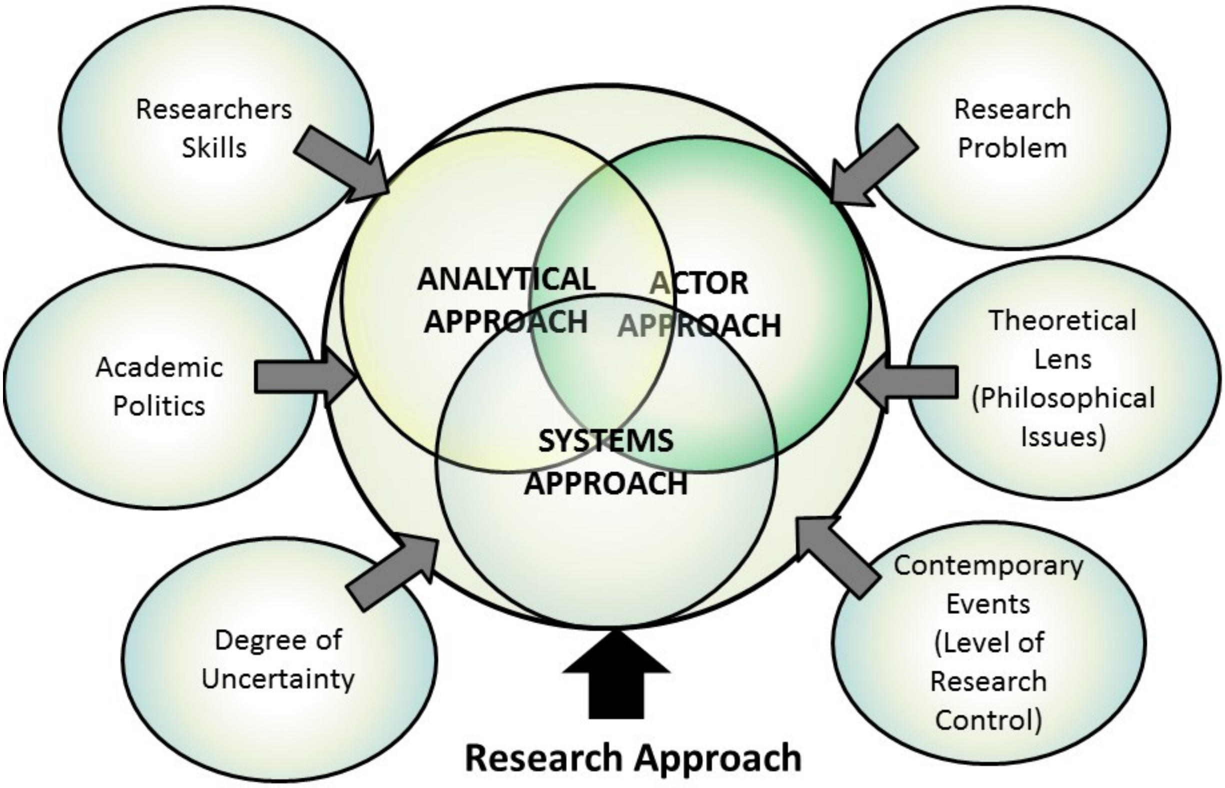


Figure 5.04: Factors affection the choice of research approach

In the analytical approach a studied object is divided into parts which are independently analysed and subsequently re-assembled to form a complete picture. The approach aims to find explanations and hard facts for the problems that are studied, using mostly logic and mathematics.

The systems approach relies on the notion that components interact with each other and are therefore studied in a complex environment, where the whole is prioritized. Components are described in their contexts in which the researcher interacts with the environment of the components and with the people involved. A picture of the system is subsequently developed and the components and their relations can be described and understood.

In the actors approach the focus is the deep understanding of social situations and human consciousness from the view of individual participants. There is no interest in explanations, rather in an understanding of the holistic expression of the present problems and phenomena.

The approach adopted to gain a greater understanding of BIM implementation was a systems approach. This systems approach was undertaken in the setting of John McCall Architects who were transitioning to BIM. This approach was adopted because BIM embraces the three elements of people, process and technology (Matta 2010).

The research approach can be inductive or deductive.

Deductive reasoning works from the more general to the more specific. Sometimes this is called the top down approach. The conclusion of this sort of research follows logically from the available facts. A deductive research approach is suggested to be suitable for scientific research, where the researcher develops a hypothesis, which is tested and examined to establish a theory (Hussey 1997).

Inductive reasoning moves from the specific observations to broader generalizations and theories. This sometimes is known as a bottom up approach. Conclusions are likely to be based on premises. This approach involves a degree of uncertainty. The conclusion of this thesis will use an inductive systems approach to take the specific observations made at John McCall Architects and then to develop broader generalizations.

5.4 Research Strategy

The research methods that can be used when adopting different research philosophies have been set out below (Galliers 1992) (Mingers 2003) (see table 5.01).

Research Philosophy	Mingers' (2003) Classification of Research methods	Galliers (1992) classification of research methods
Positivist	Observation (passive) measurements and statistical analysis	Laboratory Experiment
	Experiments	Field Experiment
	Survey, questionnaire, or instrument	Survey
	Case Study	Case Study
		Theorem Proof
		Forecasting
	Simulation	Simulation
Interpretivist	Interviews	Subjective/argumentative
	Qualitative content analysis	Reviews
	Ethnography	Action Research
	Grounded Theory	Descriptive/ interpretive
	Participant observation	Futures Research
		Role/game playing
Methods involving interventions	Action Research	
	Critical Theory	
	Consultancy	

Table 5.01: Research Philosophy and research methods (Adapted from Galliers 1992; Mingers, 2003)

The options for research strategy in the research to be adopted include, experiment, survey, case study, action research, grounded theory, action research and archival research. The range of research strategies and their interdependencies are set out (see figure 5.05).

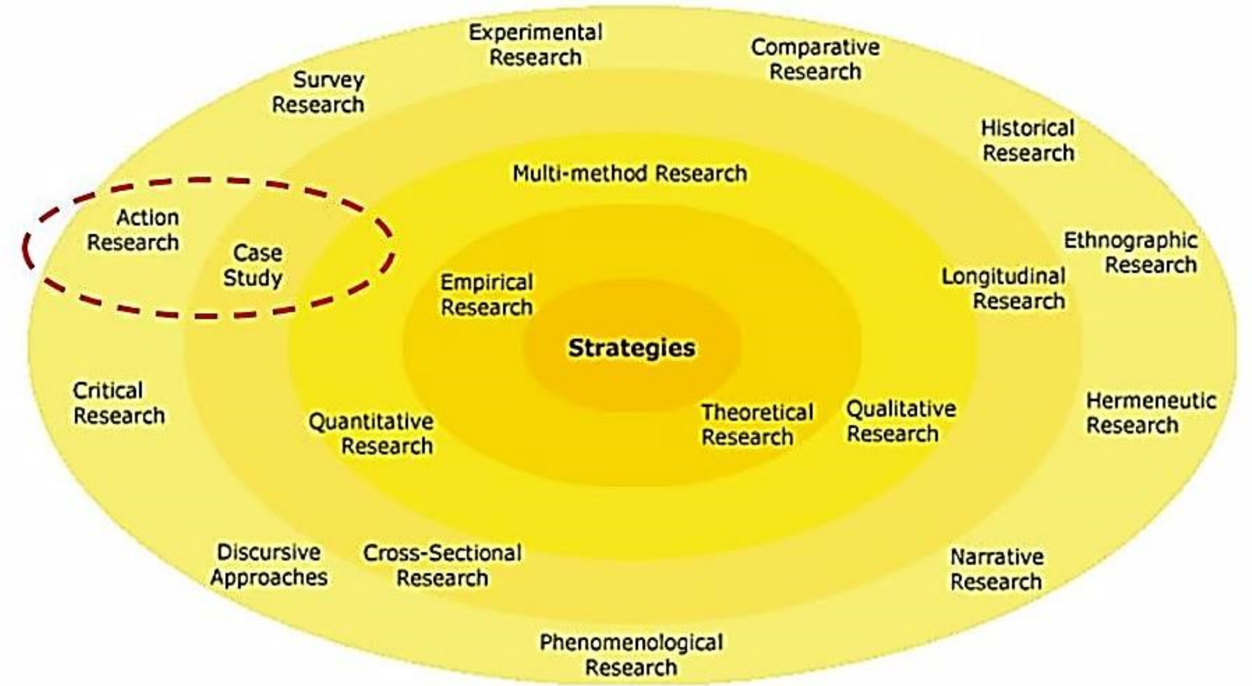


Figure 5.05: Possible Research Strategies (Lähdesmäki et al, 2010)

As part of the knowledge transfer partnership at John McCall Architects several of the different research strategies could have been applied. The adopted research strategy is action research strategy since the researcher actively participated and was the primary instigator in the whole process of the BIM implementation project. Action research is said to be especially suited to the study of change processes in a social context (Blichfeldt 2006). It is regarded as a reflective process of progressive problem solving. Furthermore, it is a comparative research on the conditions and effects of various forms of social action and research that uses a spiral of steps, each of which is composed of i) Diagnosis, ii) Action planning, iii) Action taken and iv) Evaluation. This is illustrated in figure 5.07 and 5.08. This is similar to the action research model put forward by Kuhne and Quigley (1997) even though other action research models do exist (Altrichter, Posch and Somekh 1993). Action research can be regarded as a process of unfreezing, changing and refreezing of form of practice (see figure 5.06, 5.07, 5.08)

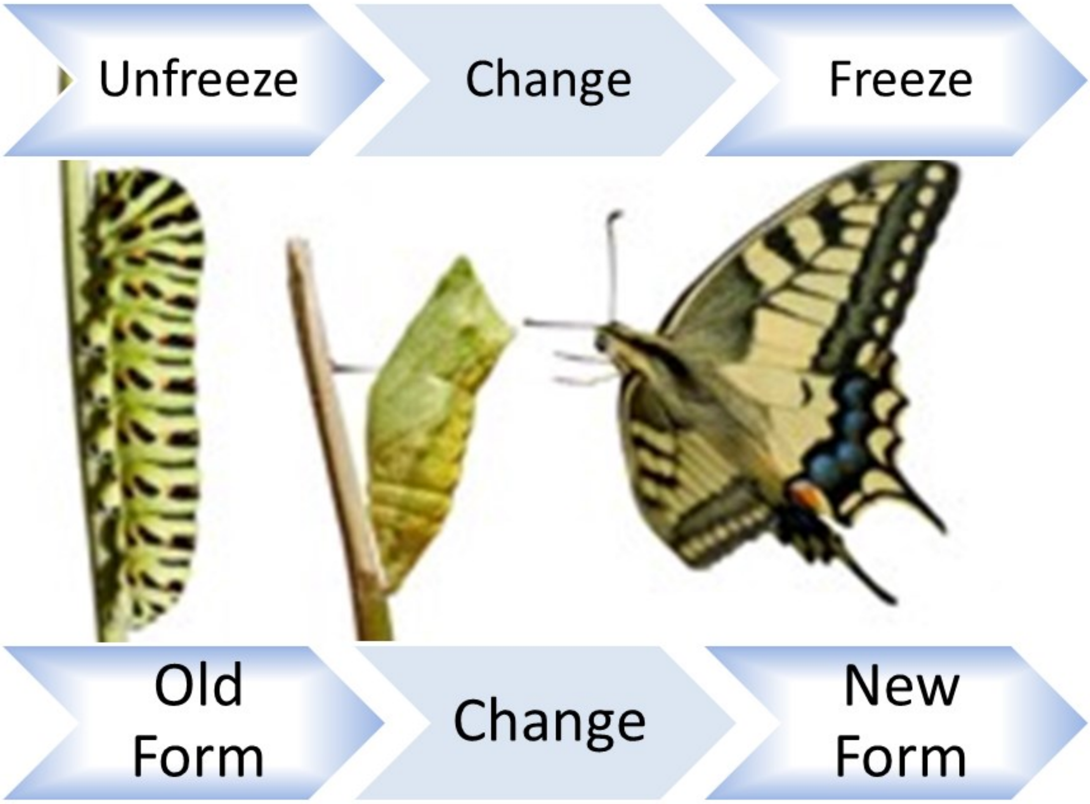


Figure 5.06: Action research as unfreezing, changing and refreezing in a new form

Figure 5.07: Action Research Cycle

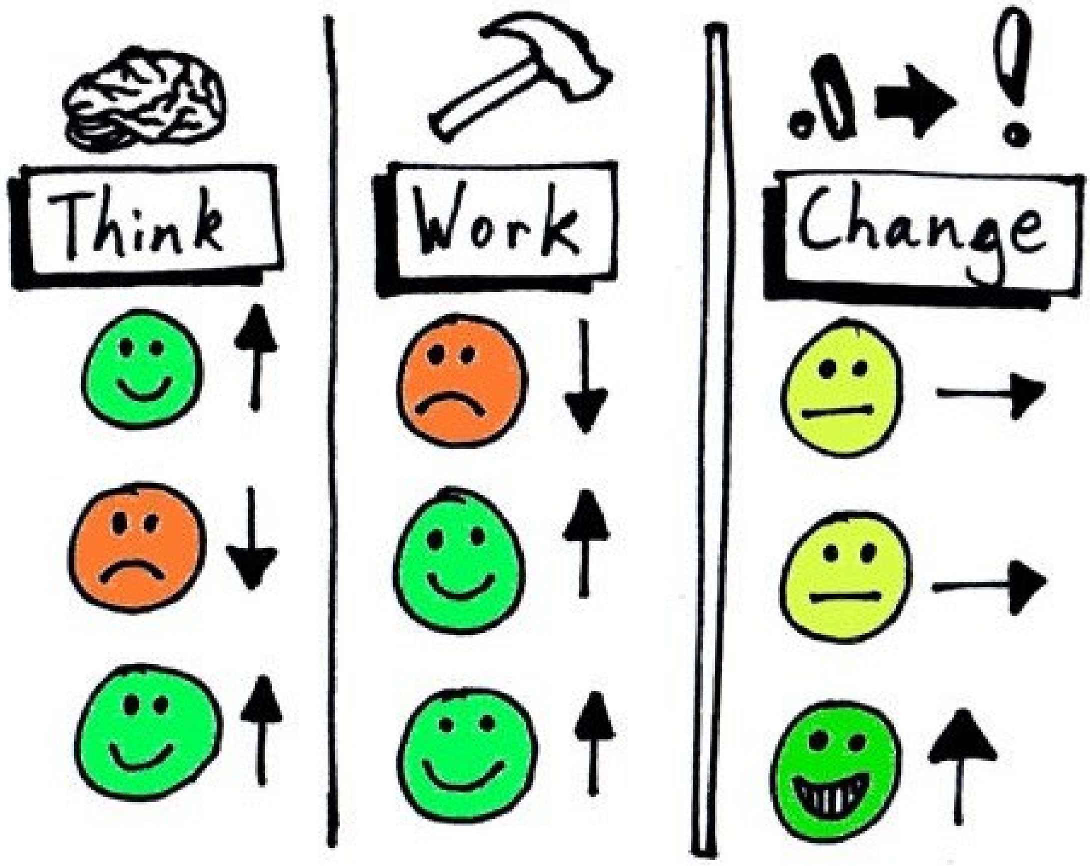


Figure 5.08: Action Research (Stephenson 2012)

Action research is an interactive inquiry process that balances problem solving actions implemented in a collaborative context with a data driven collaborative analysis or research to understand underlying reasons future predictions about personal and organisational change (Reason & Bradbury, 2007). Action research is especially useful in situations where participation and organizational change processes are necessary. (Baskerville & Pries-Heje 1999) Kaplan (1998) introduced a concept of innovation action research where researchers work with client organizations to enhance and test an emerging theory that has been pro-posed to improve organizational performance.

Action research is a participatory, democratic, process concerned with the development of practical knowing in the pursuit of worthwhile human purposes, grounded in a participatory worldview. It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people, (Reason and Bradbury 2006).

These action research steps in the cycle are opened up and described below:

Step 1: Diagnosis: This is where the background knowledge, rationale for research is built up via primary and secondary data sources. This step uses triangulation in data collection in order to increase the reliability and accuracy of the background knowledge required for the identification of a BIM Implementation Strategy Framework for small architectural practices in the next step. For example, broad spectrum of literature review, webinars, interviews, field trips, best practice projects are all carried out at this stage. Broad range of data collection at this stage is critically important for i) building up the contextual knowledge in BIM implementation, ii) justifying the research and its rationale for a BIM implementation strategy framework, iii) increasing the baseline understanding to be able to establish a best possible BIM implementation strategy framework for small architectural practices.

Step 1 corresponds to how to achieve Objective A, Objective B, Objective C.

Step 2: Action Planning: it is at this step where the initial identification and establishment of the BIM Implementation Strategy Framework is carried out. Using the information collected from the Diagnosis step, a generic framework of BIM implementation for small architectural practices is prescribed, which will form the hypothesis of the PhD research, by considering change management and requirements engineering techniques within the action research strategy such as Contextual Design Technique that covers varying work modelling syntax such as flow modelling, sequence modelling, artefact modelling, culture modelling, etc. The BIM implementation framework to be described at this step is considered to be comprehensive covering techniques and methods in subsequent phases including preparation, rolling-out and post implementation, of a BIM implementation project.

Step 2 corresponds to how to achieve Objective D

Step3: Action Taking: at this stage the researcher participated in case study project of actual BIM implementation for an architectural practice, which is considered a small architectural company based in Liverpool in the UK. In Step 3, the identified BIM implementation Strategy Framework is used for the actual BIM implementation project. This implementation covered many sequential activities from identifying the company's explicit and implicit need and requirements, review of current company practice, BIM systems, identification of efficiency gains, business process reengineering, piloting and testing of BIM systems, knowledge management, measuring and monitoring company capabilities over time and many others. The raw data gained by this action research was often in the form of documents, emails, minutes, charts, power point slides and model images. Many of these have been included in this thesis for better understanding of the key findings and outcomes from the research.

Step 3 corresponds to how to achieve Objective E

Step 4: Evaluation: in step 4, experiential learning from step 3 of the action research strategy is analysed and evaluated in order to master the initial BIM implementation framework for validation and propose it for other small architectural companies in the construction industry that need to adopt BIM to improve their company performance and practice. Evaluation step will use both qualitative and quantitative methods for analysing, mastering and validating the BIM Implementation Strategy Framework. Validation meetings took place with both company directors and academic advisors throughout the period of research. This enabled recent experience and finding to be review shortly after events. Where necessary the participants of those events were present at the reviews and contributed to the evaluation.

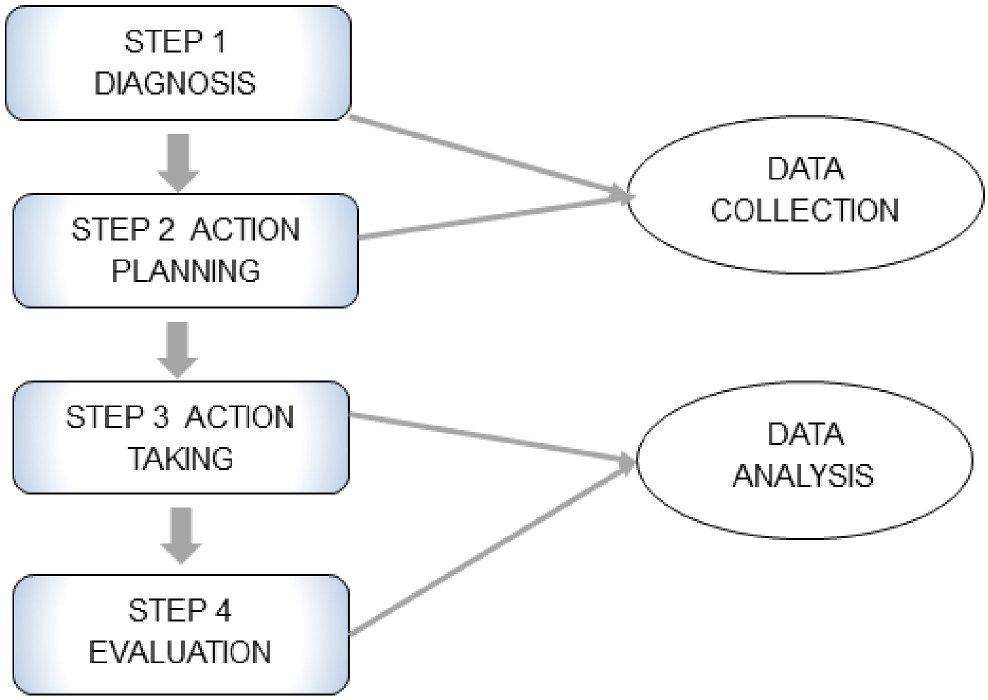


Figure 5.09: Research Process Design

There are two types of practice related research: practice-based and practice-led (Candy 2006):

- If a creative artefact is the basis of the contribution to knowledge, the research is practice-based.
- If the research leads primarily to new understandings about practice, it is practice-led.

Within this thesis there are element of both practice based and practice led research. But the major contribution is practice led research. Scholarly accounts of practice represent a powerful way to contribute to the knowledge base of architectural practice. Through the process of writing up this thesis and developing figures and diagrams a further understanding was achieved relating to the area of study. Journals and conference papers written as part of this research have also allowed further evaluation of the actions taken.

5.5 Research Process Design

4.5.1 Research Techniques for Data Collection

Many methods exist for data collection these vary in the level of involvement required by the researcher and the number of participants involved. The different methods applicable to socio technical issues and how they demand different levels of participation are illustrated (see figure 5.10 and 5.11).

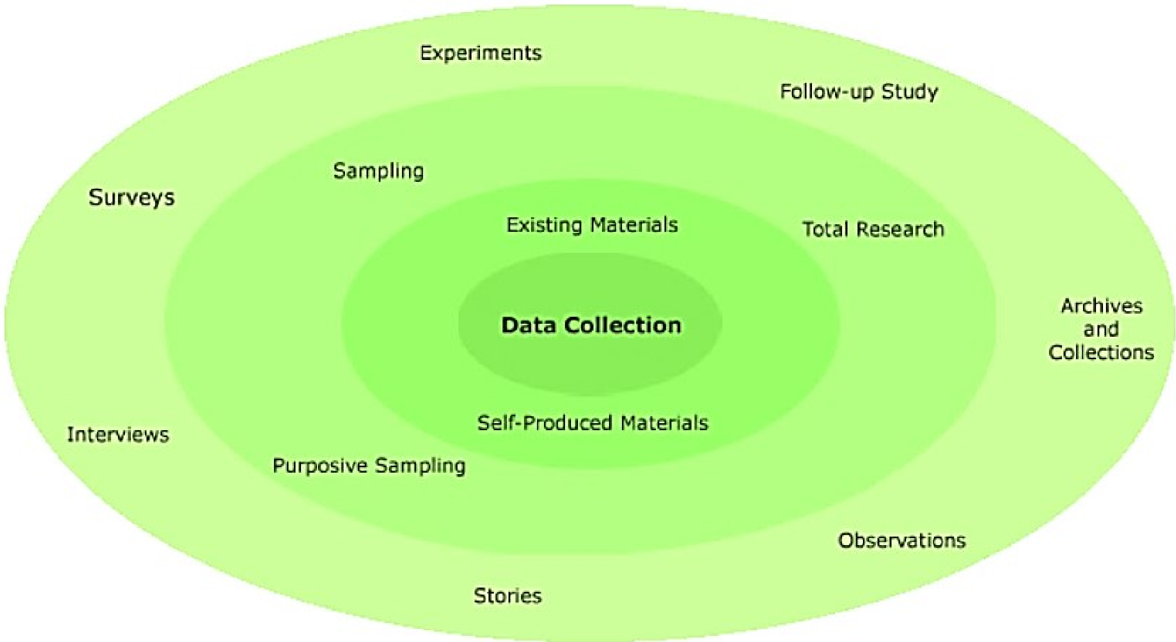


Figure 5.10: Possible Data Collection Strategies (Lähdesmäki et al, 2010)

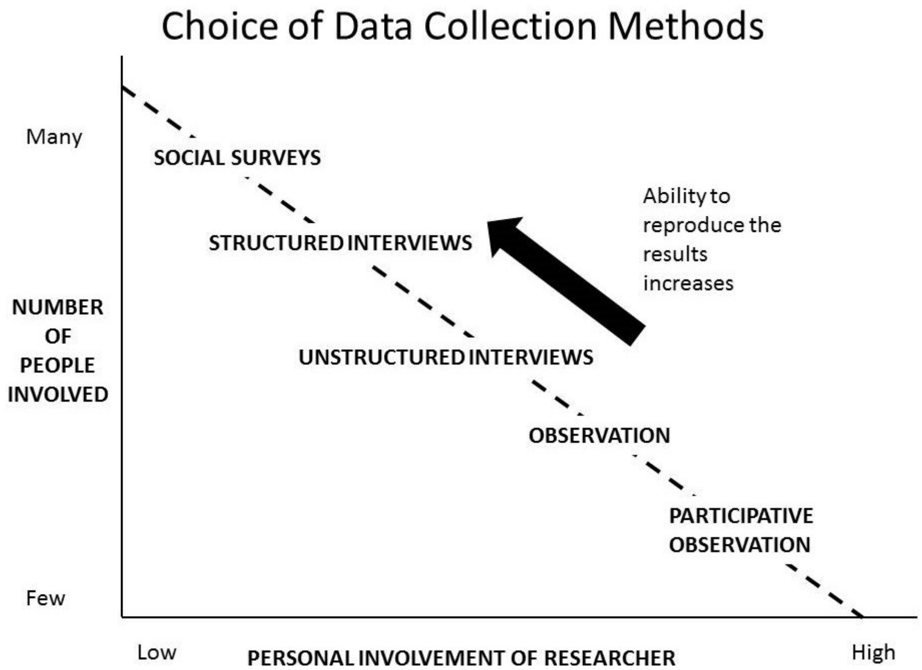


Figure 5.11: Choice of Data Collection Methods for social sciences (Sridhar 2008)

To establish the data required at the outset a knowledge review was undertaken (see figure 5.12).

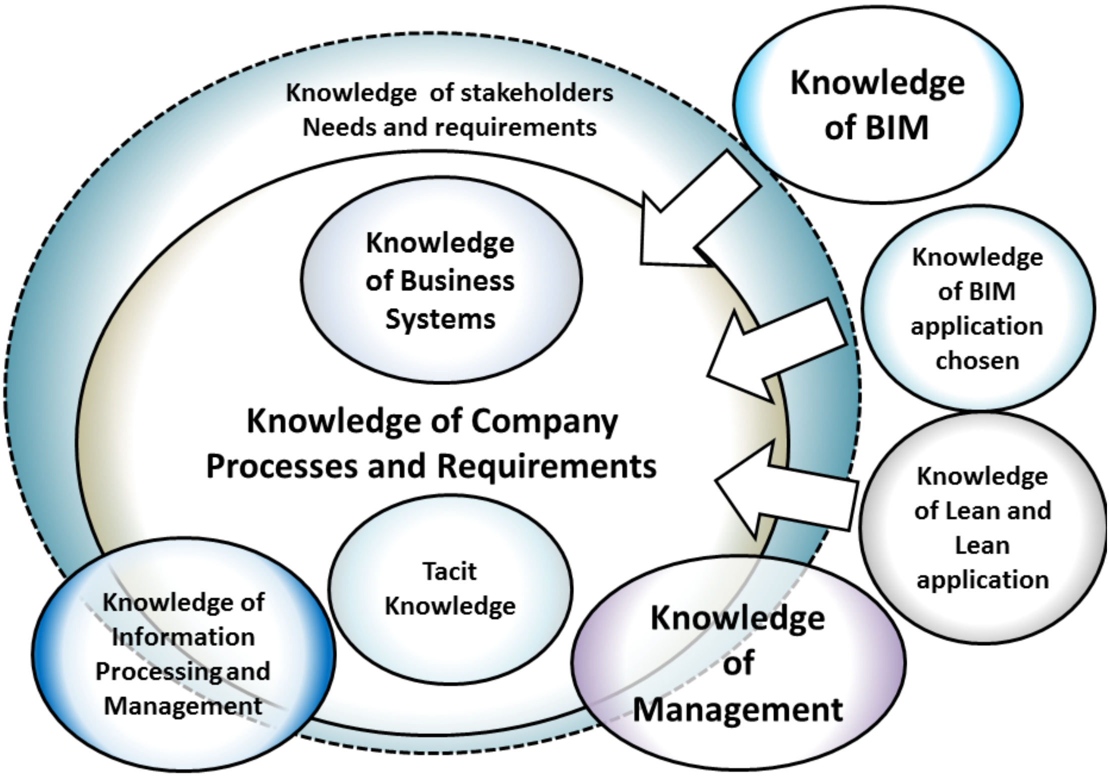


Figure 5.12: Knowledge Requirement Analysis diagram for BIM implementation

The knowledge review defines the areas of knowledge required and the interconnection and interdependencies of these areas of knowledge.

Having established the areas where knowledge was required and an analysis was undertaken on the best way to collect this knowledge. Verbal, visual, participatory and active methods of data capture was all considered. A knowledge acquisition analysis chart was generated to help in this approach (see figures 5.13 and 5.14).

Knowledge and skills that need to be developed to successfully complete the BIM			**Knowledge of Company Processes and Requirements**		
Knowledge Required	**Method of attaining**	**Date required**	**Completed**	**Type**	**Priority**
How to do process analysis	Read	03/03/2009	Yes	Verbal	5
Prepare questions to be asked	Doing	03/03/2009	Yes	Cerebral	5
Undertake staff interviews	Participating	03/03/2009	Yes	Participating	5
Observe working situation	Visual	03/03/2009	Yes	Visual	5
Discuss with University best method	Verbal	03/03/2009	Yes	Doing	5
Review results	Participating	03/03/2009	Yes	Participating	5

Figure 5.13: Example of analysis of Data and Knowledge Acquisition

	Input	Enabler	Output (Action Plan Objective)	Complexity	Cost	Time	Gain	Comment
1	Learning from Books	Purchase (Money), Time, Thinking	A good understanding of lean principles and its application	Low	Low	Medium	Medium	Books not on Architecture
	Learning from Best Practice	Reading books on Best Practice	A good understanding of lean principles and its application	Low	Low	Medium	Medium	Much best practice already in place
	Learning from others	Confererences (Money, Time, Thinking)	A good understanding of lean principles and its application	Low	High	Medium	Medium	New ideas, if right conference
	Learning by actions	Giving presentations and conferences (Money, Time)	A good understanding of lean principles and its application	High	High	High	High	Feedback from others
	Applying Lean Principles	Time. Research, methodology	A good understanding of lean principles and its application	High	Low	High	High	Cost low because part of KTP
	Learning by Writing	Write Conference papers (Time, research)	A good understanding of lean principles and its application	High	Low	High	Medium	Research Takes Time
2	Learning from Books	Purchase (Money), Time, Thinking	A good overall knowledge of BIM and associated applications	Low	Low	Medium	Medium	Not many books (field changes)
	Learning from others	Confererences, webinars (Money, Time, Thinking)	A good overall knowledge of BIM and associated applications	Low	Low	Medium	Medium	New ideas, Webinar often free
	Learning from others	Shadow in operational BIM office	A good overall knowledge of BIM and associated applications	High	High	Medium	High	Complexity in arrangement
	Learning by actions	Giving presentations and conferences (Money, Time)	A good overall knowledge of BIM and associated applications	High	High	High	High	Feedback from other
	Learning by Writing	Write Conference papers (Time, research)	A good overall knowledge of BIM and associated applications	High	Low	High	High	Research Takes Time
3	Undertake prototype project	Time , hardware, software	A hands on advanced user knowledge of one BIM application	Medium	Low	High	High	Valuable
	Learning from Printed Material	Time, money, not many books	A hands on advanced user knowledge of one BIM application	Low	Low	Medium	Medium	Only one book?
	Learning from others	Webinars	A hands on advanced user knowledge of one BIM application	Low	Low	Low	High	One cost effective way of learning
	Learning from others	Formal Training	A hands on advanced user knowledge of one BIM application	Low	High	Medium	High	Costly but effective
	Learning by teaching	Knowledge, format, setting, equipement, students	A hands on advanced user knowledge of one BIM application	High	Low	Medium	High	Requires existing knowledge base
	Learning by Writing	Writing BIM process plans	A hands on advanced user knowledge of one BIM application	Medium	Low	High	High	Requires time and Research

Figure 5.14: Deciding the best method to acquire knowledge

In many cases it was decided that undertaking soft system analysis was the best method of data and knowledge capture. Soft systems methodology (SSM) is a systemic approach for tackling real-world problematic situations. SSM treats the notion of system as an epistemological rather than ontological entity, i.e., as a mental construct used for human understanding. This has the potential to give an understanding of a specific organisation and the way that it operates.

To undertake this study the following methods of data collection were used:

- Literature Analysis
- Interviews
- Reflective Diary
- Focus Group
- Observation
- Participative Observation

5.5.2 Research Techniques for Data Analysis

The challenge of qualitative research is to make sense of the massive amounts of data, reduce the volume of information, identify significant patterns, and construct a framework for communicating to essence of what the data revealed (Patton 1990).

The options available for data collection are shown (see figure 5.15).

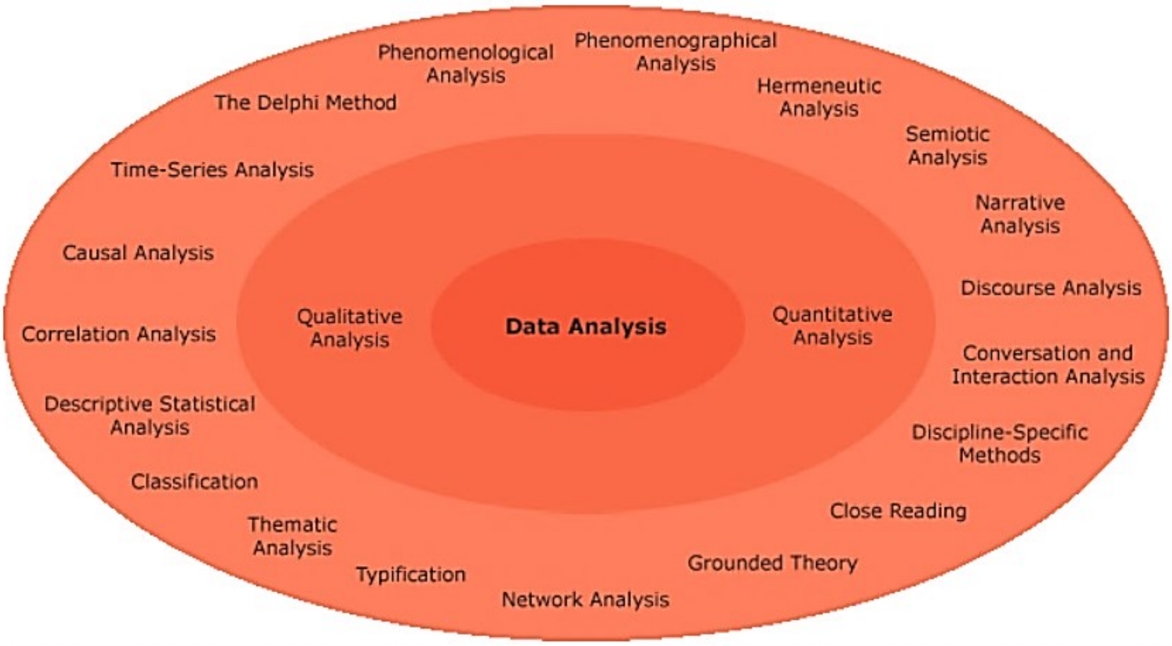


Figure 5.15: Possible Data Analysis Strategies (Lähdesmäki et al, 2010)

Once the data is collected there is a need for data analysis. Data analysis is a process of inspecting, cleaning, transforming, and modelling data with the goal of highlighting useful information, suggesting conclusions, and supporting decision making. The research undertaken for this thesis is predominately qualitative in nature.

De Vos (1998) states that when data collection begins the process of data analysis also begins. The process of sense making take place as the research starts to make sense of the setting (Morse and Field 1996). A stage of comprehension is reached when the researcher has enough data to be able to write a detail coherent and rich description.

Many data analysis techniques exist to review qualitative data. The basis process is indicated (see figure 5.16). This involves noticing things, collecting things and thinking about things. Using action research an iterative movement between data collection and continuous refining of interpretation can be instigated. This can be assisted by engagement of other participating within the BIM implementation process.

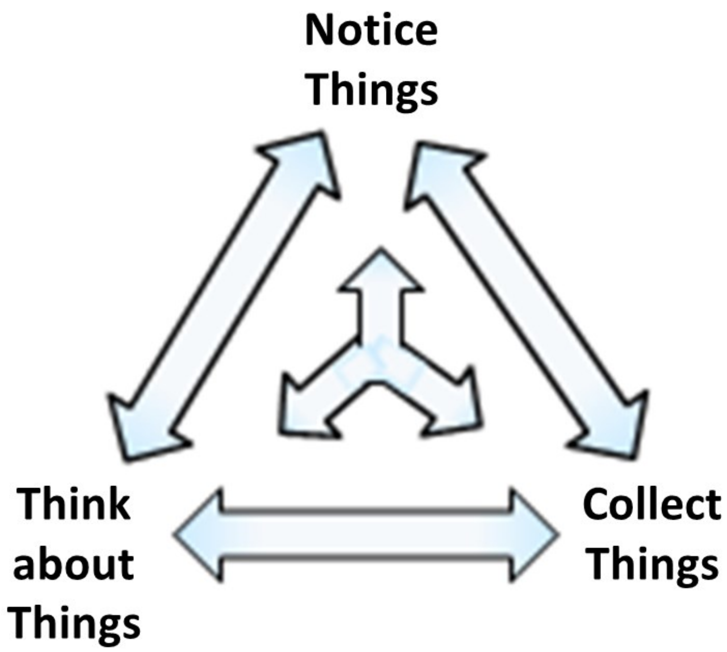


Figure 5.16: The Data Analysis Process (Seidel, 1998)

The approaches for qualitative data analysis include: typology, taxonomy, constant comparison, analytic induction, logical analysis, quasi statistic event analysis, metaphorical analysis, domain analysis, hermeneutical analysis, discourse analysis, semiotics, content analysis, heuristic analysis and narrative analysis. Of these forms of analysis for this research analytic induction, logical analysis, metaphorical analysis and heuristic analysis would seem to offer the potential for clear findings.

In analytic induction the process is one of looking at event and developing a hypothetical statement of what happened. Then look at another similar event and see if it fits the hypothesis. Logical analysis uses an outline of generalized causation with a logical reasoning process. This often results in flow charts and diagrams. In metaphorical analysis various metaphors are tried on to see how well they fit. In heuristic analysis the effect of the research on the researcher is evaluated.

A major element of sense-making adopted as part of this thesis was the use of visualization and externalization of concepts. To help decide the appropriate visualizations to adopt to address or clarify the task in hand the work of Eppler and Burkhard (2007) was referred to (see figure 5.17).

KM Process / **Formats**	Creation	Codification	Transfer	Identification	Application	Measurement	Marketing
Structured Text / Tables		✓✓	✓			✓	
Mental Images Stories	✓		✓✓		✓✓		✓✓
Heuristic Sketch	✓✓		✓		✓		
Conceptual Diagram	✓	✓✓	✓				
Image / Visual metaphor	✓		✓✓				✓✓
Knowledge Map	✓			✓✓			✓✓
Interactive Visualization	✓✓				✓✓		

Figure 5.17: Visualization formats for different knowledge management tasks

(Eppler and Burkhard 2007)

5.6 Ethical Considerations

Denscombe (2005), states the general research ethics principles as respect for the rights of those being researched and, specifically, the duties of researcher with regard to privacy, confidentiality, anonymity and informed consent. The researcher will carefully consider all these principles throughout the research.

In this research an ethical approval form was submitted to John McCall Architects the company which provided the material for the development of this research.

5.7 Introduction to the case study company

John McCall Architects (the case study “small” architectural practice) was established in 1991 in Liverpool in the UK. John McCall Architects Limited was registered at companies house on 30 Mar 2000 with its registered office in Merseyside.

The company has been involved in architecture and construction designing buildings throughout the Northwest of England.

The company lists its services as architecture, master planning, conservation, eco design and CDM (Construction Design and Management regulations). Additional services at John McCall Architects include landscape design, interior design and estate regeneration. Focusing primarily on social housing and regeneration, private housing and one off homes and large extensions, the company is known for good quality, economical, environmentally sustainable design. Historically the company has designed many houses for individuals but this is regarded as less profitable than undertaking the design of housing estates.

It is typical for John McCall Architects to have an involvement in projects from early feasibility to handover of the completed building to the client. Projects in which John McCall Architects are involved are typically of 2½ years duration, involving many stakeholders and requiring considerable transfer of documentation and dynamic information. The majority of projects undertaken at John McCall Architects are fee earning projects but architectural competitions are undertaken from time to time if they are deemed in line with the practices design ethos.

John McCall Architects shortly before the initiation of the BIM implementation had become certified under the ISO 9001 Quality Management scheme. For ISO 9001 certification procedures and standards for working practices had been developed. These were accessible to all staff in the company with access to the computer network through the company intranet. The ISO 9001 standard requires the company to maintain certain documents relating to:

- Control of Documents
- Control of Records
- Internal Audits
- Control of Nonconforming Product / Service
- Corrective Action
- Preventive Action

The company is audited by external auditors against these procedures on an annual basis. Adapting these procedures in line with BIM methodologies was one of the considerations as part of the BIM adoption at John McCall Architects. The company had also recently participated in the investors in people scheme now administered by the UK Commission of Employment and Skills. The development and interaction of people is an important element of BIM and BIM adoption.

A major proportion of John McCall Architects clients are housing associations although they undertake a range of work. The images shows the wide range of projects typical of those undertaken by John McCall Architects (see figure 5.18). The projects include extensions, single homes, housing estates, flats, old people's homes, housing refurbishments, interior design, single stand-alone buildings and unitized buildings.

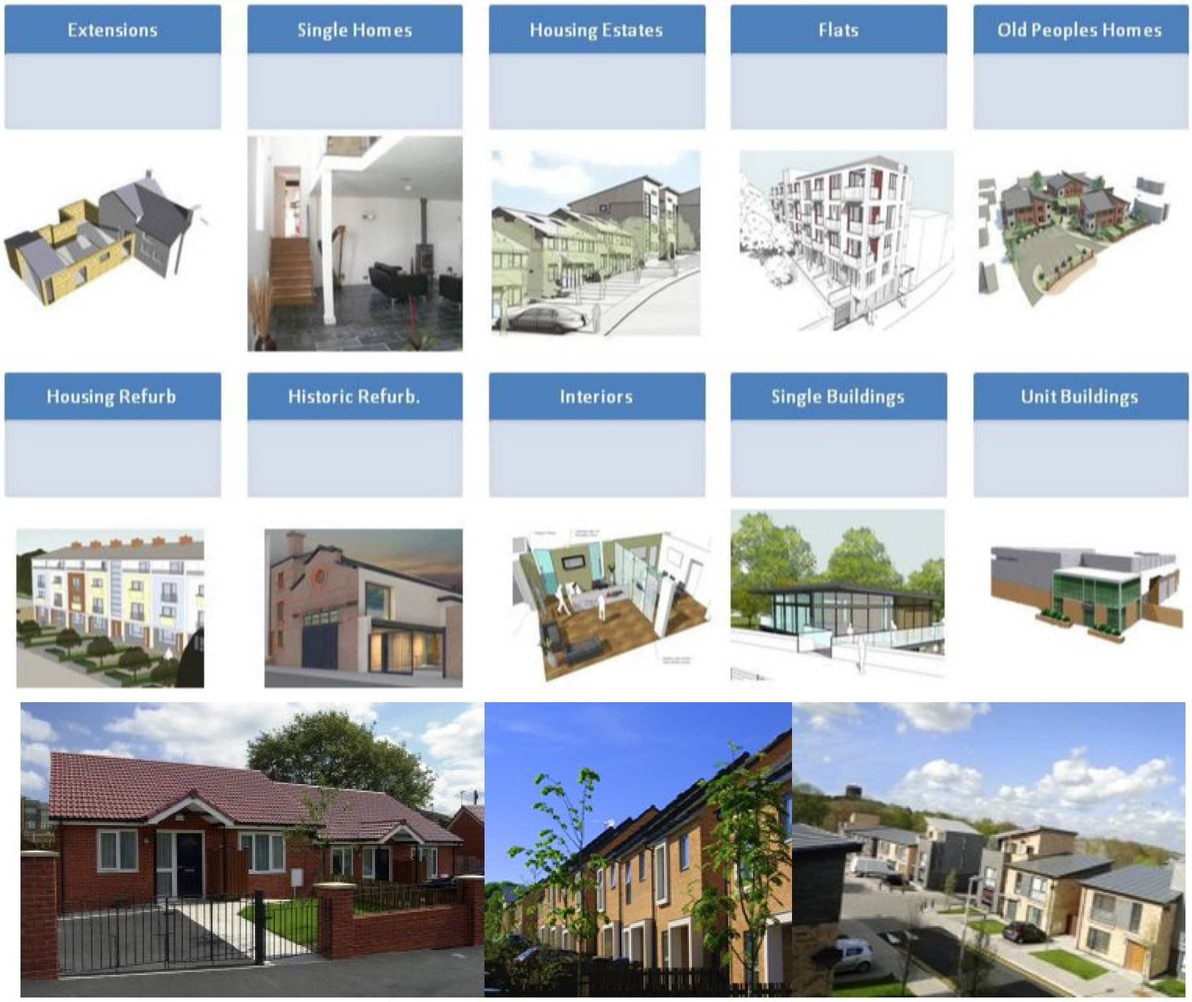


Figure 5.18: Projects typical of those undertaken by John McCall Architects Project

It is envisaged that in the fullness of time all the project types from new build to historical refurbishment will be produced using BIM at John McCall Architects.

The organisational structure adopted at John McCall architects is shown (see figure 5.19). Basically the three architectural directors each manages a team of six architectural staff. This means that the company is maintained at about 20 members of full time staff.

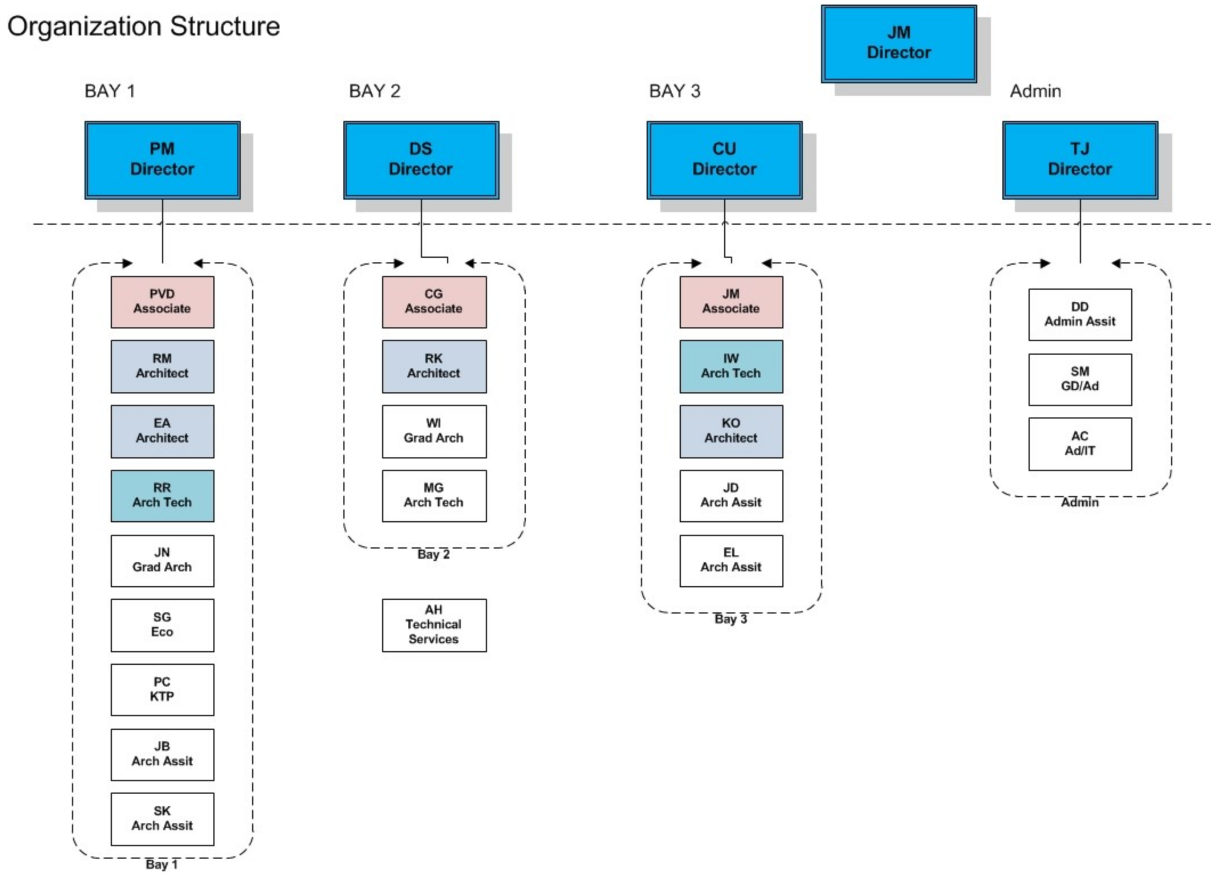


Figure 5.19: Example of the existing organisation structure at John McCall Architects

During the period of the BIM implementation there were also members of staff at John McCall Architects specifically addressing Code Assessment (sustainability) and Health and Safety Issues. This is indicative of the increasing importance of sustainable issues and health and safety issues within architectural practice.

The founder John McCall was in the process of transferring his directorship to four new directors in the practice. This is perhaps gave the drive to adopt new ideas such as BIM into the practice. Historically John McCall Architects was one of the first architectural practices to adopt CAD (the predecessor of BIM) in the early 1990's. This had given the practice an advantage at that time. This earlier advantage from new technology may also account for the practices enthusiasm to adopt BIM.

Each architectural project undertaken at John McCall Architects was administered by a project architect with supervision and management input from an associate and a director (see figure 5.20). Architectural technicians in some cases supported the project architects. Projects also had allocated administration, graphic design and IT support.

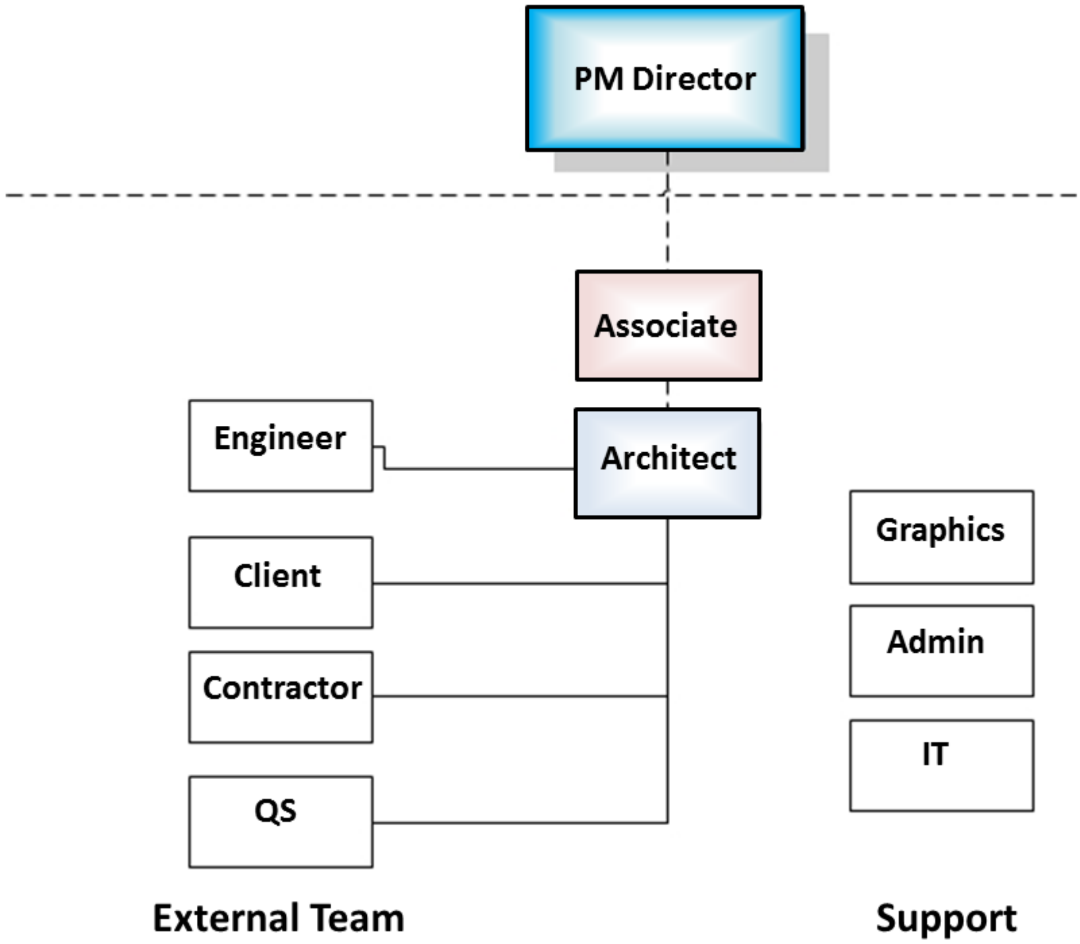


Figure 5.20: Example of the staffing structure to undertake an Architectural Project

5.8 The legacy systems at John McCall Architects

Project administration at the start of the research period was undertaken using a system of hard copy files. These contained letters and other correspondence. As a discreet project an electronic document management system was instigated in the company during the period of research.

Sometimes hand drawn sketches were produced at John McCall Architects but drawing boards were not used. Experiments were also tried out to see if BIM models could be made to look like hand drawn sketches.

The IT infra-structure adopted at John McCall Architects was on of a hard wired Ethernet network linking pc computers to a NAS (Network-attached storage) drive data server (see figure 5.21). A local wireless network was being considered in the conference room area. There was some discussion within John McCall Architects whether to adopt cloud computing but this was not adopted at the time the research was undertaken.

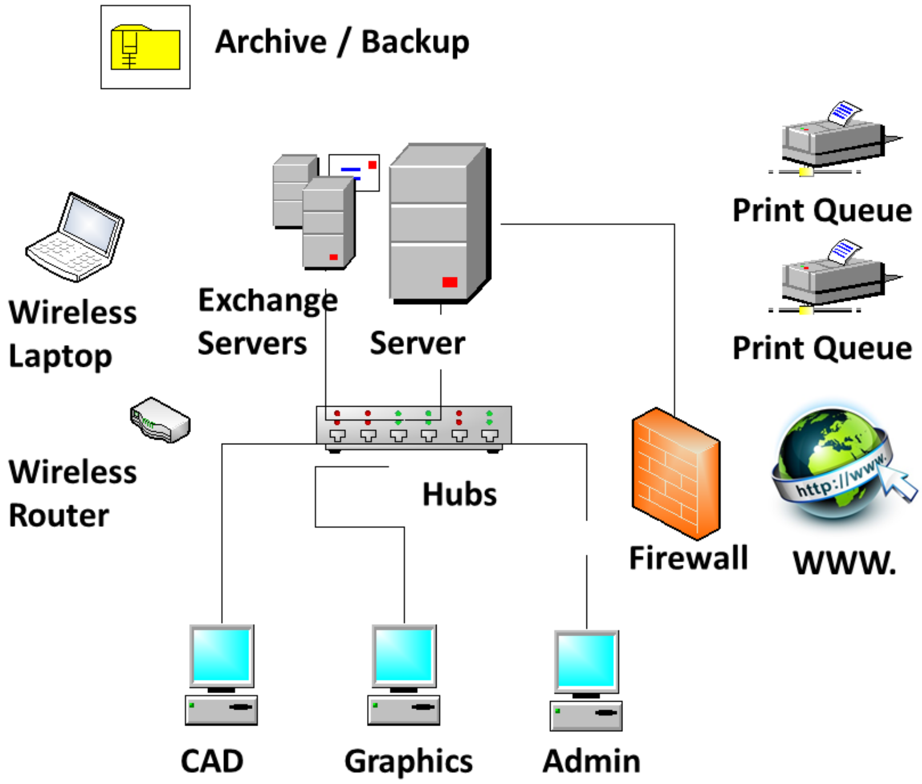


Figure 5.21: Network diagram for John McCall Architects

The pc workstations were loaded with both CAD and MS Office tools running on a Microsoft windows operating system. Sketchup, a free or low cost building modelling software was also loaded onto some machines and was used from time to time for early design studies. Since the time of the case study Sketchup has been purchased by Trimble as part of their Design Build Operate Suite. It seems likely that the BIM capabilities of Sketchup will be further developed (see figure 5.22).

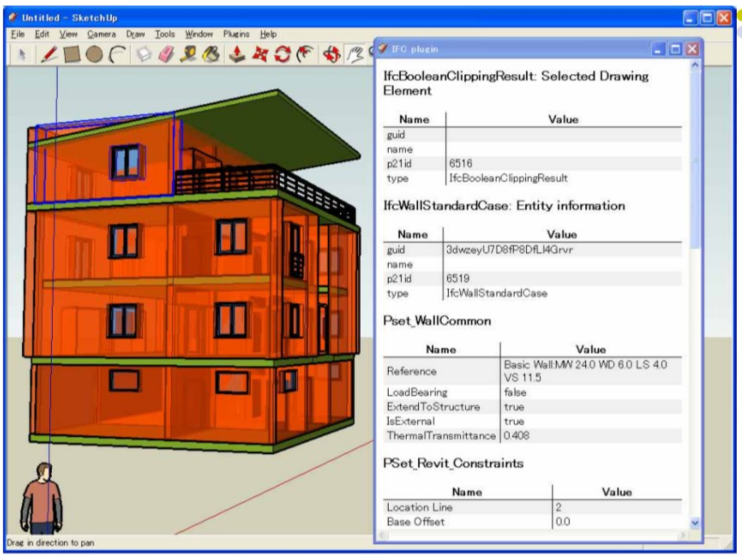


Figure 5.22: Sketchup software demonstration IFC capabilities using the IFC2SKP plugin

Adobe Photoshop was also a software tool regularly used in the office. This is used to make photo montages and amend images. The most powerful PC's in the practice were allocated for photo editing and rendering. To create presentational images Photoshop software was often used to save time as opposed to creating the surrounding buildings as 3d models.

The ability to use the software varied between different members of staff. But the expectation was that staff should be CAD literate and be able to create drawings, documents and write emails. The open plan nature of the office enabled the easy transfer of architectural knowledge and computer related skills between the members of staff. The IT system was managed by a computer manager assisted by various service level agreements for IT equipment. A service contract was also in place with an external computer management company.

The computer aided design system used at John McCall Architects was Microstation V8 and PowerDraft both running on a windows operating system on a PC platform. Both Microstation and PowerDraft are products marketed by Bentley Systems. PowerDraft is a professional-level application used for production 2D/3D drafting and detailing but has a reduced functionality when compared with Microstation V8. This range of capabilities of Microstation V8 is reflected in its higher price. PC based Bentley Microstation is a system which had been used by the practice since its inception in 1991. A Microstation consultant was also employed from time to time to offer assistance and expertise to the company. Microstation customisation was also supplied at a cost as required.

The critical issue with Microstation as a CAD package is the fact that currently it only comprises about 5-10% of the architectural software market in the UK. Mostly Microstation is used in the larger architectural practices and engineering organisations. Microstation is used for a wide range of project types, not just architectural projects. Microstation has a vast amount of tools available to expedite free form modelling for architectural projects. This has meant that the software has many features that are not necessary in the architectural process for projects such as housing. This also means that the software has a larger than necessary learning overhead.

Different CAD packages although they tend to be icon based use different words and icons to describe similar concepts and unique concepts also exist (see figure 5.23). This leads to difficulty when it is necessary to learn or use alternate CAD authoring software.

Microstation	AutoCad
Element	Object or Entity
Level	Layer
Attributes	Properties
Cells	Blocks or Wblocks
Active Design File	Drawing File or Drawing Database
Reference Files	Xref or Reference Files
Seed Files	Prototype or Template File
Drop	Explode
Active	Current
Tags	Attributes
Fit	Zoom Extents
Window Area	Zoom Window
Fence	N/A – closet match is the Selection Window Crossing
Pattern	Hatch

Figure 5.23: A comparison of terms commonly used in Microstation and AutoCAD, AutoCAD being the most widely adopted CAD software (Aarhus 2005)

The typical WIMP (windows, icon, mouse, pointer) is used by Microstation software (see figure 5.24). Using a square approach as shown to develop the elevations allows the sizes of the elevations to be coordinated. Often a ground or first floor plan is referenced central to the square and the elevations are worked on through rotated view or viewports. Such complexities are not necessary when elevations are generated from a central BIM model.

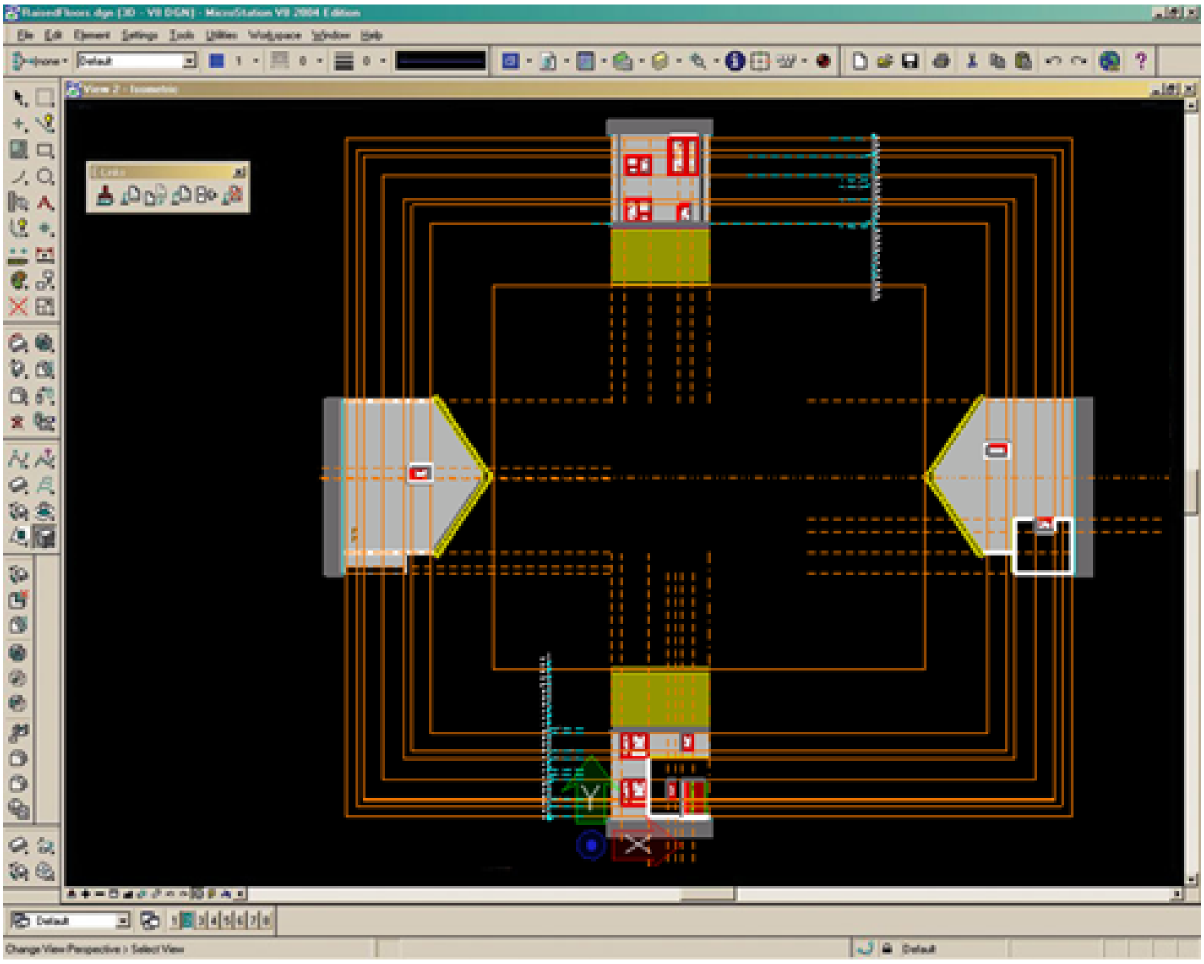


Figure 5.24: A typical Microstation V8 interface showing the development of coordinated housing elevations

Microstation and PowerDraft were predominately used by the architects, architectural technicians and architectural assistants within the organisation. PowerDraft does not include the following functionalities;

- Advanced rendering (Luxology)
- Animation
- Schedule Simulation
- Batch convert
- Batch Processing (this is particularly beneficial when plotting multiple files)
- 3D solid model tools (construct or modify)
- Feature Solids
- Parametrics and Dimension driven design (DDD)
- Mesh tools

The primary deliverables produced by the practice were 2d drawing sets for planning applications, building control submissions and construction drawings for tender. These were typically printed out on A1 sized sheets. Early design work was often undertaken in Sketchup.

Although object attributed data (data attached to objects) is possible in Microstation cells (objects) this was not a feature that was used at John McCall Architects. Standard libraries for rooms, furniture and title blocks had been developed. Using attributed objects or cells as they are known in Microstation automated scheduling also becomes possible. The major frustration when using Microstation seemed predominantly to be around the need to translate .dgn formats to .dwg formats when issuing electronic files to other disciplines. This is because external disciplines predominately use Autodesk software which uses .dwg as its native format. A work around for this problem were proposed (see figure 5.25) but not accepted as some of the Microstation functionality would have been lost if the solutions had been adopted. One consideration was to adopted a BIM system where such issues did not represent a problem. (This did not prove possible).

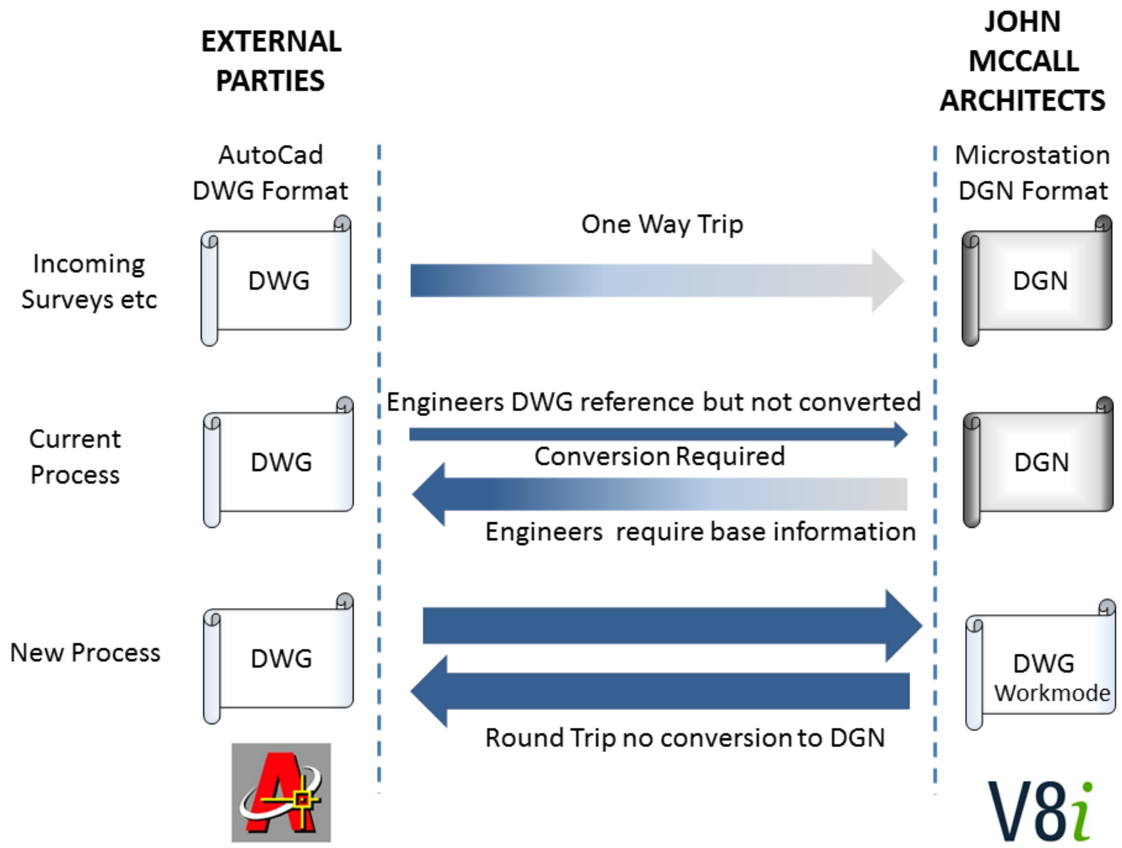


Figure 5.25: Methods of changing John McCall Architects file format to remove the task of file translation

Project specifications were also a major deliverable and another potential area of liability. This is a document defining the work and materials necessary to undertake a building project and the standards of workmanship required. The specifications were produced by the architectural technicians in the office. The National Building Specification (NBS) is the most common specification provider in the UK. But it was not used at John McCall Architects. Using NBS incurs a cost of about £1000 per year. Practice developed specifications were preferred. (Undertaking specifications in this way incurs an element of risk).

At John McCall Architects a range of peripheral devices were available such as scanners, colour printers and high speed large format laser printers and projectors. Investment in a large AO laser printer was also used to offset external printing costs. The advantages of using “print at point of use” was also investigated as another spinoff of the research being conducted. On projects undertaken some distance from the practice this would have enabled drawings to be generated at a location closer to the recipient.

A major task of any architectural company is knowledge management. Many regulations and standards apply to the housing designs produced by John McCall Architects. These standards change over time. This is particularly true for part L of the building regulations relating to the conservation of fuel and power. This raises the importance in the practice of developing models that can be tested for heat loss and sustainability. It is important that new up to date knowledge is shared throughout the practice. About a third of the staffs time is spent dealing with sustainability related issues. (An important element is to ensure that the objects and BIM assemblies used are updated to ensure they comply with the latest standards and regulations.) John McCall Architects maintained a limited library of books and standards as part of their knowledge management regime within the practice. This was supported by an educational programme which typically took place on Friday afternoons.

The workspace / office itself consisted of an open plan studio on the first floor of a converted warehouse. An open plan office space facilitated staff management and control. A meeting room and administration office and print room were located on the ground floor. The archiving was stored in the basement but this was not ideal because of the potential risk of flooding. The office was located a short distance from Liverpool town centre and the river Mersey.

5.9 The case study company financial status

Over the period of research John McCall architects experienced difficult market conditions (see figure 5.26). In such a climate it is difficult to justify investment in people process and technology. This represented a major impediment to overcome when justifying the investment necessary to undertake BIM adoption. (The cost of a single BIM software varied at the time of research between £3500 and £4000.) This is at a time when student staff, were on minimum wages. Staff wages were also being reduced and pensions withdrawn at the time the research was being undertaken. The change to the use of BIM alone may not be enough to make any company profitable and healthy in such market condition.

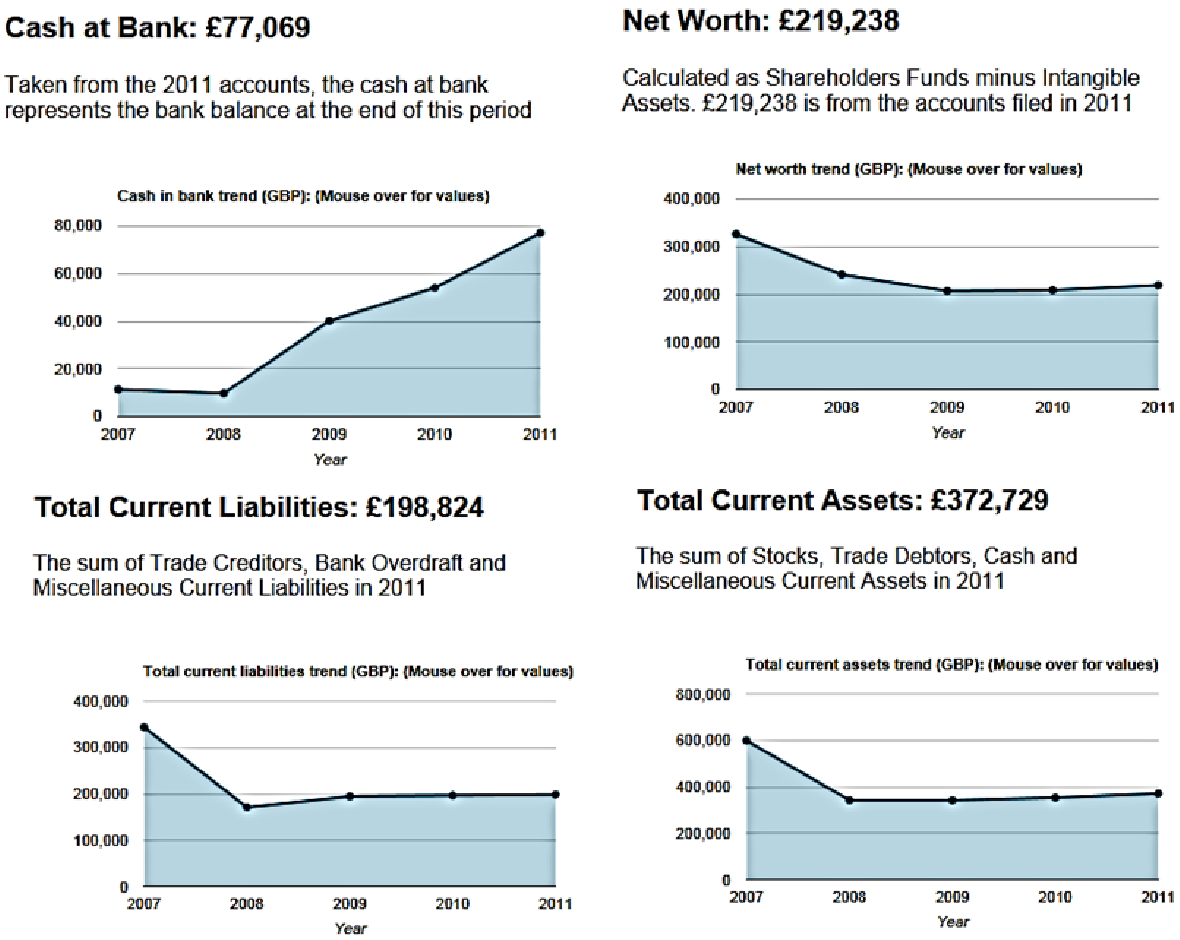


Figure 5.26: John McCall Architects, cash in the bank, net worth, current liabilities and current assets up to 2011 (Companycheck 2012)

The company has assets totalling £341,125 plus total liabilities totalling £183,475. They owe £169,657 to creditors and are due £215,803 from trade debtors. As of their last financial statement, they had £19,115 in cash reserves. Their book value is £157,650, and the value of their shareholders' fund is £157,650.

5.10 Summary of Chapter 5

The purpose of this chapter was to describe the research methodology of this study, explain the sample selection, and the selection of procedures used. The reason for selecting interpretivism as the philosophical base and action research as the approach were illustrated. The methods of data collection were also determined and the method of data analysis discussed. This chapter also provides details concerning the case study company John McCall architects where the action research was conducted. The rest of this thesis will focus on the actual research undertaken and the findings related to the research.

Chapter 6

Chapter 6: This establishes an initial BIM implementation strategy framework that proposes an approach for BIM adoption at a strategic level. The framework also provides well prescribed roadmap of BIM implementation at operational level. This chapter aims to provide a context for the later chapters where the BIM implementation at John McCall Architects is documented.

CHAPTER 6 Initial BIM Implementation Framework

6.1 Introduction

When the decision is made to adopt BIM in a practice, the question then becomes what is the best way implement BIM. This adoption involves a range of activities, skills and essential decisions. This chapter sets out to the initial framework used for BIM adoption in a small architecture practice.

The core benefits of BIM adoption were already highlighted in chapter 4. These benefits to some extent offset the initial implementation costs (see section 3.4).

When implementing BIM in an architectural practice, it is important that the benefits that are possible are fully realized for that practice.

Also it is important that the resources (financial and human) allocated to the implementation achieve the maximum return for the efforts they make. If this return on efforts is to be achieved a structured and managed approach must be adopted to BIM implementation.

BIM adoption is one aspect of organisational change, reengineering and business improvement. These areas of business change are not unique to architectural practice or the construction industry. As such current practices in change management and organisational re-engineering are considered and how they should be applied in the case of implementing BIM.

Central to a successful BIM adoption is an understanding of what a particular architectural practice does (diagnosis of what they do and the issues they need to address). Different architectural practices operate in different ways which often relate to the type of projects they produce and the client organisations they serve. With an understanding of the existing operation, the new tools and processes can be aligned in a bespoke fashion to maximise the return on investment.

Expectations of BIM adoption needs to be understood planned for and delivered. When developing a BIM implementation framework it is important that it is based on sound project management principles and established business reengineering approaches. Enterprise architecture approach, the process of translating a business vision and strategy into effective operation is considered as part of this research and lessons are taken from this approach. Change and improvement as part of BIM adoption is achieved by considering business, data, application, technology and organisational change.

Bringing about change in a controlled way draws on many skills. Also there is need for the early and informed involvement of all stakeholders. The time spent on planning change management elements of project is critical to the successful outcome of the BIM adoption.

First the change management structure for BIM adoption should be defined. Following from this a review of the individual activities and tasks needs to be undertaken to achieve the necessary deliverable. Thus a process of management by objectives as put forward by Drucker (1955) can be achieved. The deliverables and milestones related to the goals and objectives can be defined.

There are generic issues related to bringing about organisational change within small companies, which should be noted and considered. The business process engineering approach can be used for BIM implementation. Alternative possible business reengineering approaches are reviewed in relation to the specific issues of small architectural practices and the optimal approach selected. The BIM implementation framework used as a pilot for action research is documented. Then the findings at each stage of this research are recorded. Taking all of these findings an improved BIM implementation strategy is then developed.

6.2 BIM implementation in the context of enterprise architecture

The adoption of new technologies into existing industries occurs in all industries from time to time. Practices that do not adapt can no longer remain as viable business concerns. The practice of architecture raises specific issues and problems. For example one issue peculiar to architectural profession and the creative industries is the non- linear nature of iterative design.

To develop a strategy framework, similar endeavours within different sectors are considered. The most common approach that is adopted in several forms is that of enterprise architecture solutions. The development of this approach over time is shown (see figure 6.01).

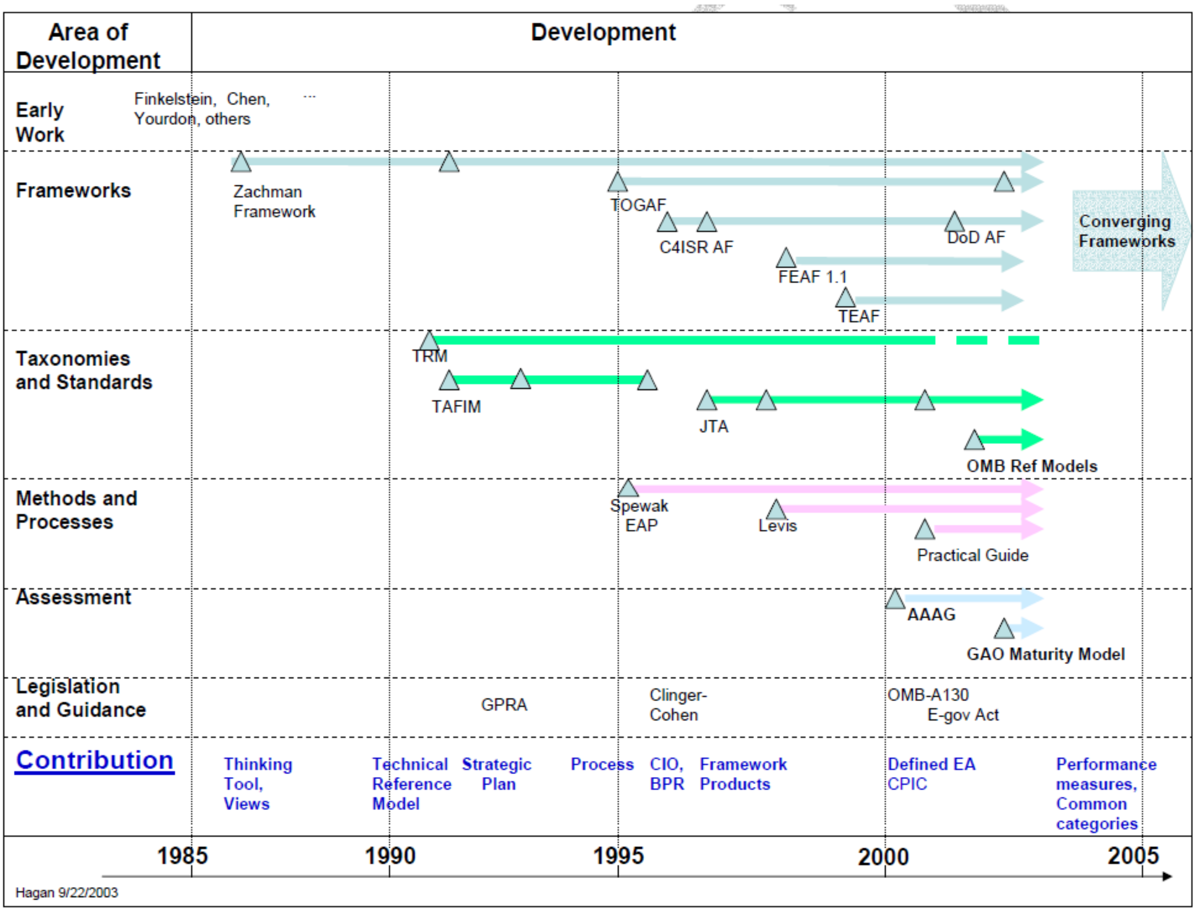


Figure 6.01: Major developments in the history of enterprise architecture (Hagan 2004)

Enterprise architecture (EA) is not a term regularly discussed within architectural practice. Training in such areas is outside the normal remit of architectural training and most management education. The purpose of EA is to align organizational strategy, business processes, information technology hardware and software, and IT spending. The planned structure document for an EA solution is defined in an EA Framework (also known as Architecture Framework). This framework contains many required design documents (e.g. data models, dashboard specifications), business models (e.g. organizational charts), covers multiple perspectives of the enterprise (application tier/perspective, information tier/perspective, technology perspective), and defines the required EA output activities also known as artefacts (see figure 6.02).

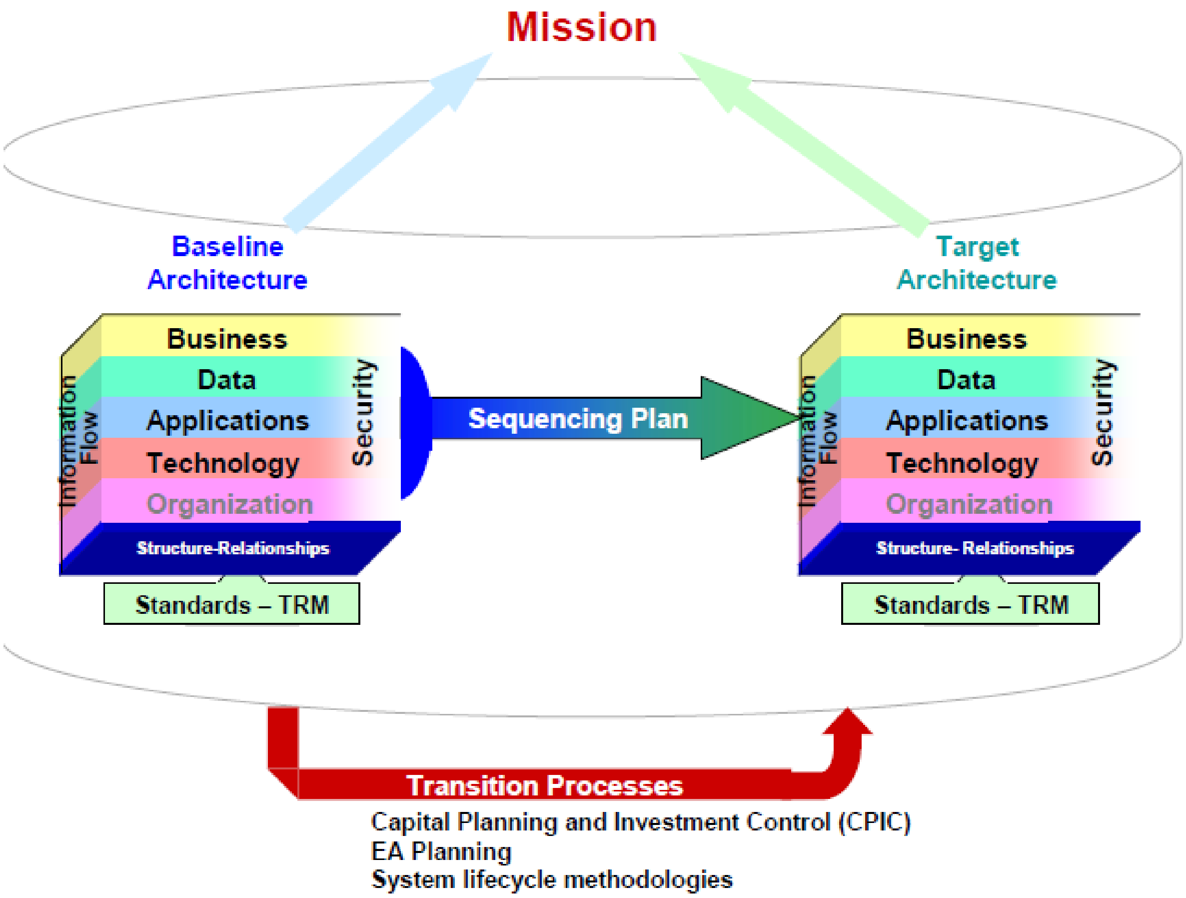


Figure 6.02: How business may change to improved enterprise architecture (Hagan 2004)

The adoption of BIM should be seen as part of a wider adoption of an appropriate EA within an architectural practice. The data exchange with BIM should be set up if an enterprise system is to be developed (see figure 6.03).

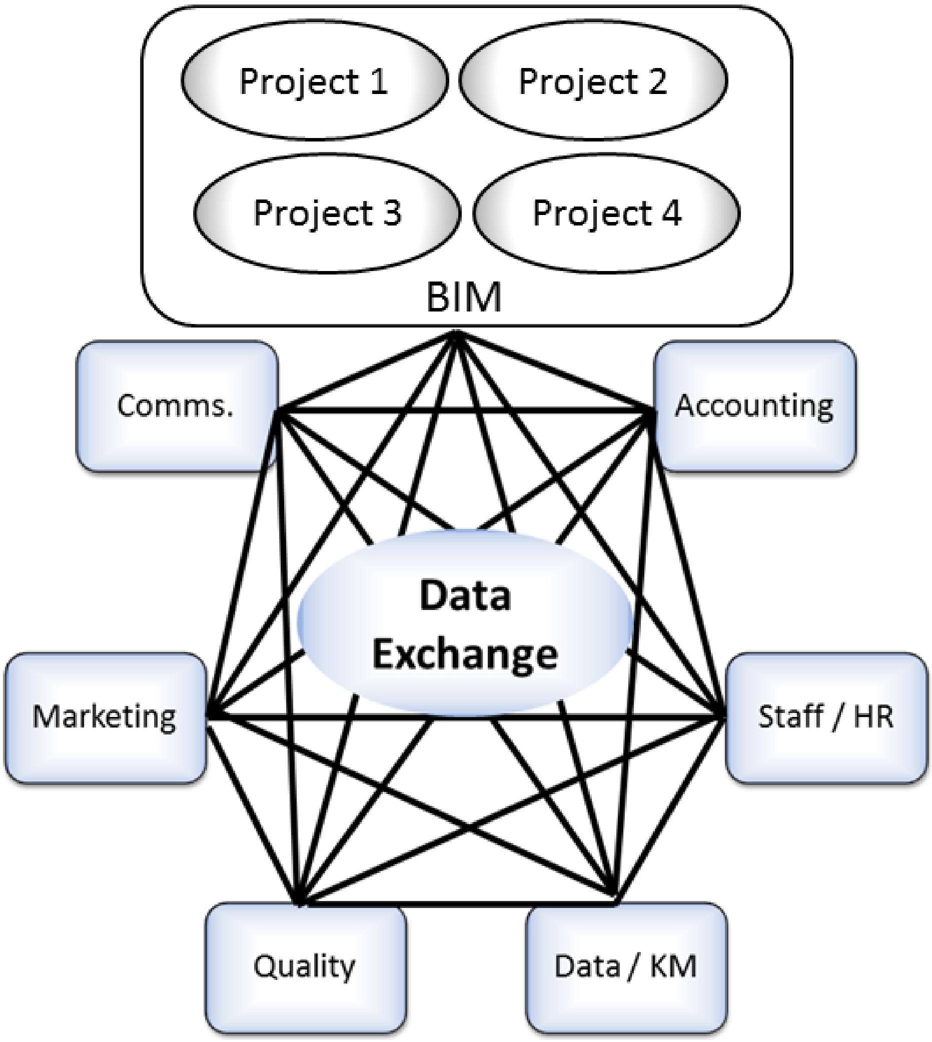


Figure 6.03: BIM and its possible links to other data systems used within architectural practice

The full implementation of such as system is regarded as beyond the scope of this thesis. But for large architectural practice with greater resources they may wish to see and manage the BIM adoption as part of a wider adoption of EA. A full implementation of EA would embrace all the functions of the organisation which might include marketing, human resource management and financial management. To embrace these functions the interactions need researching into. However, these interactions are beyond the scope of the thesis where the focus is on the effective implementation of BIM within EA.

6.3 Review of business reengineering approaches

BIM implementation is an example of business process reengineering (BPR) (Ayyaz 2012). Business process engineering is the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical modern measures of performance, such as cost, quality, service, and speed (Hammer and Champy 1993). As such the activities required to undertake a BIM implementation are defined in general terms within BPR methodologies. The proposed steps required to achieve a successful BPR defined by different authors are documented in the table 6.01.

Different models have been developed in relation to diffusion and assimilation of innovation (Lee, 1998; Levy et al., 1998; Rodgers, 1995) in business. However, Finchman (2000) suggests that researchers should develop mid-range theories “tailored to specific classes of technologies and particular adoption contexts”.

Proposed stage / Activity	Peppard and Rowland 1995	Sengala and Farzaneh 1996	Vakola et al 2000	Yung 1997	Zinser et al 1998	Fowler 1998	Tissari and Heikkila 2001
Activity 1)Build a vision / Identify strategic goals, objectives and scope of the project	X	X	X	X		X	X
Activity 2) Recognise and define the problem					X	X	
Activity 3)Gain Management support / acceptance / commitment	X	X		X	X		
Activity 4)Formulate a plan / choose a change mechanism	X	X		X		X	
Activity 5) Understand - analyse existing processes / problems and cause / performance gaps / define principles of change / quantify measures	X	X	X	X	X	X	X
Activity 6)Identify / select (core) processes	X	X	X	X		X	
Activity 7)Appoint a team / champion responsible for implementing the whole program	X			X	X		X
Activity 8) Communicate / win acceptance from employees / disseminate results	X		X	X		X	X
Activity 9) Provide training	X						
Activity 10)Benchmark	X						
Activity 11)Redesign	X	X	X	X	X	X	X
Activity 12)Review people and technology requirements	X						
Activity 13)Validate new process and realize temporary measures	X		X	X	X		
Activity 14)Review organisational structure, competences and motivation	X	X	X				X
Activity 15)Define New roles	X						
Activity 16)Develop action plans				X			
Activity 17)Pilot implementation	X		X				X
Activity 18)Verify if improvement principles are correct							X
Activity 19)Phased implementation roll out through the company	X		X		X		X
Activity 20)Monitor performance (indicators)	X			X	X		
Activity 21)Assess performance / evaluate	X		X		X		
Activity 22)Identify new uses for the capability developed	X						
Activity 23)Stabilise success / standardise process use and implement method					X		X
Activity 24)Continuous Improvement	X	X	X				

Table 6.01: Activities required to bring about organisational change (Tzortzopoulos 2004)

The following chapters of this thesis are written considering each of these activities in the table as they integrate with the framework previously developed.

At John McCall Architects the actions undertaken between 2009 and 2011 were those deemed appropriate at the time by the research and the company. Since that time perceptions and expectations of BIM held by the researcher and those more widely accepted have moved forward but the stages of business change model can remain the same, even though how it is applied should change.

The action research into BIM implementation was undertaken before the UK government COBie mandate. However, the government mandate does not currently apply to the housing projects such as those undertaken by John McCall Architects. The COBie mandated significantly changes what is considered to be BIM. Also several new standards and guidelines have been issued since the time the research was undertaken.

6.4 BIM implementation what type of project is it?

When conducting a BIM adoption project it is important to understand what type of project it is. Obeng (1994) set out a range of project typologies (see figure 6.04).

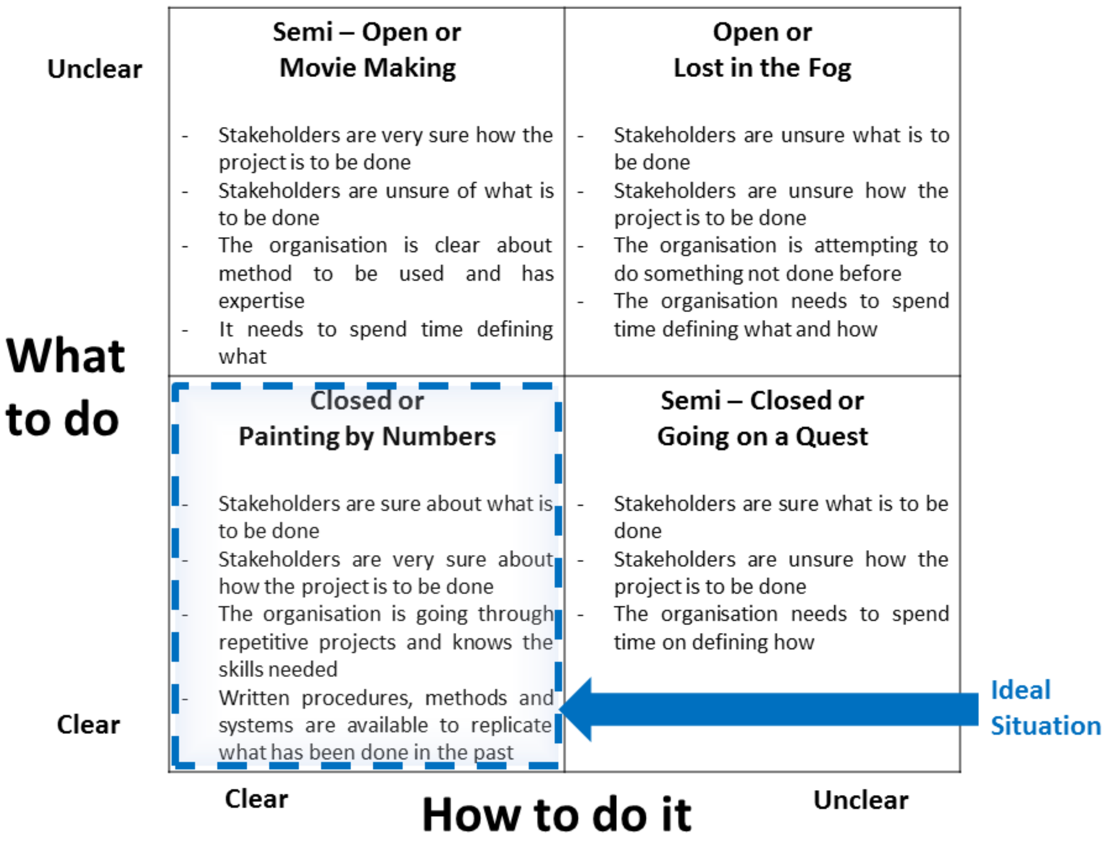


Figure 6.04: Definition of different types of projects (Obeng 1994)

Although it would be preferable to undertake a BIM adoption as a closed, predictable or “paint by numbers” project (as defined by Obeng 1994) this is unlikely to be possible. To gain the maximum from a BIM implementation there should be a continual questioning on what should be done and how it should be done through the life span of the BIM adoption project. Thus an agile project methodology with the opportunity to assess the direction of a BIM adoption project throughout the development of its lifecycle is likely to achieve the best results. With this in mind the importance of building learning cycles into the framework can be better understood.

6. 5 Initial Hypothetical Framework to be used and tested through the Action Research Cycles

The desired change in any organization cannot be brought about without implementing organizational change strategies. The whole process requires evaluating, planning, implementing, benchmarking and monitoring the goals and objectives of the organization. To develop an implementation strategy framework several areas and questions have been investigated.

- Firstly what is BIM?
- How do we implement BIM – Approaches and levels of change?
- What are the stages of a BIM implementation?
- What is required from the preliminary briefing
- How do we define objectives
- What should be included with the Gap analysis
- What knowledge will need to be acquired
- What documentation and System development is required
- What standards need to be in place
- How should BIM implementation be planned
- How should BIM be rolled out
- How should BIM be used
- How should a BIM system be maintained

These questions are generated through a process of brainstorming. Writing down the concepts brainstormed then formulating these concepts into a mind map. By undertaking this exercise the research could call on experiences of implementing CAD within several architectural practices many years before.

How these questions were and should be addressed will be covered in the following chapters of this thesis. These chapters (6-10) also indicate where the original framework was adapted where necessary.

The approach adopted was aligned to PRINCE 2. PRINCE 2 is a project methodology endorsed by the UK government. It outlines the stages, deliverables and approval points to be progressed through to achieve a successful BIM adoption.

The table 6.02 indicates the process that was used for BIM adoption at John McCall Architects Liverpool. This table of actions was generated through group deliberation and the experience of undertaking similar change management projects. This framework was tested through a process of action research. At key stages of the BIM adoption this framework was reviewed and modified as required. Prior to undertaking a new stage of the framework the stage was review taking account of the lessons already learnt from previous stages.

Stages	Activities
Stage 1: Detail Review and Analysis of Current Practice and Identification of Efficiency gains from BIM implementation	1.1 Production of Current Process Flowcharts
	1.2 Soft System Analysis
	1.3 Review of overall ICT systems in the company
	1.4 Stakeholder Review and Analysis
	1.5 Identification of competitive advantages from BIM implementation
Stage 2: Review of Lean Gains	2.1 Detailed review of Lean efficiency gains
Stage 3: Design of new business processes and technology adoption path	3.1. Identification of Lean Efficiency Gains
	3.2. Production of detail strategies
	3.3. Documentation of Lean Process and Procedures
	3.4. Documentation of BIM implementation plan
	3.5 Review of BIM tools for the company
Stage 4: Implementation & roll-out of BIM	4.1. Piloting BIM on different projects (past, current, and future)
	4.2. Training the John McCall Architects staff and stakeholders
	4.3. Devising, improving and documenting companywide capabilities and processes
Stage 5: Project review, dissemination	5.1. Sustaining new products and processing offerings
	5.2. Evaluation and dissemination of the project

Table 6.02: Showing the main stages of BIM implementation considered

The appropriateness of the total framework was reviewed following the actions taken.

6.6 The Hypothetical BIM implementation strategy framework

By definition, a framework is a systematic set of relationship or a conceptual scheme, structure, or system (Webster 1986). A good framework should be easily to understand, clear, have boundaries and be expandable where necessary (Booth 2013).

To understand frameworks several existing frameworks originating from other sectors or with other applications were reviewed. Many of the issues involved in the adoption of BIM are covered in the Integration Project Toolkit produced by the Strategic Forum for construction (The Strategic Forum for Construction 2003). Although issues of supply chain integration most probably fall within the remit of big BIM rather than little BIM.

To understand the basics of BIM implementation the relationships and interdependencies of why, how, what and how and when were sketched out (see figure 6.05). The why is determined by defining the objectives of the project. What is required is defined by undertaking a Gap Analysis, the how is defined by the change in process, people and technology.

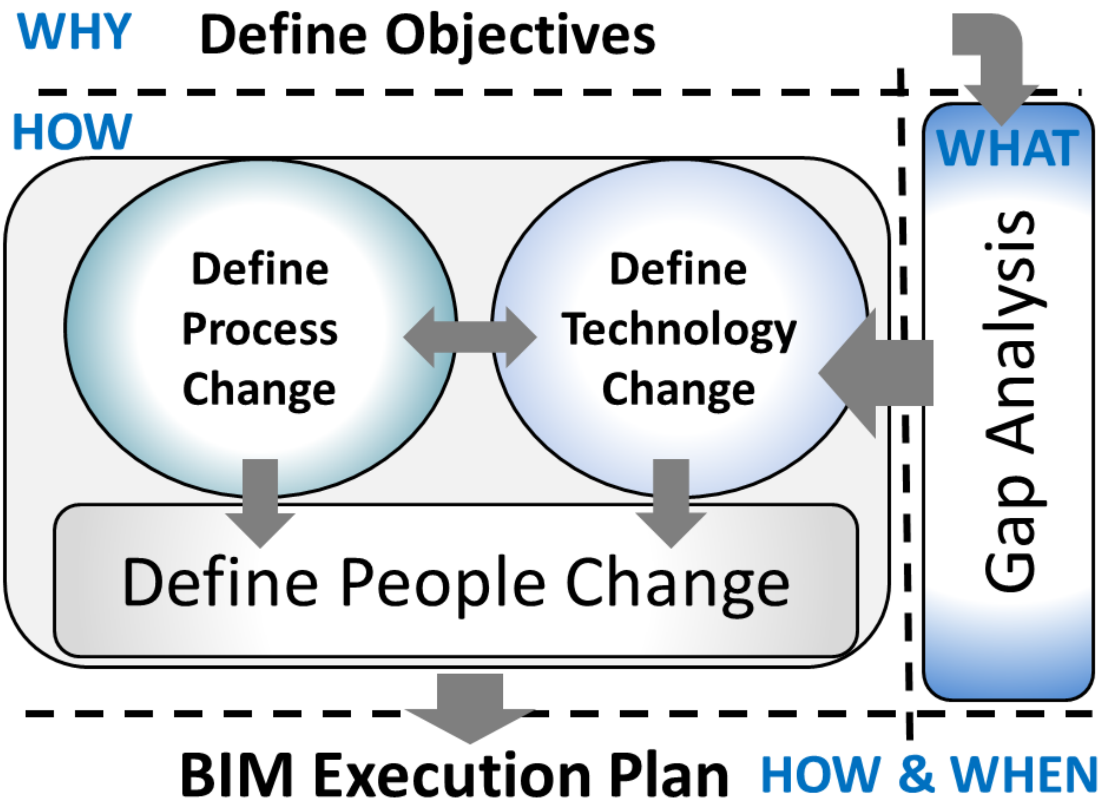


Figure 6.05: Defining change as the basis of developing the BIM execution plan

The BIM implementation strategy framework was converted into simple programme to make it usable (see figure 6.06 Appendix A). This was further refined into a more complex programme (see figure 6.07 Appendix A).

Each stage should be undertaken as a gated process with approval sort and gained before moving on to the later stages.

Gates provide various points during the process where an assessment of the quality of an idea is undertaken. It includes three main issues:

- Quality of execution: Checks whether the previous step is executed in a quality fashion.
- Business rationale: Does the project continue to look like an attractive idea from an economic and business perspective.
- Action plan: The proposed action plan and the requested resources reasonable and sound

6.7 Summary of Chapter 6

In this chapter the original BIM implementation framework was documented. The general issues around the development of such frameworks are also recorded. This is placed within the context of other change management frameworks and the activities suggested. The application of BPR and enterprise architecture are also considered.

Chapter 7

Chapter 7: This chapter reviews the diagnosis stage of the action research undertaken at John McCall Architects as part of BIM implementation. The sections of chapter are structured using a preferred sequence derived after completion of the action research. This preferred sequence more adequately aligns with what did and what needs to take place as part of a BIM adoption.

CHAPTER 7 Explanation of the Framework used at John McCall Architects, The Diagnosis Stage

7.1 Introduction

Diagnosis of the issues and problems of the architectural practice forms the basis for later actions and improvements as part of the adoption of BIM. In this chapter we consider the activities undertaken during the diagnosis stage at John McCall Architects (the case study company). Recommendations where appropriate are given on how the activities may be improved or undertaken in a more efficient way.

The actions identified and undertake during this diagnosis stage were:

- Development of a business case
- Setting up of a project structure and authorization
- Initial Project Mobilization
- Defining Project Parameters
- Analysis of business objective
- Analysis of current process
- Analysis of Data Handling
- Determination of Current Best Practice
- BIM Tool Review

These in part were generated from reviewing activities for organisational change management (Tzortzopoulos 2004).

7.2 Development of the Outline Business Case

Fundamental to any BIM adoption is the development of a business case showing potential possible benefits or needs and justifying the project proposal. The business case was developed at John McCall Architects before to involvement of the researcher. It is documented here as it represents a critical first step when commencing a BIM implementation project.

The benefits to the architectural practice need should outweigh the costs incurred by implementing BIM. Without a business case it is unlikely and inappropriate that funding will be provided to undertake further investigation, diagnosis or action planning or action taking.

Before change commences (indeed, as part of the initial investment analysis) it is essential to gain a clear understanding of baseline service levels and costs (see figure 7.01). Both tangible and intangible costs should be evaluated. These will give an indication of the benefits that changes in the service can bring, but also provide a benchmark against which targets can be set and improvement measured.

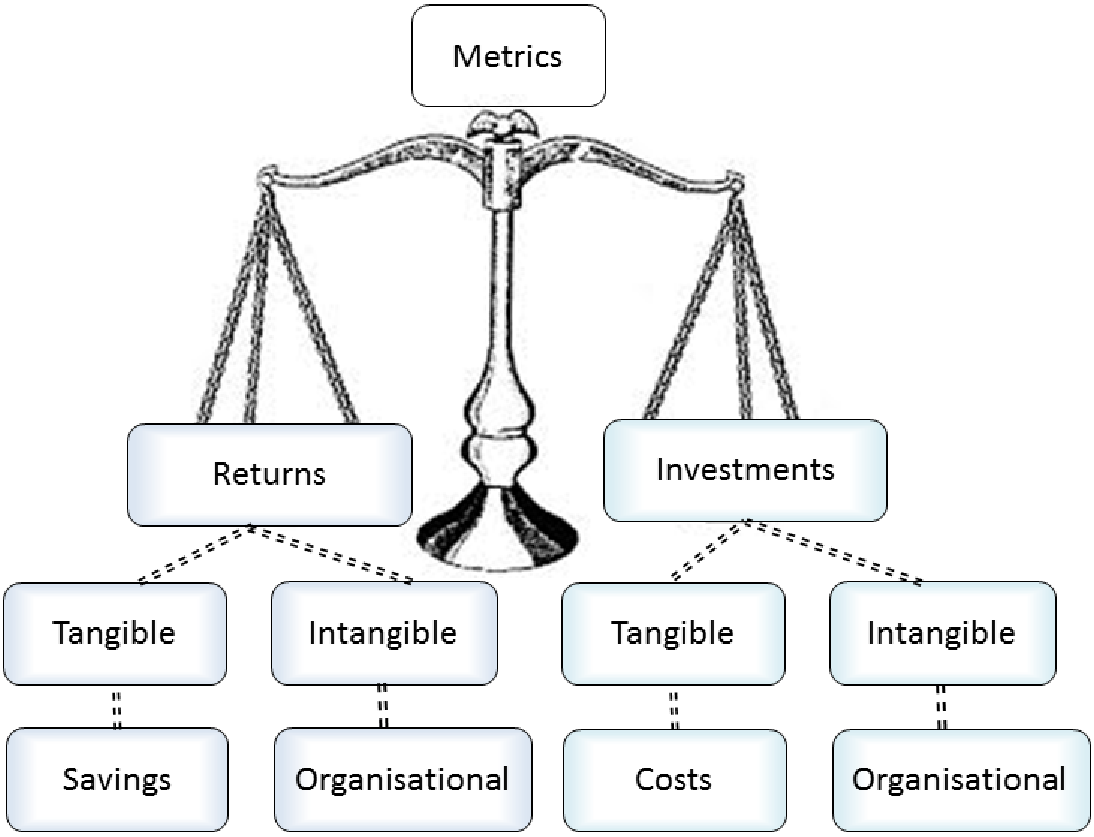


Figure 7.01: How to measure the benefits of BIM (adapted from Barlish 2011)

The investment required should also be compared with the return possible from that investment if applied to other projects or to achieve other benefits.

The suggested method of developing the business case is to have a business case review meeting. The proposed format for such a meeting is illustrated (see figure 7.02).

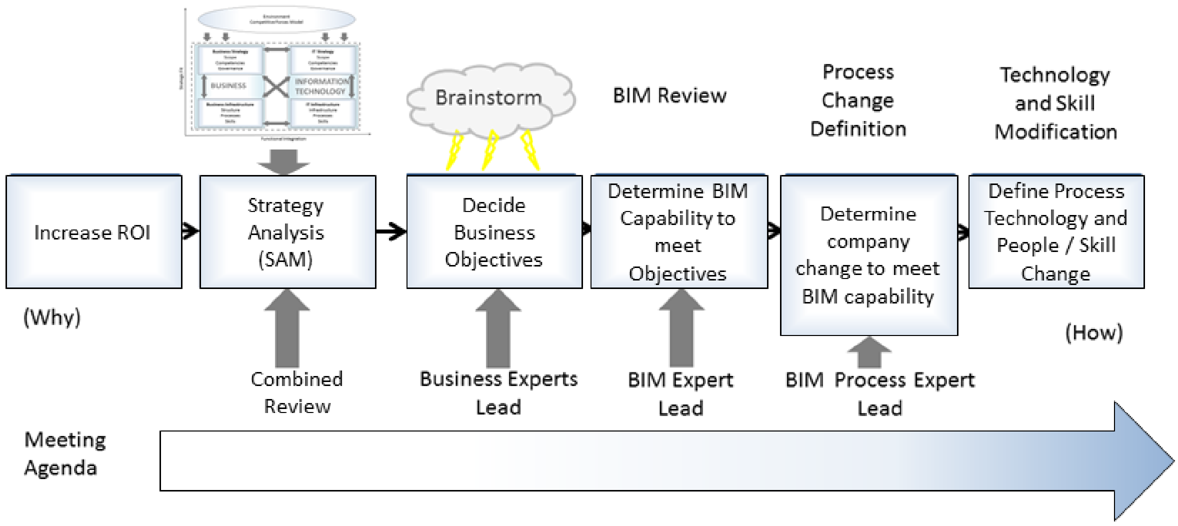


Figure 7.02: Process to be undertaken as part of the business case review workshop

It is important that the business is seen from three viewpoints a business viewpoint, a user view point and a client / supplier viewpoint. Ideally all of these understandings should form part of the workshop group (see figure 7.03).

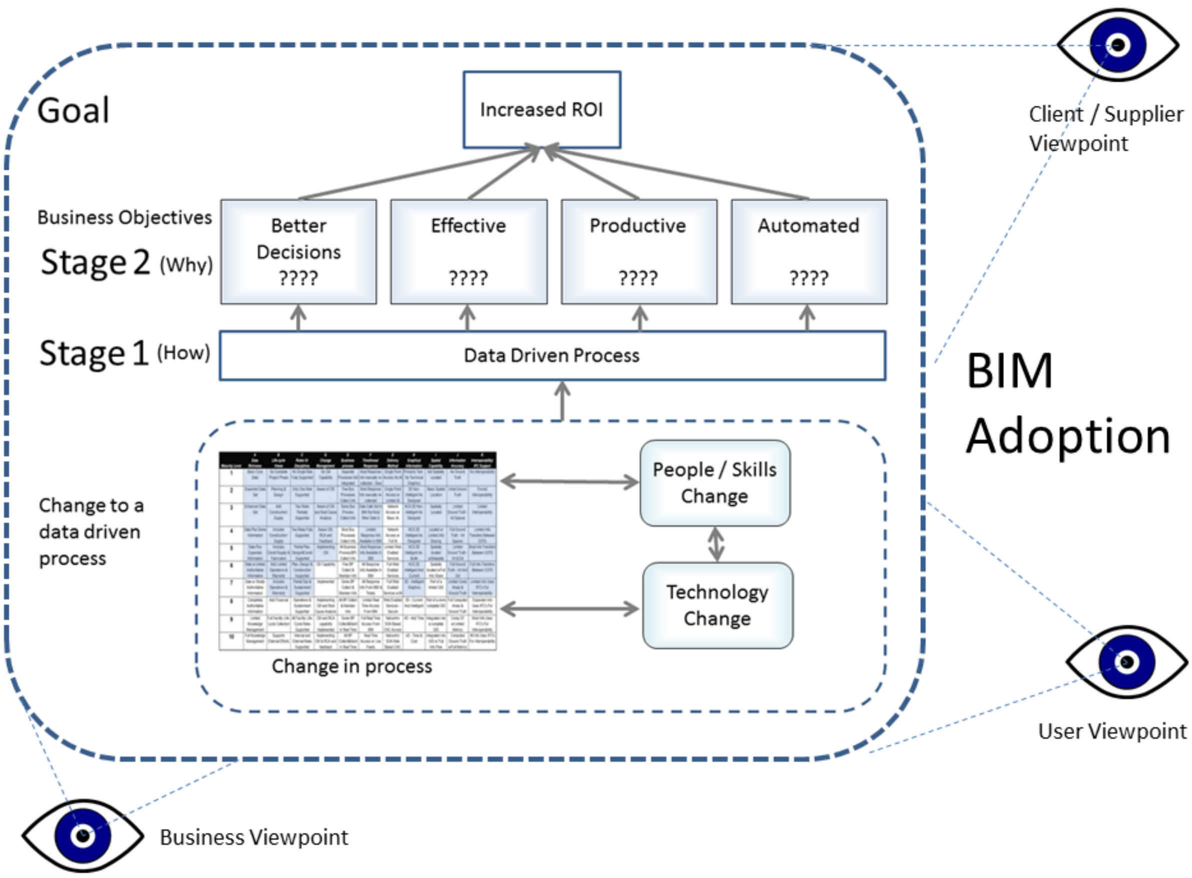


Figure 7.03: The link between data driven process and business objectives

According to Reiss et al (2006) projects create deliverables and a combination of these deliverables generates the capabilities that enable the desired benefits to be achieved. This in indicated by stage 1 and stage 2 on figure 7.03.

Using the strategic alignment model Venkatraman (1994) (see figure 7.04) analysis can take place on current and future business and IT practices. An important element here is adapting to the external factors driving change.

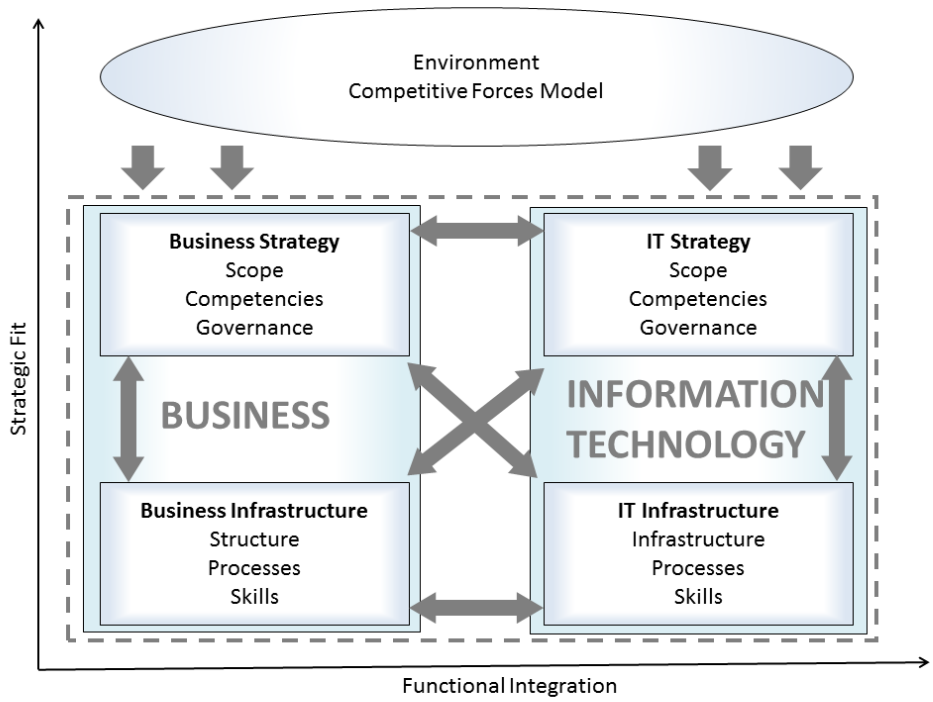


Figure 7.04: The Strategic Alignment Model (Adapted from Henderson and Venkatraman 1994)

The key benefits of adopting BIM were identified using a brainstorming exercise undertaken by the researcher (see figure 7.05).

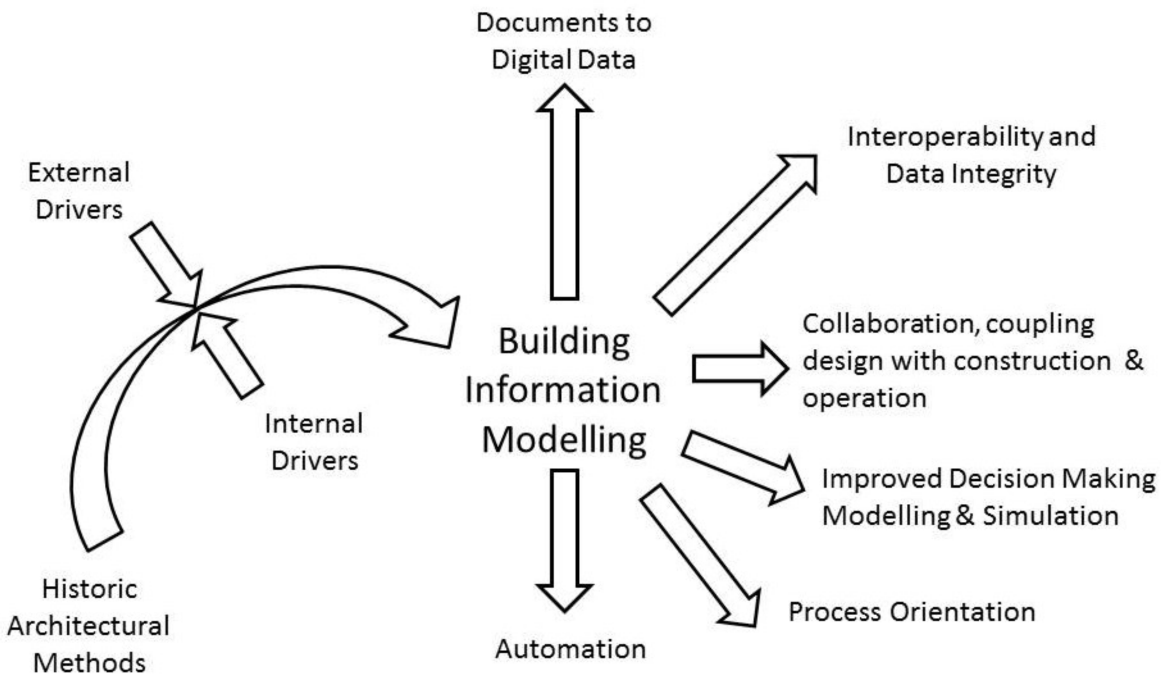


Figure 7.05: The associative benefits of adopting BIM

The current estimated cost to get an operational BIM user is £10,000 (Miller 2010). This includes hardware software and training. This will vary depending on the hardware software and training methods adopted. Considering BIM costs at a user level is perhaps inappropriate because what is aimed for is organisational capabilities and inter-organisation productivity. Future practice workload demands and returns need to be factored in here to ensure that an appropriate business case is developed.

Architectural practices adopting BIM need to invest in their staff in the form of training. But staff once trained may be more eligible to find alternative more profitable employment.

Making the decision whether to adopt or not adopt BIM should be based on a benefit analysis. Benefit analysis determines whether BIM is a sound investment decision and provides a basis for comparing project investment. The benefits identified should be balanced against the cost, time and resources that it will take to implement BIM. The radar chart is an effective form to show possible metrics to evaluate an adoption of BIM (see figure 7.06).

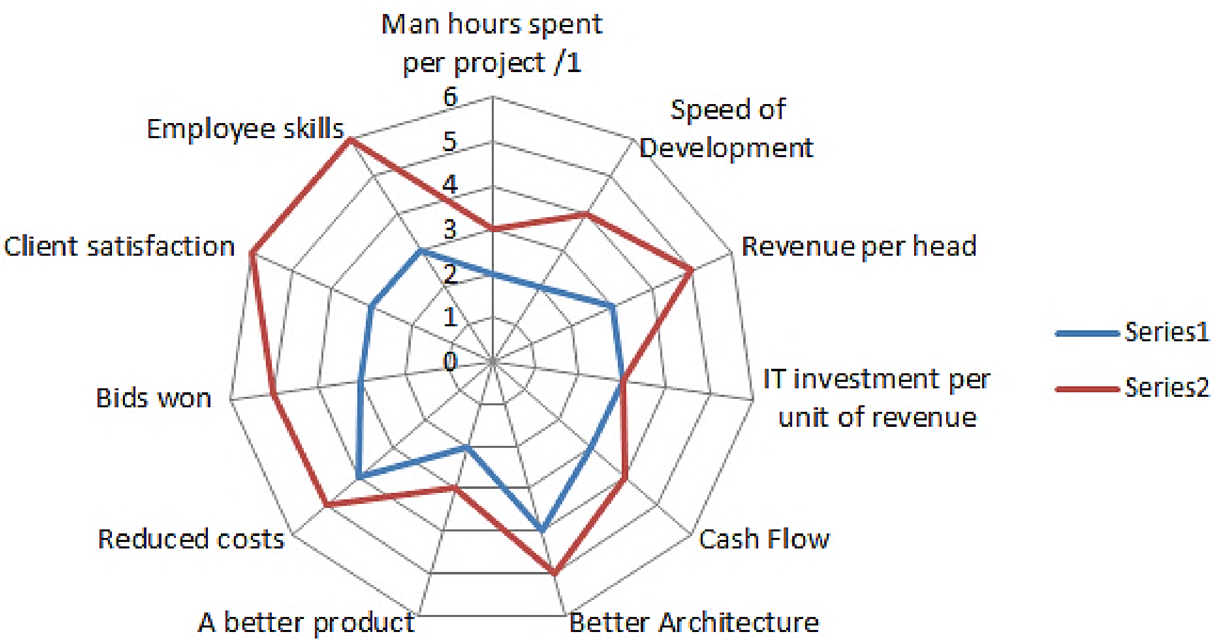


Figure 7.06: Use of metrics to evaluate the level of success of a BIM adoption

Such radar charts can be produced for a whole organisation, a whole project or individual stages of a project. A similar radar chart was developed by NBIMS to indicate BIM adoption and BIM maturity (see figure 7.07) (McCuen 2008). COBIT, CMMi, CSCMM, I CMM, LESAT, P3M3, C MM, (PM)", SPICE, BPO, the Indiana University BIM proficiency matrix and the knowledge retention maturity levels were all maturity models relating to BIM identified by Succar (2009).

Maturity Level	A Data Richness	B Life-cycle Views	C Roles Or Disciplines	G Change Management	D Business process	F Timeliness/ Response	E Delivery Method	H Graphical Information	I Spatial Capability	J Information Accuracy	K Interoperability/ IFC Support
1	Basic Core Data	No Complete Project Phase	No Single Role Fully Supported	No CM Capability	Separate Processes Not Integrated	Most Response Info manually re-collected - Slow	Single Point Access No IA	Primarily Text - No Technical Graphics	Not Spatially Located	No Ground Truth	No Interoperability
2	Expanded Data Set	Planning & Design	Only One Role Supported	Aware of CM	Few Bus Processes Collect Info	Most Response Info manually re-collected	Single Point Access w/ Limited IA	2D Non-Intelligent As Designed	Basic Spatial Location	Initial Ground Truth	Forced Interoperability
3	Enhanced Data Set	Add Construction/ Supply	Two Roles Partially Supported	Aware of CM and Root Cause Analysis	Some Bus Process Collect Info	Data Calls Not In BIM But Most Other Data Is	Network Access w/ Basic IA	NCS 2D Non-Intelligent As Designed	Spatially Located	Limited Ground Truth - Int Spaces	Limited Interoperability
4	Data Plus Some Information	Includes Construction/ Supply	Two Roles Fully Supported	Aware CM, RCA and Feedback	Most Bus Processes Collect Info	Limited Response Info Available In BIM	Network Access w/ Full IA	NCS 2D Intelligent As Designed	Located w/ Limited Info Sharing	Full Ground Truth - Int Spaces	Limited Info Transfers Between COTS
5	Data Plus Expanded Information	Includes Constr/Supply & Fabrication	Partial Plan, Design&Constr Supported	Implementing CM	All Business Process(BP) Collect Info	Most Response Info Available In BIM	Limited Web Enabled Services	NCS 2D Intelligent As-Builts	Spatially located w/Metadata	Limited Ground Truth - Int & Ext	Most Info Transfers Between COTS
6	Data w/Limited Authoritative Information	Add Limited Operations & Warranty	Plan, Design & Construction Supported	CM Capability	Few BP Collect & Maintain Info	All Response Info Available In BIM	Full Web Enabled Services	NCS 2D Intelligent And Current	Spatially located w/Full Info Share	Full Ground Truth - Int And Ext	Full Info Transfers Between COTS
7	Data w/ Mostly Authoritative Information	Includes Operations & Warranty	Partial Ops & Sustainment Supported	Implemented	Some BP Collect & Maintain Info	All Response Info From BIM & Timely	Full Web Enabled Services w/IA	3D - Intelligent Graphics	Part of a limited GIS	Limited Comp Areas & Ground Truth	Limited Info Uses IFC's For Interoperability
8	Completely Authoritative Information	Add Financial	Operations & Sustainment Supported	Implementing CM and Root Cause Analysis	All BP Collect & Maintain Info	Limited Real Time Access From BIM	Web Enabled Services - Secure	3D - Current And Intelligent	Part of a more complete GIS	Full Computed Areas & Ground Truth	Expanded Info Uses IFC's For Interoperability
9	Limited Knowledge Management	Full Facility Life-cycle Collection	All Facility Life-Cycle Roles Supported	CM and RCA capability implemented	Some BP Collect&Maint In Real Time	Full Real Time Access From BIM	Netcentric SOA Based CAC Access	4D - Add Time	Integrated into a complete GIS	Comp GT w/Limited Metrics	Most Info Uses IFC's For Interoperability
10	Full Knowledge Management	Supports External Efforts	Internal and External Roles Supported	Implementing CM & RCA and feedback	All BP Collect&Maint In Real Time	Real Time Access w/ Live Feeds	Netcentric SOA Role Based CAC	nD - Time & Cost	Integrated into GIS w/ Full Info Flow	Computed Ground Truth w/Full Metrics	All Info Uses IFC's For Interoperability

Figure 7.07: NBIMS CMM Chart (McCuen 2006)

The business case review process undertaken at John McCall Architects was part of the standard KTP (knowledge transfer partnership) initiation approval process. As part of this process it was necessary to indicate the value of additional fees that were predicted through adopting BIM. The key decision makers at John McCall Architects were the four directors. Unfortunately at the end of the research period it was too early to validate the business case predictions made.

As part of the business case there should be key elements:

- The aim or aims should be clearly set out
- Why it is important to the company to adopt BIM should be clearly understood
- The potential impact on the company should also be clearly understood
- Project scope, tolerances and exclusions of the BIM adoption should be defined
- Outline deliverables or desired outcomes of the BIM adoption should be defined
- Constraints if any should be established
- Known risks associated with BIM adoption should be identified

Once these elements have been determined they can be correlated, issued for approval and project authorization in a formal report. A presentation to key decision makers of the business case is also appropriate at this time. Also this can be kept as a record which can be referred to later as the project develops. At John McCall Architects the funding application documents for the KTP effectively addressed the need to demonstrate a business case.

At John McCall Architects the business case was reiterated using the A3 method (Sobek 2008). A3 is one of the many Lean techniques developed as part of the Toyota planning system. The A3 was generated fairly early in the project (see figure 7.08). The normal flow of the A3 design is shown in the figure (see figure 7.09 Appendix A).(Using the A3 method is perhaps an over simplistic way to develop a business case for such a complex project as the adoption of BIM but it has the benefit of explaining the concepts in a concise and simple form.)

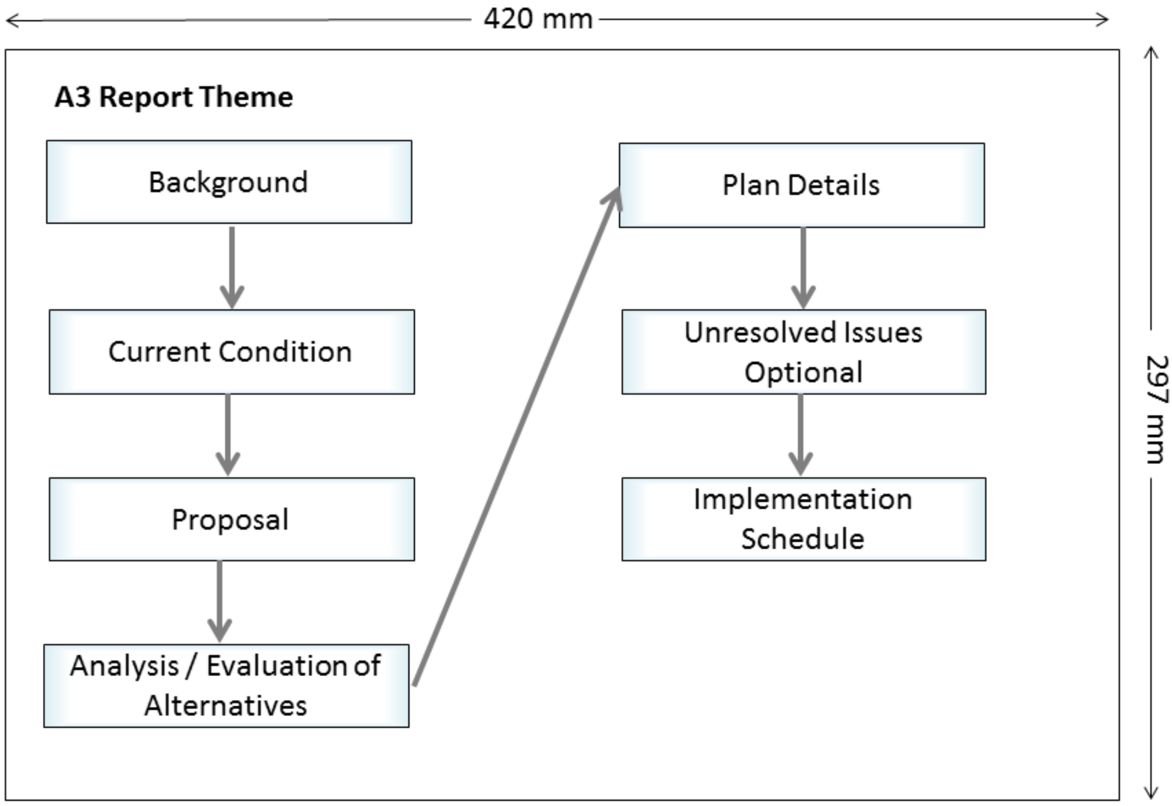


Figure 7.08: The normal flow of an A3 sheet design

The BIM metrics for choosing a company by a client organisation were set out by Race (2012). These are:

- Having BIM champions (On the top Table)
- Policy
- Experience
- Technology Integration
- Implemented Information Standards
- Flexibility (Ability to adapt to any project situation)
- Teamwork
- Innovation
- Openness
- Project Vision

Although a major aspect of adopting BIM is to increase productivity it is also important to ensure that new work is coming into the architectural practice. So the aforementioned BIM metrics should be built into BIM adoption to ensure clients and new business opportunities are acquired through the implementation of BIM. Ideally some form of customer analysis (such as Kano Analysis (Kano 1984)) should form part of the business case.

The ability to undertake projects using BIM was a capability that was later included in John McCall Architects project bids. Although on many of the bid forms there was no appropriate place to record practice BIM capabilities.

7.3 BIM implementation - Project Structure and Authorization

Project governance depends on defining a project structure, defining actors roles and information inputs and outputs.

At John McCall Architects this activity of setting up the project structure and authorization had already been undertaken before the researcher's direct involvement. The project methods of communication, standard documents, methods of change control and planning for risks was all provided as part of the KTP approach.

The flowchart (see figure 12.01) which has been developed as part of this thesis is a good example of how to define the project structure. The project is broken down into gated phases with key activities identified.

Ideally as part of the project structure development certain project management tools will be made available to the BIM implementation team and BIM Champion. Such tools might include project programming software, process visualization software, mind map software, word processing software, internet access and presentation software.

The project structure should be re-evaluated at the end of each stage taking into account what has been learnt from that stage. Authorization is also likely to require outline budgets and a system of financial management of the BIM implementation project. Identifying who has the authority to approve the completion of the stage is important to establish at this early stage. At John McCall Architects monthly meetings were setup to monitor the progress and resourcing needs of the adoption of BIM and provide input and approval where necessary.

What needs to be clear when authorization is allocated is that those given the authority also need to be able to release the funds necessary to undertake the project.

7.4 Initial Project Mobilization

The BIM team and the BIM Champion are both important elements of a successful BIM adoption. It is usual for the adoption of BIM to be facilitated using a change champion, this maybe a member of staff from within the organisation. Although it is more likely that the skill and aptitudes that are required will be found in an external expert who may then be embedded within the organisation to facilitate change. At John McCall Architects a major element of the initial project mobilization was the recruitment of the KTP associate or BIM Champion. There are various reasons why firms should employ a BIM consultant (see figure 7.10).

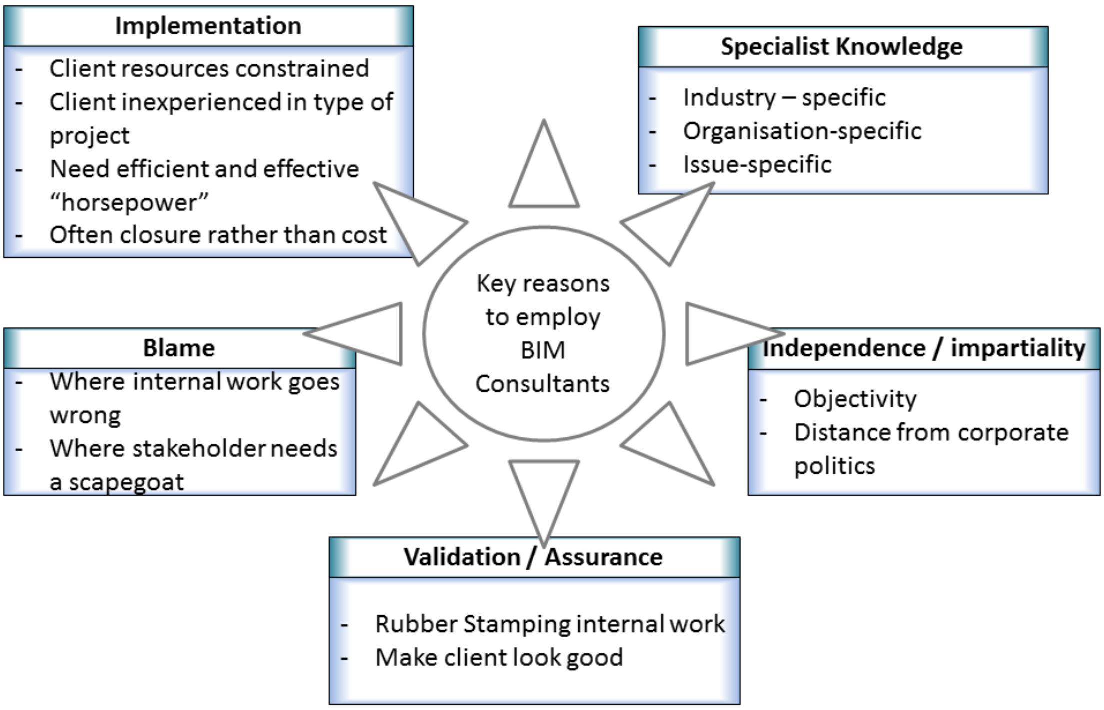


Figure 7.10: Why Organisation use Consultants (adapted from Ringland and Skaukat 2004)

In order to employ an appropriate BIM Champion it was necessary to define an appropriate job description and terms of employment. An advert was then posted in various architectural journals and on various websites (see figure 7.11). At the time there were over 50 applicants for this position with five selected to be interviewed. Interviews were conducted by the directors of the architectural company with academic support.

Figure 7.11: The advert posted to attract the BIM Champion for the BIM implementation project at John McCall Architects

The criteria used to select the BIM Champion for the BIM implementation project at John McCall Architects are shown (see figure 7.12).

Person Specification

Qualifications

The successful candidate should:	Essential/ Desirable	Tested by*
A good honours degree (1st or 2:1) or higher degree in Architecture, Architectural Technology or some CAD/IT related discipline	E	A

Background & Experience

The successful candidate should have:		
Commercial experience	D	A/I
Experience of process mapping techniques	D	A/I
Experience of lean thinking implementation	D	A/I

Knowledge

The successful candidate should have demonstrable knowledge of:		
CAD/IT applications	E	A/I
Network/Server based communication Technologies	E	A/I

Skills & Competencies

The successful candidate should demonstrate:		
Excellent IT/IS Skills	E	A/I
An effective communicator both orally and in writing with excellent interpersonal and analytical skills	E	A/I
Empathetic approach – enjoy meeting people; The ability to motivate and inspire a wide range of people from different backgrounds; lead staff at all levels through a programme of change	E	A/I
Ability to undertake multiple tasks, work under own initiative and/or as part of a team, and lead a team.	E	A/I
Confidence and assertiveness to drive and manage projects and prioritise Tasks	E	A/I
Professional attitude	E	A/I

Figure 7.12: The selection criteria used at John McCall architects to select the BIM champion

Another way to consider the skills necessary for a BIM Champion is to review them against the preliminary BIM learning outcomes framework (see figure 7.13). This is available from the UK Government BIM task group website and lists the areas of knowledge / skill needed to implement BIM.

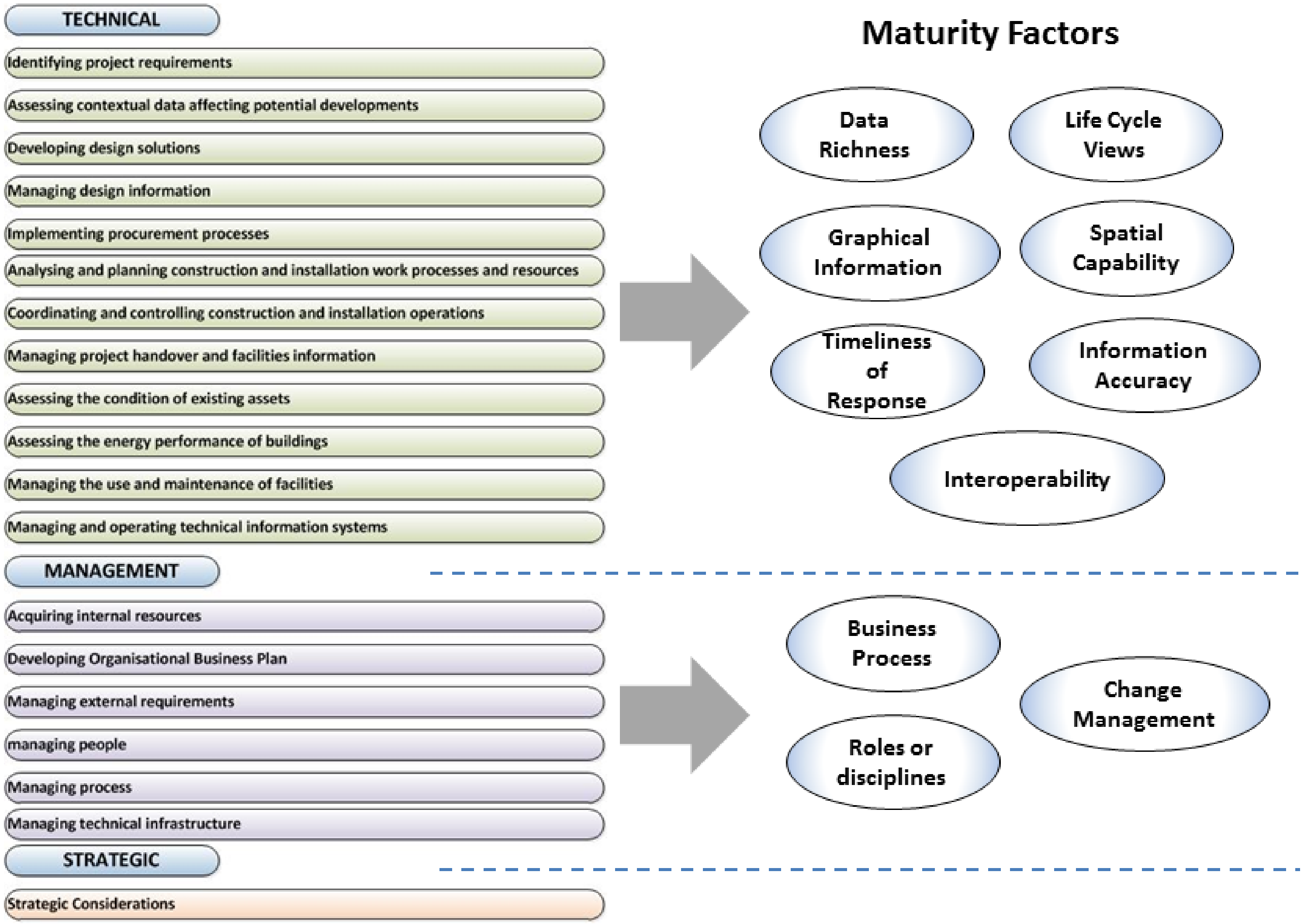


Figure 7.13: The necessary BIM Champion skills as documented in the (July 2012) related to BIM maturity tasks

BIM Competency sets have also been documented by Succar (2010). These can also be used to review the knowledge of the potential BIM Champion (see figure 7.14). Effectively in the case study company the researcher became the BIM Champion.

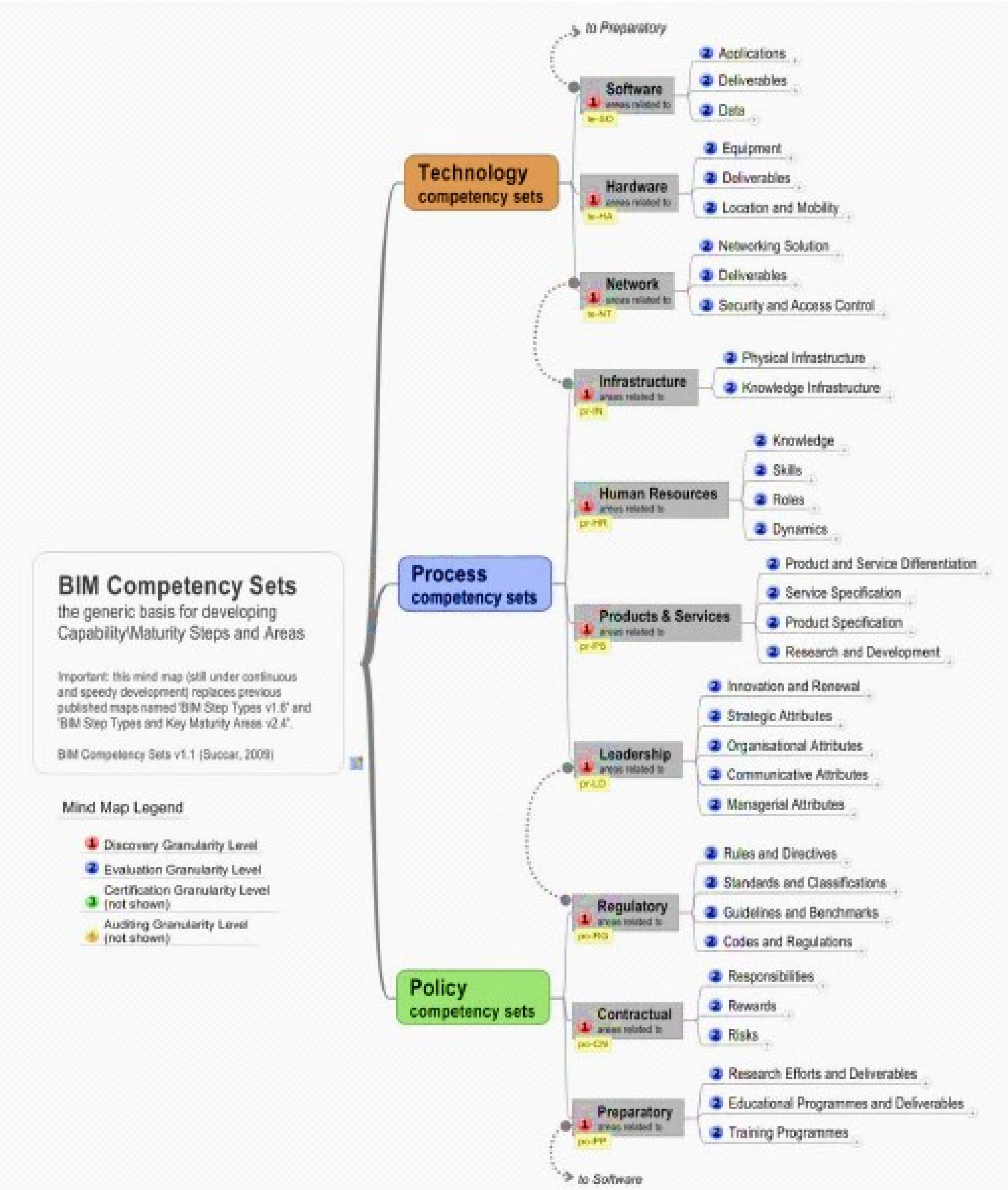


Figure 7.14: BIM Competency Sets v1.1 (Succar 2010)

If the selection of the BIM Champion is made after the BIM tool selection then the Champion can be selected with relevant experience related to the tool to be used. The learning curve for any new BIM tool can be steep particularly when a teaching output is required. If the BIM champion already has the necessary knowledge of the BIM tool to be used this represents a major saving. The spreading of BIM knowledge should be planned. The initial team on one project should provide the BIM lead on later projects thus disseminating the lessons learnt (see figure 7.15).

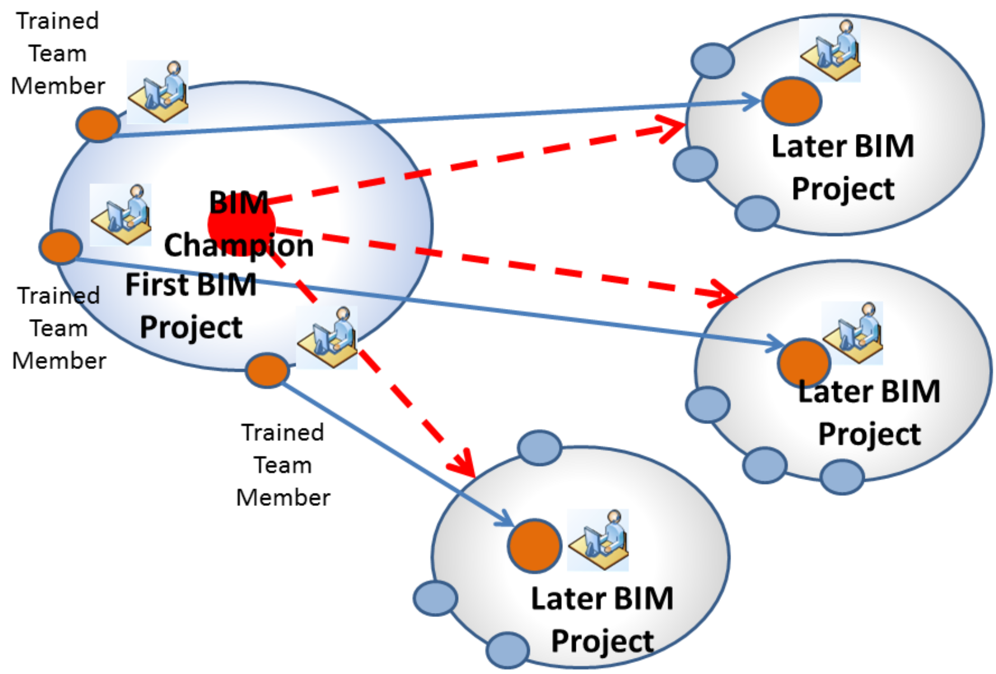


Figure 7.15: BIM knowledge being spread by staff trained by the BIM champion (Martin 2011)

From the individual with BIM skills a BIM teams can be developed. Then by placing these BIM trained individuals in new teams the knowledge is spread and the company can become BIM enabled. When students become teachers this also reinforces their knowledge and understanding of the software tools they are using and teaching. Such strategies of job shadowing were used at John McCall Architects.

At the practice were the action research was undertaken members of staff from the University of Salford provided advice concerning the BIM implementation. This was a particularly valuable contribution. Such support many not be available in other circumstances but investigation the support that is available from local academic institutions or professional bodies can provide should be investigated. These can provide a valuable direction to any BIM implementation project. This is a form of open innovation (see figure 7.16). Open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology.

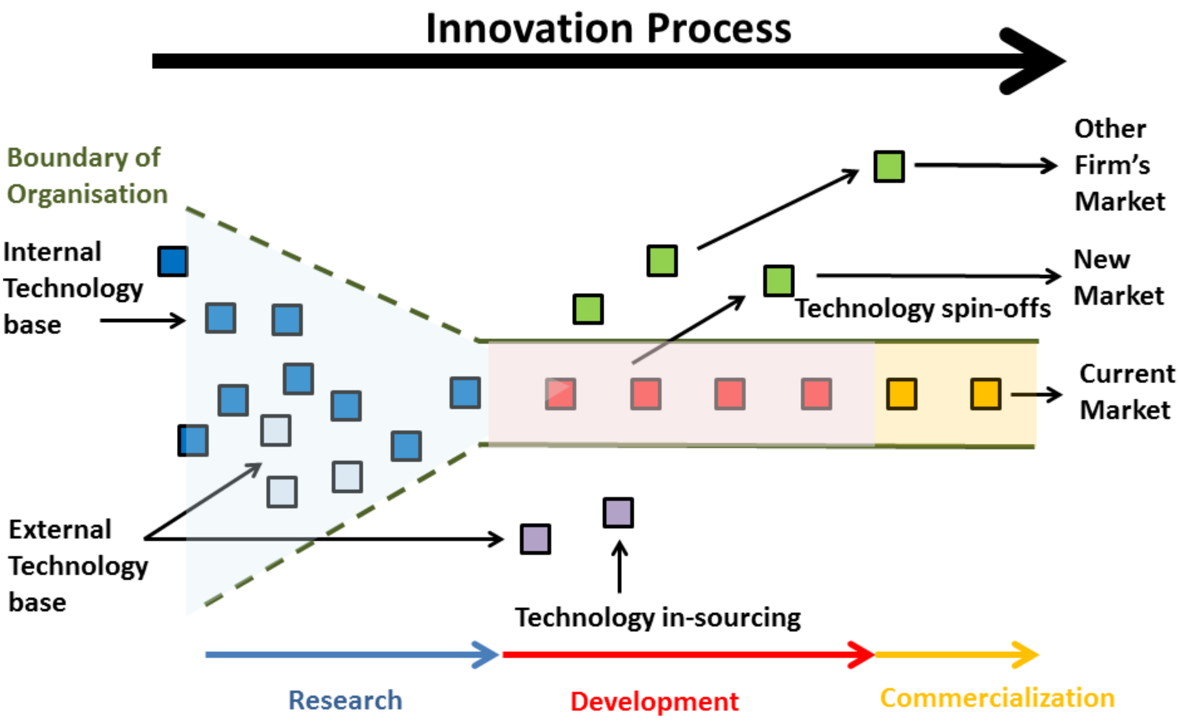


Figure 7.16: The open innovation process using an external technology base (Chesbrough 2003)

7.5 Defining BIM implementation Project Parameters

At this early stage it is not possible to fully understand the impact and benefits of undertaking the adoption of BIM unless members of the team have already been through the BIM adoption process. A fuller understanding of the benefits will be gained after the diagnosis stage is undertaken. Even so where possible it is important to define parameters of the BIM implementation. Typical project parameters should include timescales, budgets, range of application, scope and authority. These should be recorded in a report and circulated and accepted by all key parties.

7.6 Analysis of Business objectives and business model generation

When considering an existing business and its process objectives, it is important to determine several things:

- Identification of organisation objectives
- Identification of critical success factors
- Identification of competitive dimensions

John McCall Architects had no documented business plan or roadmap of future objectives. This is typical of 60% of Architects (Hurst 2012). Planning is difficult for many architectural practices as they very much depends on the winning of external contracts which is unpredictable and market dependant. As a result of this running an architectural practice can be considered in most cases as a very speculative business or venture.

At John McCall Architects management of the company was undertaken through a series of monthly directors meetings. An understanding of the non-recorded objectives was elicited by interviews that were undertaken with the directors and senior members of the practice. The underlying vision of the company seemed to be strongly based on the concept of continuation along the line that the business had be conducted, organised and delivered in the past. That is undertaking domestic architectural services for housing developers and housing associations. But there was a realization that using existing models of operation need to be reconsidered in changing markets.

At John McCall Architects the business model canvas (Osterwalder 2010) was not used to understand the company. In hindsight this would have been an appropriate approach to use to gain an understanding and insight of the organisation. For this reason it is documented here. The research undertaken to gain similar information at John McCall Architects was undertaken through semi structured interviews.

Below the findings are document and structured into a business canvas model. The business model canvas contains nine building blocks (see figure 7.17).

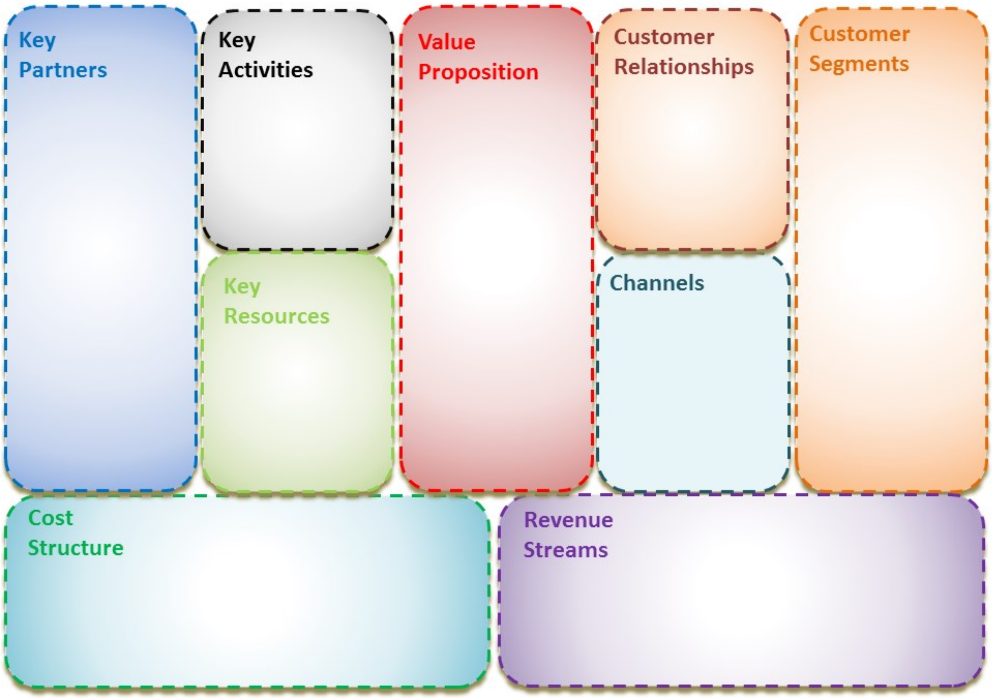


Figure 7.17: Example of a non-completed business model canvas (Osterwalder 2010)

We will consider each of these in turn in relation to the case study company John McCall Architects.

The customer segments define the different groups of people or organizations a company or practice aims to reach and serve. At John McCall Architect there was one predominant customer segment or niche market that of housing associations (see figure 7.18). The offer, distribution channels, types of relationship and profitability was similar with all these clients. At John McCall Architects there was a view among senior management that they understood the problems and values of their clients. This was to some extent confirmed by the repeat business which represented a major part of the practices workload.

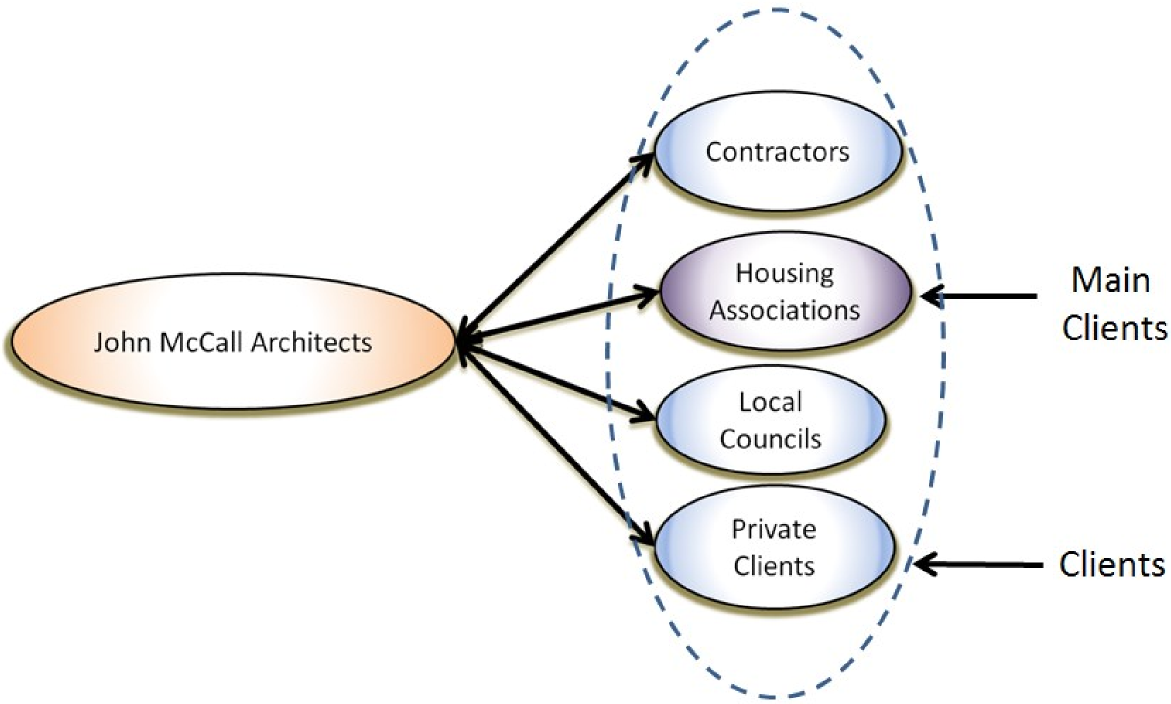


Figure 7.18: John McCall Architects Customer segments

Stakeholder analysis and how this was undertaken is dealt with in section 6.9.8 of this chapter.

The value proposition describes the bundle of products and services that create value for a specific customer segment. The introduction of BIM at John McCall Architects can be seen as a move to offer a new innovative value proposition. John McCall Architects prided themselves and was viewed by their clients to provide a high level of professional service. This was reinforced by developed design expertise in their chosen area. The value proposition can be seen to contain two elements. That is to provide a quality design for the client and to provide appropriate information for the contractor to translate those designs into a finished building (see figure 7.19). This reduces the risks to their clients. Cost of service is also an issue here.

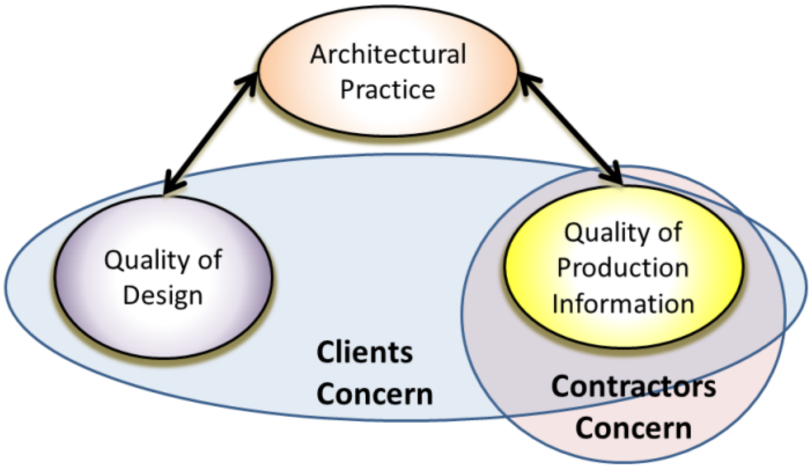


Figure 7.19: The value proposition of most architectural practices

Channels, describes how a company communicates with and reaches its customer segments to deliver its value proposition. John McCall Architects used their website and presentation at conferences to develop channels to their customers. Also as a result of John McCall Architects office being close to Liverpool Town centre it was easily accessible to clients and other consultants. This is an important factor which aids the collaboration necessary as part of building development.

Customer relationships described the types of relationships a company establishes with specific customer segments. John McCall Architects relies on customer retention part of this relationship is proving dedicated personal assistance and services to clients.

Revenue Streams represents the cash a company generates from each customer segment. In the housing sector there has been a move to framework tendering. This is where architects and other discipline submit a statement of the capabilities and unit rate. This is then used to decide whether they get one or more of the contracts available.

Key resources describes the most important assets required to make a business model work. The key resources at John McCall Architects is an intellectual resource distributed in different facets among the organisations constituent members of staff. Having the necessary knowledge resources and not over spending on them is a critical part of practice management.

Key activities describes the most important thing a company must do to make its business model work. The key activities at John McCall Architects are collecting information, problem solving and creating holistic solutions, production of construction information and connection or communication.

Key partnerships describes the network of suppliers and partner that make the business work. Although John McCall Architects was not engaged in any formal partnerships as such there was certainly a range of supporting prefer companies with whom they had work successfully in the past. The provision of BIM by a software supplier can also be considered as a key partnership.

Cost structure describes all the costs incurred to operate a business model. Certain elements at John McCall Architects were fixed costs such as premises overheads and printer provision. As the number of staff could be varied with the workload this was a variable cost element.

Using the information collected a business model canvas was developed (see figure 7.20).

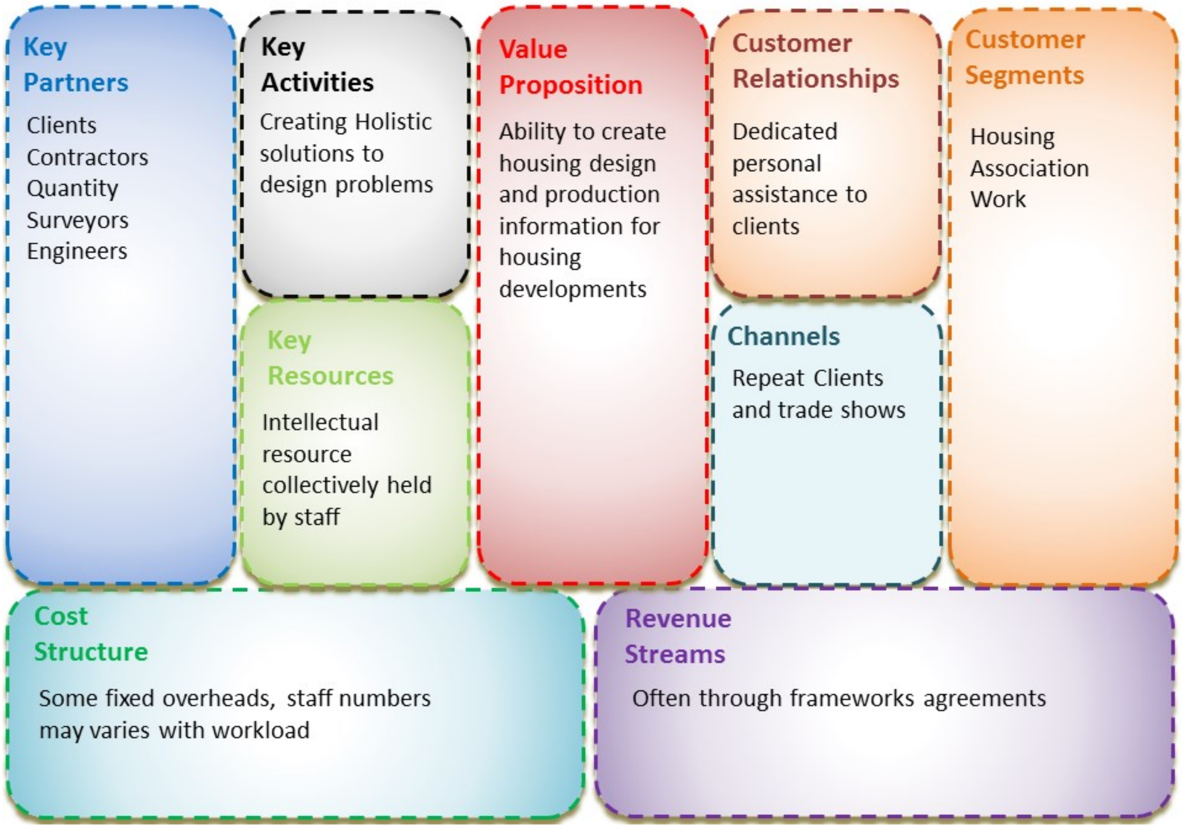


Figure 7.20: Business model canvas created subsequent to the action research being undertaken at John McCall Architects

The ideal use of a business model canvas is to develop discussion within the architectural practice. Different members of staff may have different views what these nine sectors are and what they should be in the future. The aim of this is to gain an insight into the practices current and future business models.

7.7 Analysis of current processes

The aim of this analysis is to unearth processes particularly those that are carryovers from older technologies and workflows. To do this we need to consider transformation, flow and value generation (Koskela 1999).

In most companies operational skill and efficiencies have been developed overtime. These may be to avoid certain problems or to gain operational efficiencies. When moving to a new approach such as BIM it is important to transfer these corporate capabilities to the new approaches being adopted (see figure 7.21).

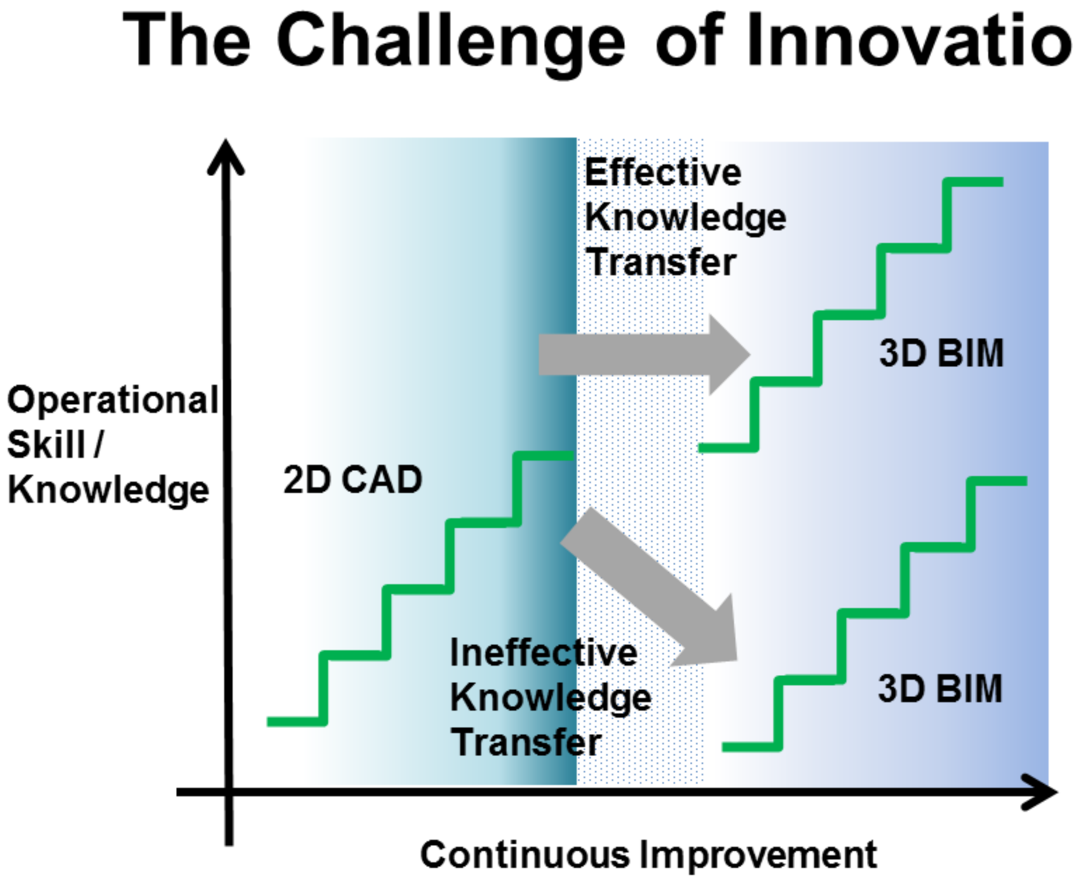
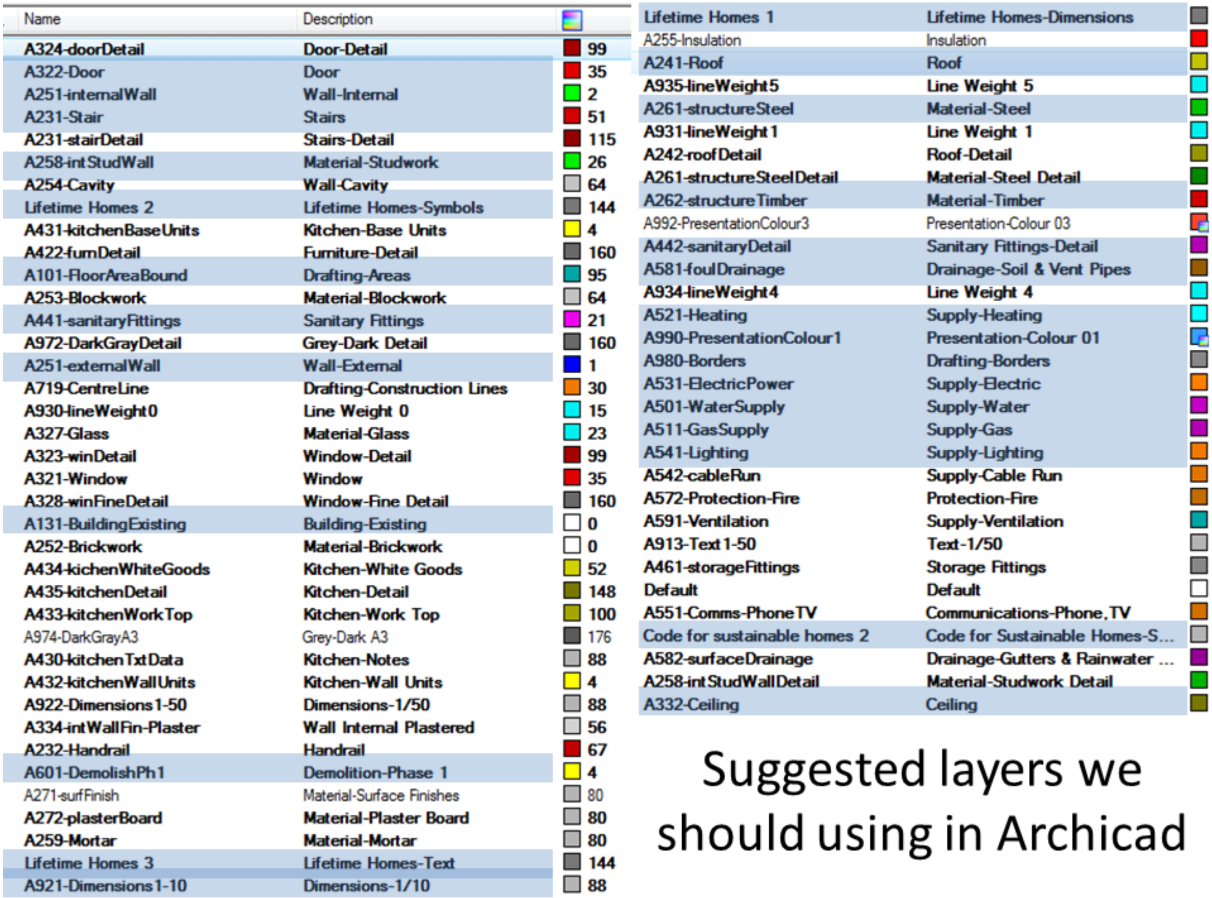


Figure 7.21: The move from CAD to BIM transferring existing knowledge

The above image was developed and used to explain to staff at John McCall Architects the importance of understanding existing process when undertaking a BIM adoption. There were many examples of where the old wisdom was applied to the new BIM process.

One such example was as a result of using Microstation V8i for drawing production. John McCall Architects had adopted file names, level naming and a directory structure. The investigation of the layers used in the existing Microstation CAD software and consideration of how they might be used in the new BIM system is an example of reviewing the old wisdom and applying to the new situation (BIM) (see figure 7.22).



Name	Description	
A324-doorDetail	Door-Detail	99
A322-Door	Door	35
A251-internalWall	Wall-Internal	2
A231-Stair	Stairs	51
A231-stairDetail	Stairs-Detail	115
A258-intStudWall	Material-Studwork	26
A254-Cavity	Wall-Cavity	64
Lifetime Homes 2	Lifetime Homes-Symbols	144
A431-kitchenBaseUnits	Kitchen-Base Units	4
A422-furnDetail	Furniture-Detail	160
A101-FloorAreaBound	Drafting-Areas	95
A253-Blockwork	Material-Blockwork	64
A441-sanitaryFittings	Sanitary Fittings	21
A972-DarkGrayDetail	Grey-Dark Detail	160
A251-externalWall	Wall-External	1
A719-CentreLine	Drafting-Construction Lines	30
A930-lineWeight0	Line Weight 0	15
A327-Glass	Material-Glass	23
A323-winDetail	Window-Detail	99
A321-Window	Window	35
A328-winFineDetail	Window-Fine Detail	160
A131-BuildingExisting	Building-Existing	0
A252-Brickwork	Material-Brickwork	0
A434-kichenWhiteGoods	Kitchen-White Goods	52
A435-kitchenDetail	Kitchen-Detail	148
A433-kitchenWorkTop	Kitchen-Work Top	100
A974-DarkGrayA3	Grey-Dark A3	176
A430-kitchenTxtData	Kitchen-Notes	88
A432-kitchenWallUnits	Kitchen-Wall Units	4
A922-Dimensions1-50	Dimensions-1/50	88
A334-intWallFin-Plaster	Wall Internal Plastered	56
A232-Handrail	Handrail	67
A601-DemolishPh1	Demolition-Phase 1	4
A271-surfFinish	Material-Surface Finishes	80
A272-plasterBoard	Material-Plaster Board	80
A259-Mortar	Material-Mortar	80
Lifetime Homes 3	Lifetime Homes-Text	144
A921-Dimensions1-10	Dimensions-1/10	88

Lifetime Homes 1	Lifetime Homes-Dimensions
A255-Insulation	Insulation
A241-Roof	Roof
A935-lineWeight5	Line Weight 5
A261-structureSteel	Material-Steel
A931-lineWeight1	Line Weight 1
A242-roofDetail	Roof-Detail
A261-structureSteelDetail	Material-Steel Detail
A262-structureTimber	Material-Timber
A992-PresentationColour3	Presentation-Colour 03
A442-sanitaryDetail	Sanitary Fittings-Detail
A581-foulDrainage	Drainage-Soil & Vent Pipes
A934-lineWeight4	Line Weight 4
A521-Heating	Supply-Heating
A990-PresentationColour1	Presentation-Colour 01
A980-Borders	Drafting-Borders
A531-ElectricPower	Supply-Electric
A501-WaterSupply	Supply-Water
A511-GasSupply	Supply-Gas
A541-Lighting	Supply-Lighting
A542-cableRun	Supply-Cable Run
A572-Protection-Fire	Protection-Fire
A591-Ventilation	Supply-Ventilation
A913-Text1-50	Text-1/50
A461-storageFittings	Storage Fittings
Default	Default
A551-Comms-PhoneTV	Communications-Phone,TV
Code for sustainable homes 2	Code for Sustainable Homes-S...
A582-surfaceDrainage	Drainage-Gutters & Rainwater ...
A258-intStudWallDetail	Material-Studwork Detail
A332-Ceiling	Ceiling

Figure 7.22: The review of the layers used in Microstation and consideration if they should be applied when using ArchiCad

Where similar systems and approaches are adopted it makes the transition for staff easier between CAD and BIM. ArchiCad is one BIM tool that uses layers other BIM tools such as Revit have not adopted this approach. The use of layers as well as objects gives another level of model filtering that can be utilized. Model filtering in most other BIM softwares is done by object type. The use of layers is discussed further in the section on BIM tool optimization in chapter nine. This is just one example of many where valuable existing knowledge was translated into new BIM processes.

Several methods were adopted to analyse the current process this included the development of rich picture, value stream mapping mind maps and process maps (see figure 7.23).

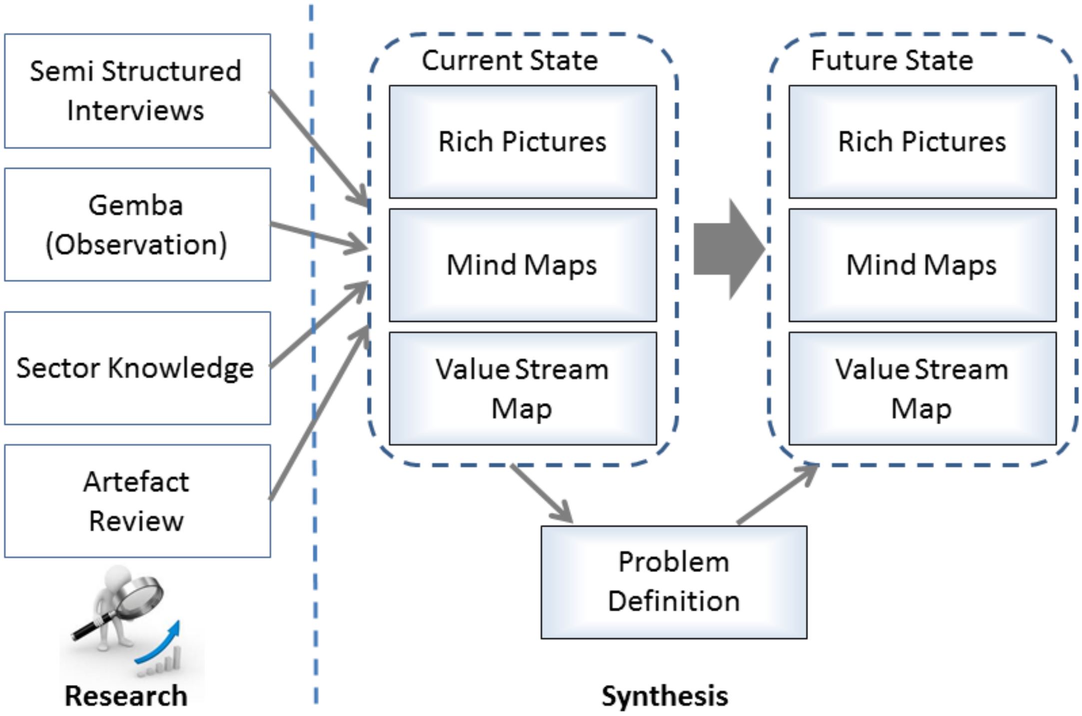


Figure 7.23: Methods adopted for analysis of the current process

The research was conducted by a series of semi structured interviews. These related to the different stages and roles undertaken. The lean “gemba” technique was used to gain an insight into the working practices. The gemba technique involves the research going to see for themselves in a typical workplace scenario. The researcher also carried out sector research and an artefact review which is documented later in this chapter.

Rich pictures were used as a method to investigate and understand the processes and activities undertaken at John McCall Architects (see figure 7.24).

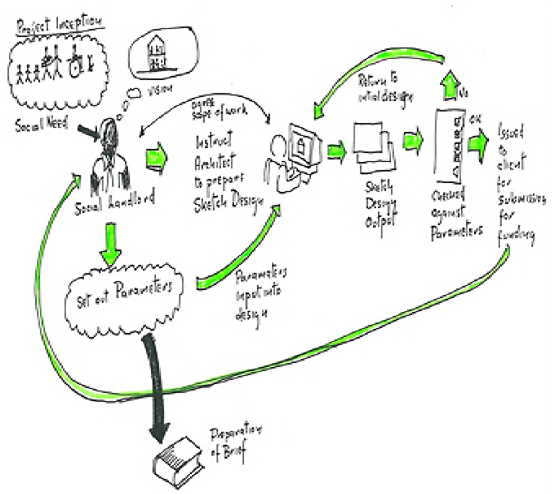


Figure 7.24: Rich pictures used at method of documenting and understanding the processes used at John McCall Architects

Rich pictures provide a mechanism for learning about complex or ill-defined problems by drawing detailed "rich" representations of them (Avison 1992). The advantage of rich pictures is that the whole meaning can be taken in at once, whereas textual languages must be digested in sequence.

The individual stages were further investigated from this Mind maps where also developed for all of the sub activities that took place at John McCall Architects (see figure 7.25).

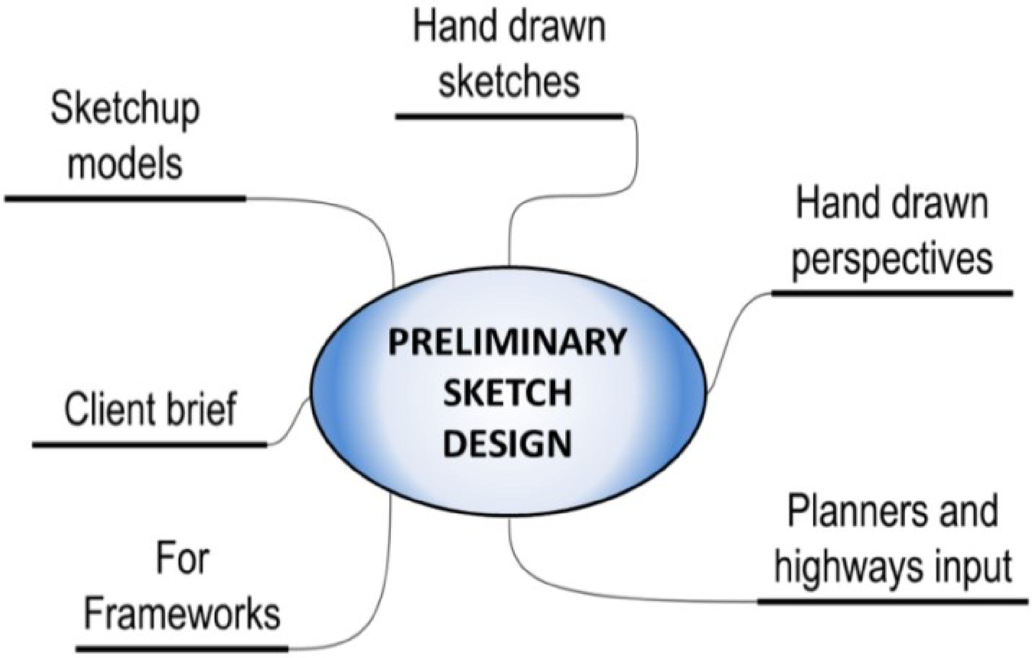


Figure 7.25: An example of a mind map generated during the analysis of John McCall Architects Processes

In figure 2.49 we have identified the collect, create, think and connect elements of the architectural operation. The RIBA has a plan of work which divides the work that architects undertake into phases. Yet the collect, create, think and connecting elements happen to varying degrees across all of the phases identified by the RIBA. Since its development first began in 1963, the RIBA Plan of Work has been the definitive UK model for building design, construction process, and has also exercised significant influence internationally. During the period of research the RIBA has issue a new outline plan of work which is designed to align to BIM (see figure 7.26).

The name RIBA plan of work is misleading in some respects because the plan identifies external outputs but not internal process. Perhaps it would be better described as a plan of deliverables rather than a plan of works. It is the internal process that determines the value embedded in the products generated.

The Plan of Work organises the progress of designing, constructing, maintaining and operating building projects into a number of key Work Stages. The sequence or content of Work Stages may vary or they may overlap to suit the procurement method, the project programme and the clients risk profile.

	RIBA Work Stages						
	1	2	3	4	5	6	7
	Preparation	Concept Design	Developed Design	Technical Design	Specialist Design	Construction	Use & Aftercare
Description of Key Tasks	- Identify **Project Objectives**, the client's **Business Case, Sustainability Aspirations** and other parameters or constraints and develop the **Initial Project Brief.** - **Examine Site Information** and make recommendations for further information, including surveys, required. - Preparation of **Feasibility Studies** and assessment of options to enable the client to decide how to proceed. - Determine client's **Risk Profile** and agree the **Project Programme** and preliminary **Procurement Strategy.** - Assemble **Project Team,** agree **Scope of Service, Contract Relationship** and **Design Responsibilities** for each participant. Develop **BIM** and **Soft Landings Strategies, Information Exchanges** and conclude **Appointment Documents.**	- Preparation of **Concept Design** including outline proposals for structural design, services systems, site landscape, outline specifications and preliminary cost plan along with environmental, energy, ecology, access or other **Project Strategies.** - Agree developments to **Initial Project Brief** and issue **Final Project Brief.** - **Review Procurement Strategy,** finalise **Deisgn Responsibility** including extent of **Performance Specified Design** and take action where required. - Prepare **Project Manual** including agreement of **Software Strategy, BIM Execution Plan** and extent of **Performance Specifed Work.** - Prepare **Construction Strategy** including review of off-site fabrication, site logistics and H&S aspects.	- Preparation of **Developed Design** including co-ordinated and updated proposals for structural design, services systems, site landscape, outline specifications, cost plan and **Project Strategies.** - Prepare and Submit **Planning Application** - **Implement Change Control Procedures,** undertake **Sustainability Assessment** and take actions determined by **Procurement Strategy.** - Review **Construction Strategy** including H&S aspects.	- Preparation of **Technical Design** information to include all architectural, structural and mechanical services information and specifications including the **Lead Designer's** review and sign-off of all information. - **Performance Specified Work** to be developed in sufficient detail to allow development and integration by **Specialist Subcontractors** during **Completed Design** stage. - Take actions determined by **Procurement Strategy** including issuing in packages where appropriate. - Prepare and submit **Building Regulations Submission** - Review **Construction Strategy** including sequencing, programme and H&S asepets.	- Progression of **Specialist Design** by **Specialist Subcontractors** including the integration, review and sign-off of **Performance Specified Work** by the **Lead Designer** and other designers as set out in **Design Responsibility** document - Review **Construction Strategy** including sequencing and critical path. - Undertake actions from **Procurement Strategy** or administration of **Building Contract** as required.	- Offsite manufacturing and onsite construction in accordance with the **Construction Programme** - Regular review of progress against programme and any **Quality Objectives** including site inspections. - Administration of **Building Contract..** - Resolution of **Design Queries** from site as they arise - Implementation of **Soft Landing Strategy** including agreement of information required for commissioning, training, handover, asset management, future monitoring and maintenance and ongoing complilation of "as-constructed" information.	- Implementation of **Soft Landings Strategy** including **Post Occupancy Evaluation.** - Conclude administration of **Building Contract** - Review of **Project Performance** in use and analysis of **Project Information** for use on future projects. - Updating of **Project Information,** as required, in response to **Asset Management** and **Facilities Management** feedback and modifications.
Procurement	The stage 1, 2, 3 and 4 outputs may be used for tendering and contract purposes depending on the **Procurement Strategy** as influenced by the clients **Risk Profile,** time, cost and quality aspirations and how **Early Contractor Involvement** and **Specialst Subcontractor** input is to be undertaken.						
Programme				Stage 4, 5 and 6 activities may occur concurrently depending on the **Procurement Strategy.** Work may also be undertaken in packages to facilitate its development by **Specialist Subcontractors.** Early package procurement may also occur during stage 3 depending on the procurement route. The **Project Programme** should set out the timesscales for these overlapping design and, where appropriate, construction stages.			
Planning		**Planning Applications** typically be made using the stage 3 (**Developed Design**) output, however, certain clients may wish this task to be undertaken earlier. The project or practice specific **Plan of Work** identifies when the **Planning Application** is to be made. Certain aspects of the **Technical Design** may also be required as part of the application or in respond to planning conditions.					
Key Information Exchanges (at stage Completion)	**The Initial Project Brief**	**The Concept Design** including **Outline Structural and Mechanical Services Design,** associated **Design Strategies, Preliminary Cost Information** and **Final Project Brief.**	**The Developed Design** including the **Co-ordinated Architectural, Structural and Mechanical Services Design** and **Developed Cost Information.**	**The Technical Design** of consultant aspects in sufficient detail to enable construction or **Performance Specified Work** to commence.	**The Specialist Design** including the integration of **Performance Specified Work.**	**"As Constructed" Information.**	**"As constructed" Information** updated in response to on-going client feedback, **Asset Management** updates and **Facilities Management** information.
Government Gateway	Information Exchange 1	Information Exchange 2	Information Exchange 3			Information Exchange 6	As Required

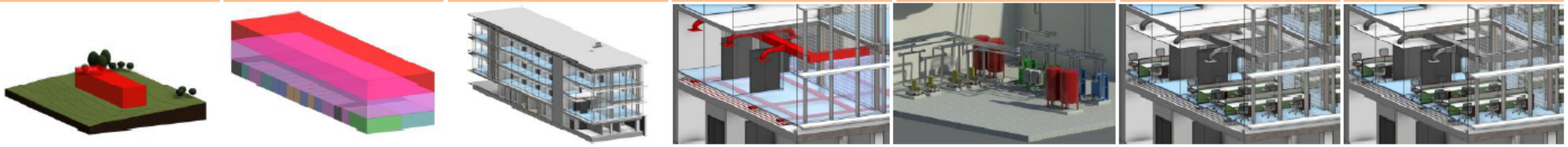


Figure 7.26: The proposed draft outline of the new RIBA plan of work (RIBA 2012)

Organisations such as John McCall Architects and members of those organisations often have a simplistic view of the processes that actually take place. This can partly be attributed to the fact that tacit knowledge is often applied to achieve the necessary results. In the case of architects this tacit knowledge is developed over a period of seven years of professional training). This is augmented by knowledge developed while working in practice. Much of the tasks undertaken are characterized by repetition. For most people, approximately 45% of everyday behaviours tend to be repeated in the same location almost every day (Neal et al 2006).

The iterative process of design is also problematic to define in terms of a standard process map. In development terms it is not possible to automate what you don't understand. The C to K theory (Hatchuel 1996) seemed to best explain what was taking place in the design development process. In order to fully understand what is actually taking place was necessary to externalize tacit knowledge.

Process analysis is an approach that helps managers improve the performance of their business activities. It can be a milestone in continuous improvement (Trischler 1996). Process analysis is step-by-step breakdown of the phases of a process, used to convey the inputs, outputs, and operations that take place during each phase. A process analysis can be used to improve understanding of how the process operates, and to determine potential targets for process improvement through removing waste and increasing efficiency.

Value stream mapping techniques can be used to extract a knowledge of the processes from the practice operatives. Value stream mapping is a lean manufacturing technique used to analyse and design the flow of materials and information required to bring a product or service to a consumer. The process involves identifying tasks and determining the best order with which to undertake said tasks. An example of a value stream map exercise is indicated (see figure 7.27). Post it notes are used to record processes. These provide a flexible method to reorganise processes into the most efficient arrangement. This can then be developed as a formal process map.

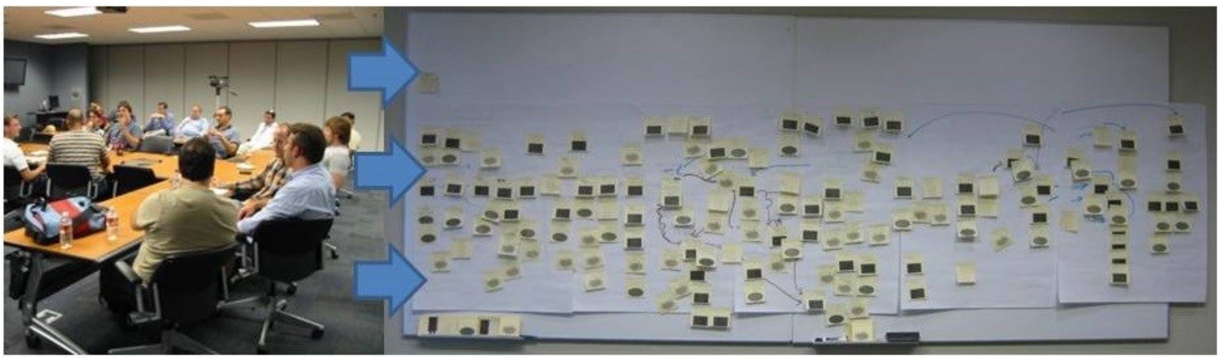


Figure 7.27: An example of the result of value stream mapping

As part of the value stream mapping process it may be possible to achieve the following:

- New types of building information that architectural and other disciplines can share
- Achieve a better understanding of how information flows through the architectural design and development process
- Identify any intermediary information exchange that might be beneficial
- Opportunities to eliminate overlaps or redundancies
- Identify any information exchanges that might accelerate iterative workflow cycles

The value stream mapping exercise was undertaken at John McCall Architects but unfortunately the directors were not prepared to allow the staff much time to be involved in the exercise. (Staff time was the critical restricted resource throughout the whole BIM implementation).

In order to understand the activities undertaken at John McCall Architects a flowchart was produced of the typical interaction of John McCall Architects with other parties and disciplines. This is a starting point to an understanding of what an architectural practice does and what methods are currently utilize to deliver the products or services. In addition, clearly stated objectives help to refine the desired outcome of an analysis of the business systems.

To achieve this it was necessary to look at the 'who' (people involved); 'what' (business activity); 'where' (work environment); 'when' (timing/sequence); and 'how '(current procedures) of the selected areas of the business. In addition to this, it is necessary to understand why business is currently conducted in this manner.

Semi-structured Interviews with directors, associates, architects and technicians were conducted and their comments, issues, and desires for improvements documented. Semi-structured interviews are conducted with a fairly open framework which allow for focused, conversational, two-way communication. The comments from these interviews were then built into the new BIM implementation plan. Group discussion also provided a rich source of ideas and concepts.

The flowchart illustrates the many formal exchanges of information and instruction using the traditional procurement approach. Many informal exchanges of information may also occur. What is clear from the information flows is that it is usually the client and the architect who are involved over the majority of building stages (see figure 7.28 Appendix A). Sub processes were again investigated with small pictorial diagrams (see figure 7.29). These were then presented and discussed with the various members of staff.

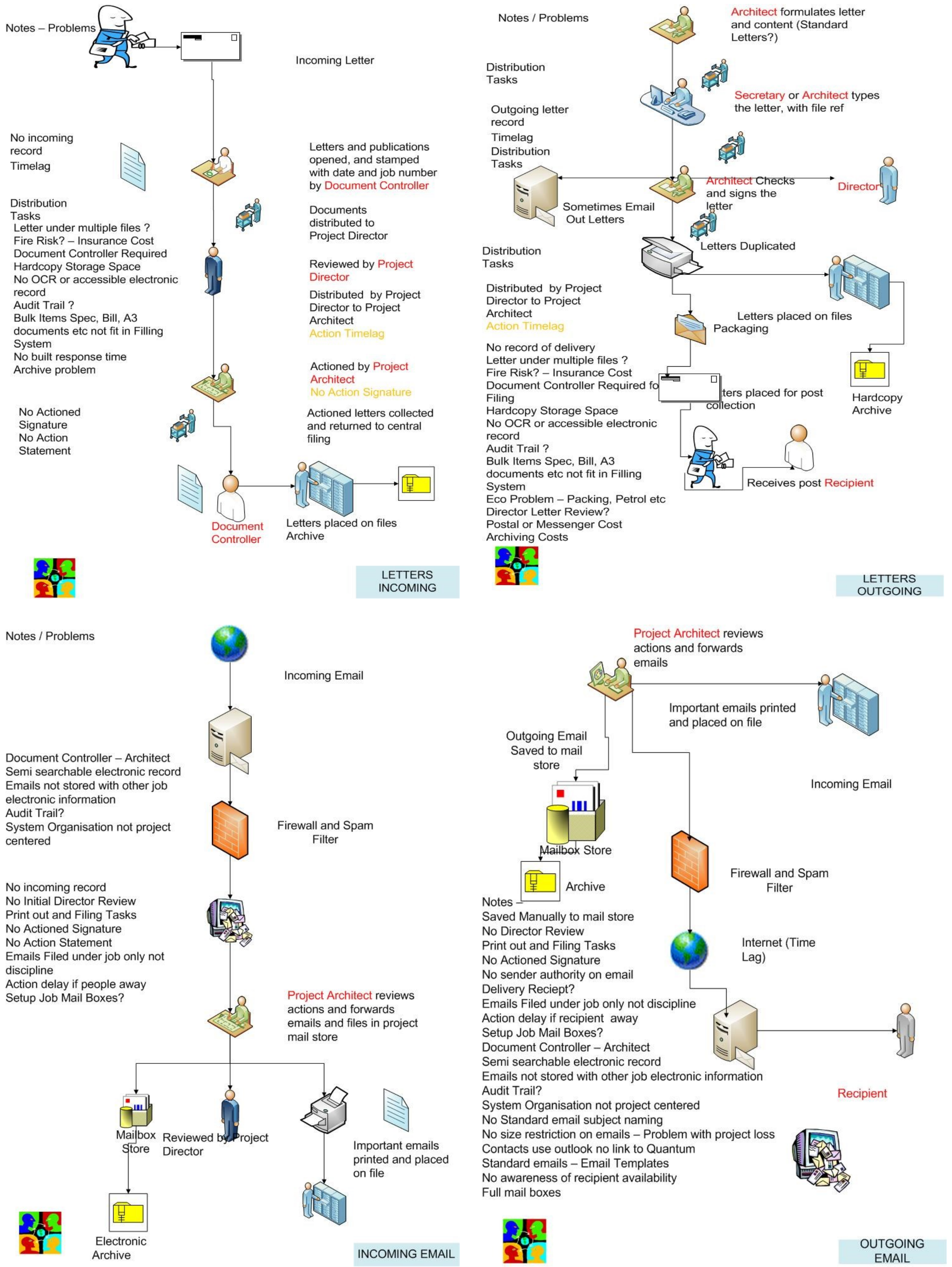


Figure 7.29: Investigation of the existing process

After the process map was completed further analysis was undertaken to determine where BIM could be used to advantage (see figure 7.30). These findings were then used as a guide when writing the BIM implementation plan.

Figure 7.30: Further analysis undertaken on the architectural process map to identify the benefits of using BIM

7.8 Analysis of Data handling

One view of BIM is that it embraces all of the information in relation to a project. This is the view adopted by Skanska (a major international contracting organisation) (see figure 7.31).

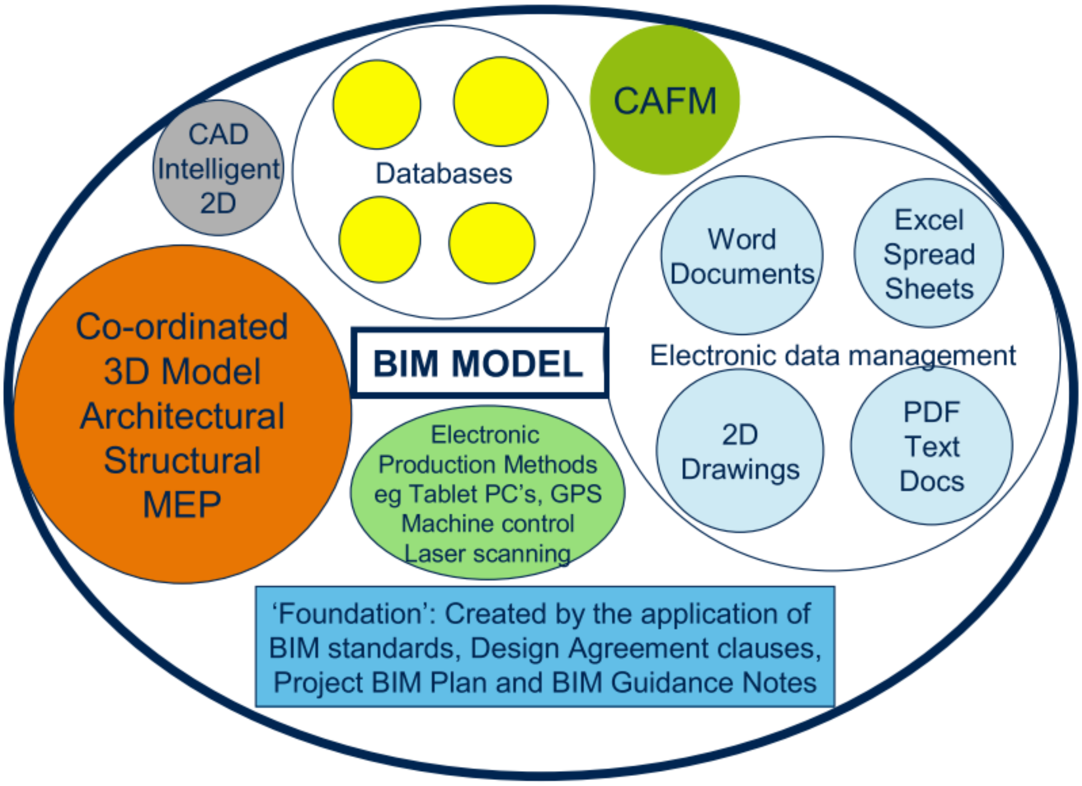


Figure 7.31: The Skanska BIM model (Jeffrey 2012)

Taking this view, looking at an architectural practice holistically at a data handling level is useful to provide an understanding when adopting BIM. Problems of data and data handling are central to the architectural deliverable process. If these problems can be successfully resolved and major gains can be achieved within the architectural practice and to external disciplines. Common problems that exist in architectural practices when dealing with data are:

- Uncontrolled or redundant data (data that may be out of date or no longer current)
- Data that is not easily accessible by the user (data that is not searchable or archived or data that is embedded in other documents)
- Lack of knowledge of the data that is available (data on different projects, data produced by different people)
- Poor data quality (data that is incorrect or inaccurate)
- Separate data stores (hard and soft copy)
- Inconsistent output (the same data input in different ways)

All of these issues were found at John McCall Architects and occur to some extent in all architectural practices. BIM represents a different way of looking at how information / data should be integrated into and shared across construction projects.

Architectural practices may not be able to control how information is controlled and utilized across the whole building lifecycle but they can control what happens within their own organisation. Thus considering practices at an informational and data level is important when developing how BIM is to be implemented.

John McCall Architects provides many deliverables and communications as part of its role in the development and construction process and the associated information was at the time of research very fragmented. This use of multiple informational forms and formats is typical across the construction sector. This means that the data is often duplicated in multiple documents, formats and files (see figure 7.32 and figure 7.33).

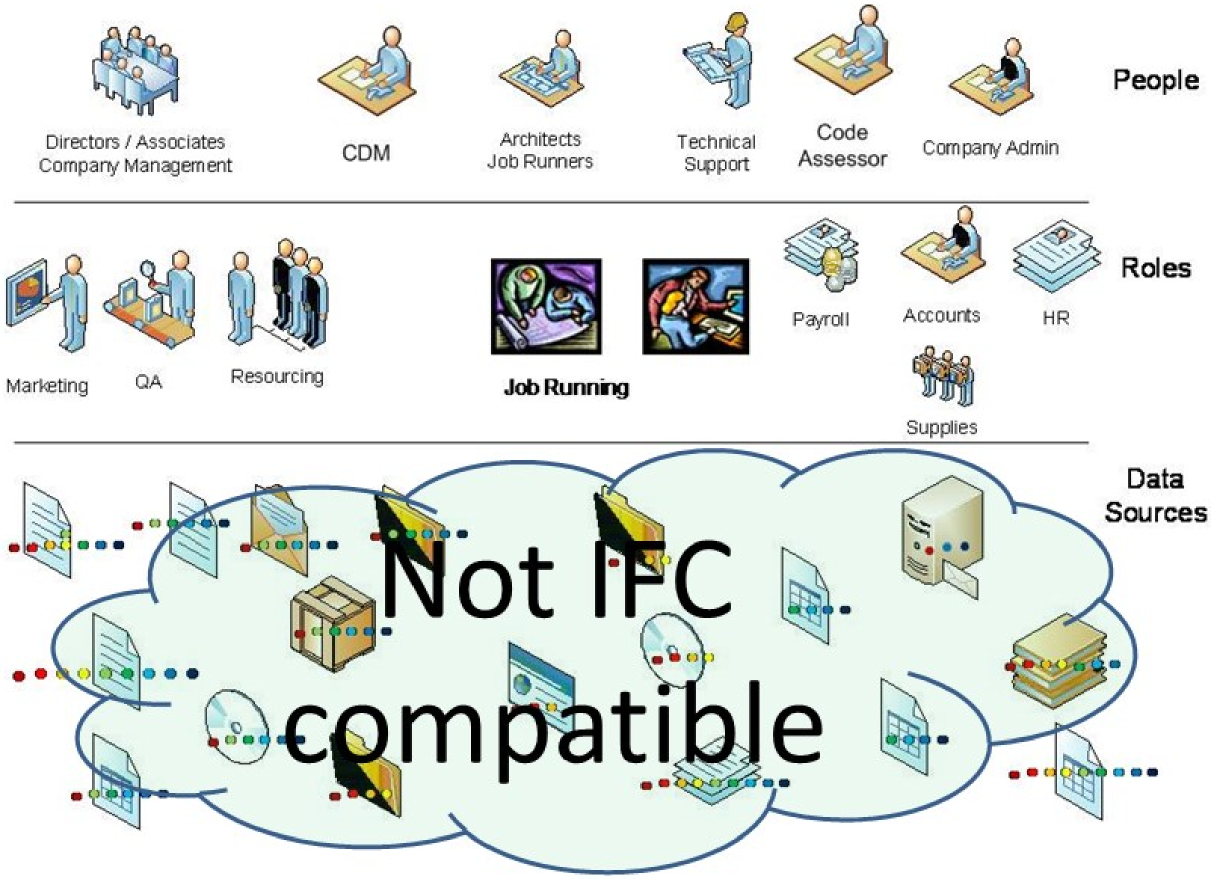


Figure 7.32: Data duplicated and store in multiple file types at John McCall Architects

Figure 7.33: Showing different file types and the duplicate data they contain

The full resolution of theses informational problems are issues of enterprise architecture which was discussed in chapter five. They are important to noted and be aware of so improvements can be adopted where possible. In future we may see a move from model data management to holistic data management where all data types are managed and integrated (enterprise architecture).

The conclusion of this research was that certain data by its nature should reside with the 3D BIM graphical data model and certain data should reside outside of the BIM graphical data model (see figure 7.34).

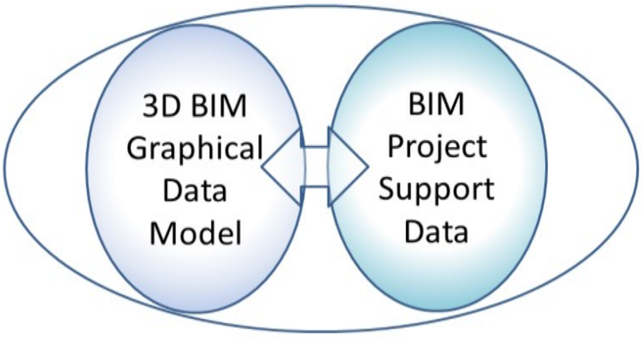


Figure 7.34: 3D BIM graphical data model and BIM project support model

As a result of this research it was decided that the researcher should develop a database for John McCall Architects. By doing this, a move from using documents to using data was instigated. Also it was decided to introduce several systems of electronic document management to better store the project data (see figure 7.35 Appendix A).

The concepts behind the development of the database were documented on an A3 sheet (see figure 7.36 Appendix A). The structure of the database developed is shown (see figure 7.37 Appendix A). BIM relies on data being in electronic format. This outcome is beyond the typical BIM implementation which are normally focused around graphical BIM tools. Subsequent research has development methods of linking these project databases with the BIM data from traditional BIM graphical tools. These outcomes are not documented here because they are believed to be beyond the focus of this thesis but indicate the wider issues and potential of ICT in architectural practice. It is also unlikely that the programming skills necessary to develop such databases would be readily available in many small architectural practices.

There were three different types of data models produced while progressing from requirements to the actual database to be used at John McCall Architects. Firstly the data requirements are initially recorded as a conceptual data model. This is a set of technology independent specifications about the data and its use. This is gained through discussions with members of staff and the company directors.

This conceptual model is then translated into a logical data model, which documents structures of the data that can be implemented in the database or databases.

Then the logical data model to a physical data model that organizes the data into tables, and accounts for access, performance and storage details. Data modelling defines not just data elements, but also their structures and the relationships between them.

The database developed at John McCall Architects was a distributed MS Access database using VBA scripting to provide functionality. A runtime engine allows the database to be accessed simultaneously on all the workstations within the practice.

The database was developed at John McCall Architects for the following reasons.

- So all important information on projects could be stored in a standardized form.

- So data can be searched and filtered on projects to find projects undertaken of a specific type.

- So directors can easily monitor projects and be informed of outstanding requirements

- So we have a historic record of projects undertaken even after other project data is archived.

- To automate the email process so job names and project numbers are automatically included in emails.

First a holist view of the practice database was developed (see 7.38). One aim of the database was to develop a system providing a central resource of quality information (see figure 7.39). This was not realized. The final resultant database developed at John McCall Architects is shown (see figure 7.40 Appendix A).

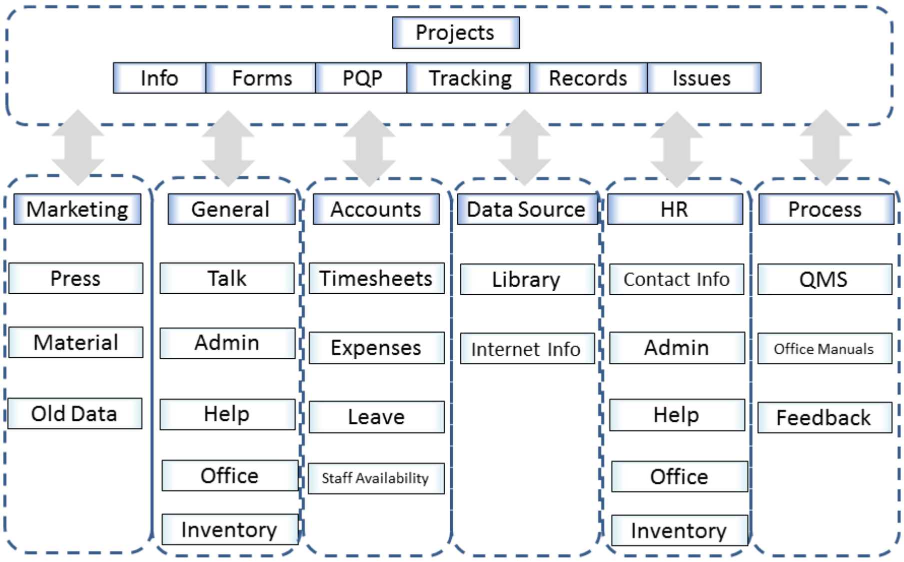


Figure 7.38: The overall structure of a practice database defined

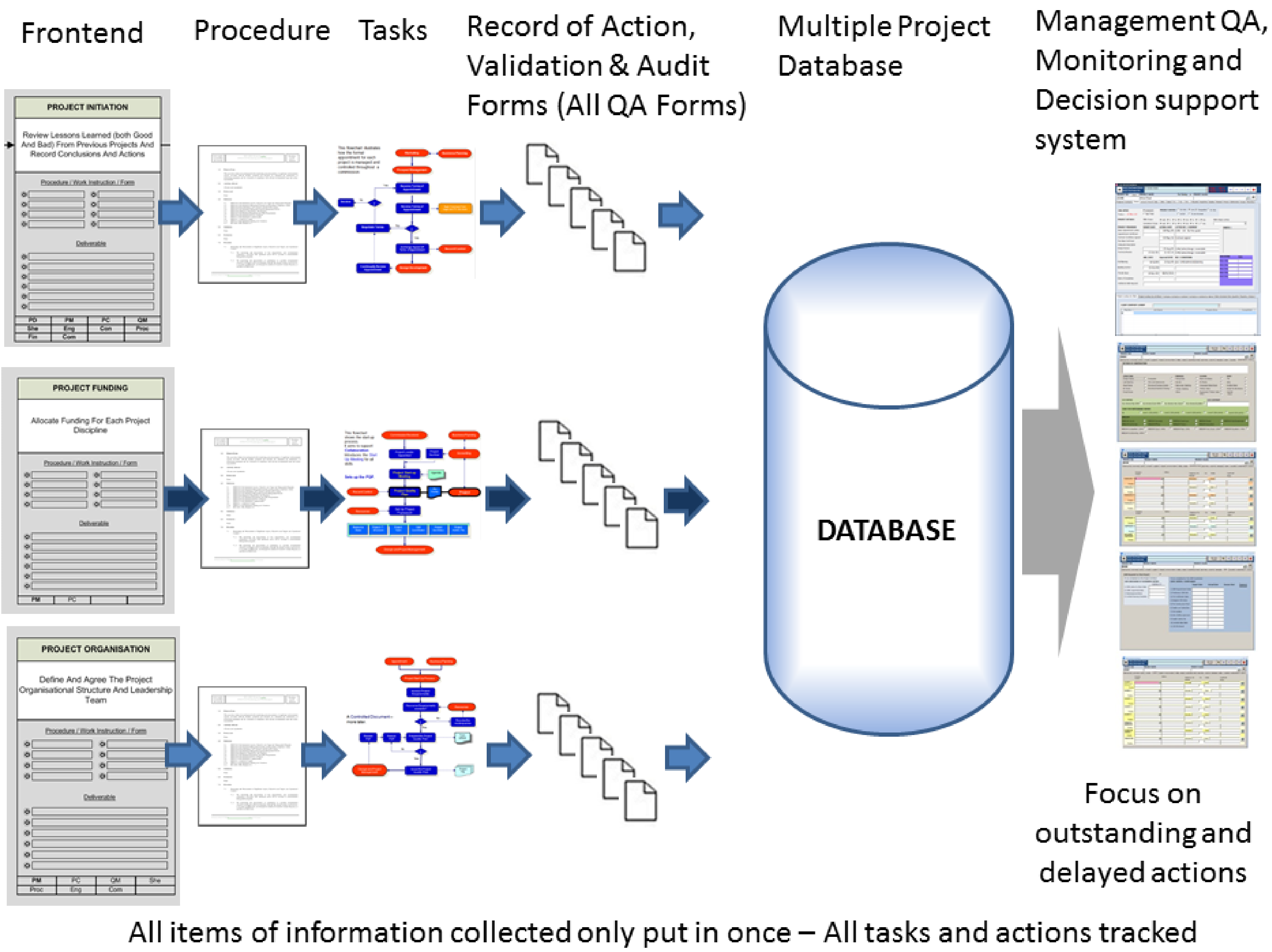


Figure 7.40: Showing the principle of a database being used to maintain quality information

Several presentations concerning the database were given to the staff at John McCall Architects. One of the slides used to explain responsibilities when using the database is shown (see figure 7.41).

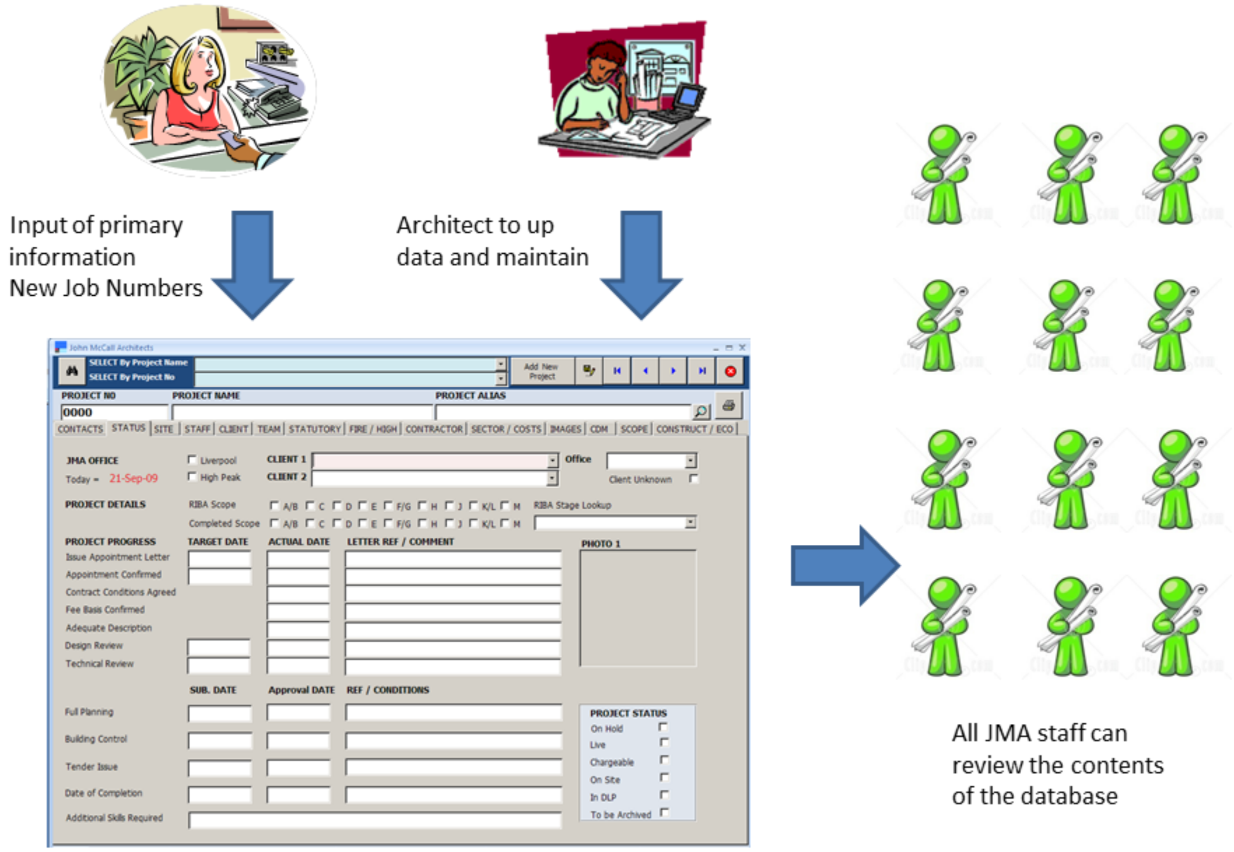


Figure 7.41: A diagram of the inputs and multiple outputs from the database developed at John McCall Architects

The database developed was integrated with the MS Exchange server. This enable d emails to be issued from and managed through the database. The following stage was to generate standard correspondence with fields populated from the database. It was not possible to undertake this further development within the time scales of the research period. The database developed remains in use at John McCall Architects. Plans were also developed at John McCall Architects to integrate all of the databases that existed into a single data environment (see figure 7.42).

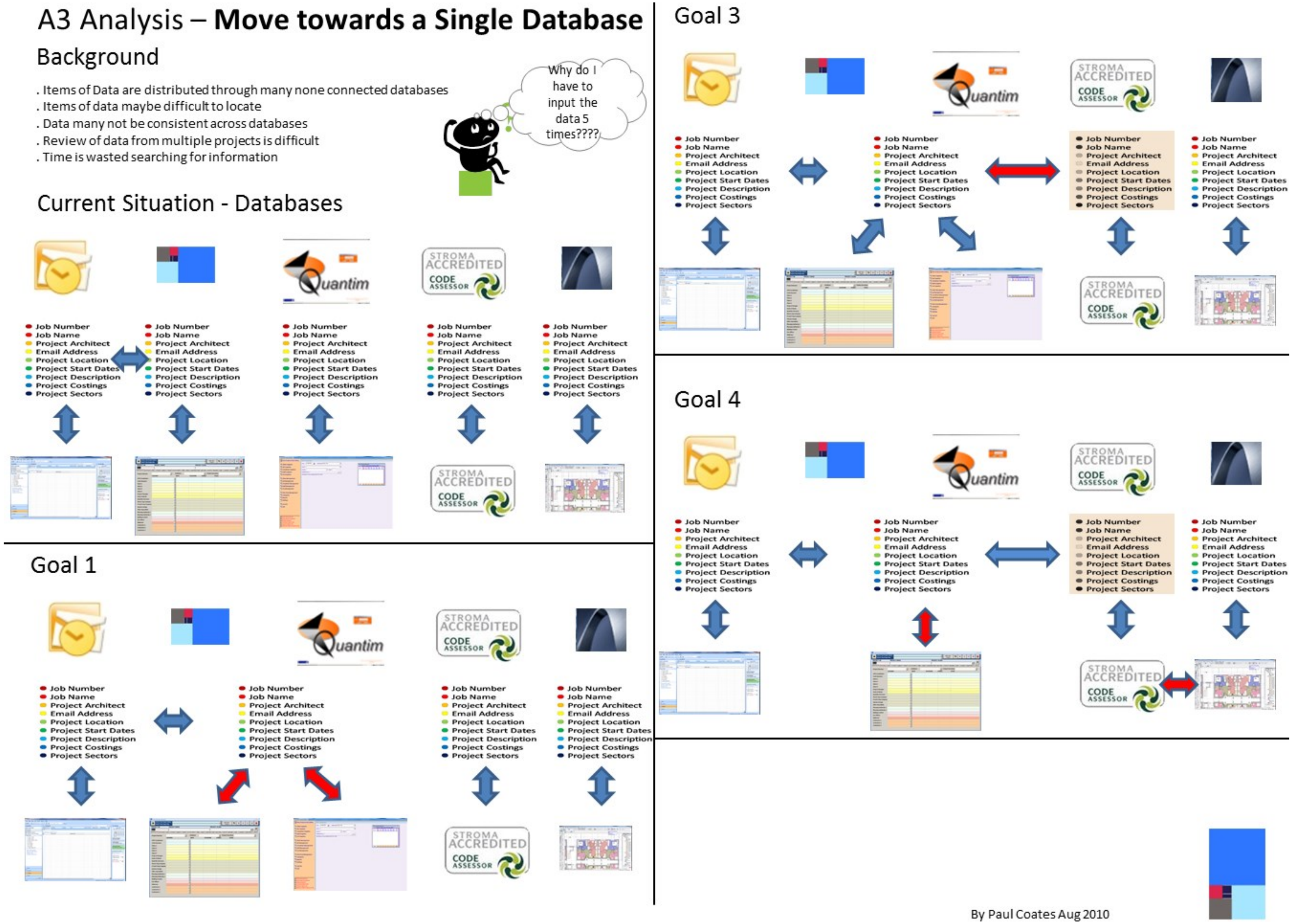


Figure 7.42: Creation of a single database environment from all of the databases at John McCall Architects

Subsequent to the research at John McCall Architects enhanced versions of the database have been developed by the researcher utilizing and visualizing IFC data generated from BIM graphical tools.

It is the view of the researcher that BIM in the future will evolve into a data management system integrated with a range of associated enabling technologies.

7.9 To determine Current Best practice and Benefit Analysis

A best practice is a method or technique that has consistently shown results superior to those achieved with other means. Best practice is the aspirational benchmark that companies may wish to achieve.

The problem and advantage of best practice is that often superior practices are developed within organization but because they represent a competitive advantage therefore they are not shared to other organizations. There are those who suggest best practice should be called contextual practice because what is the best course of action is dependent on context (Ambler 2011). Only when staff transfer between organizations is best practice shared. Several strategies were developed to gain a better understanding of best practice in small architectural firms (see figure 7.43).

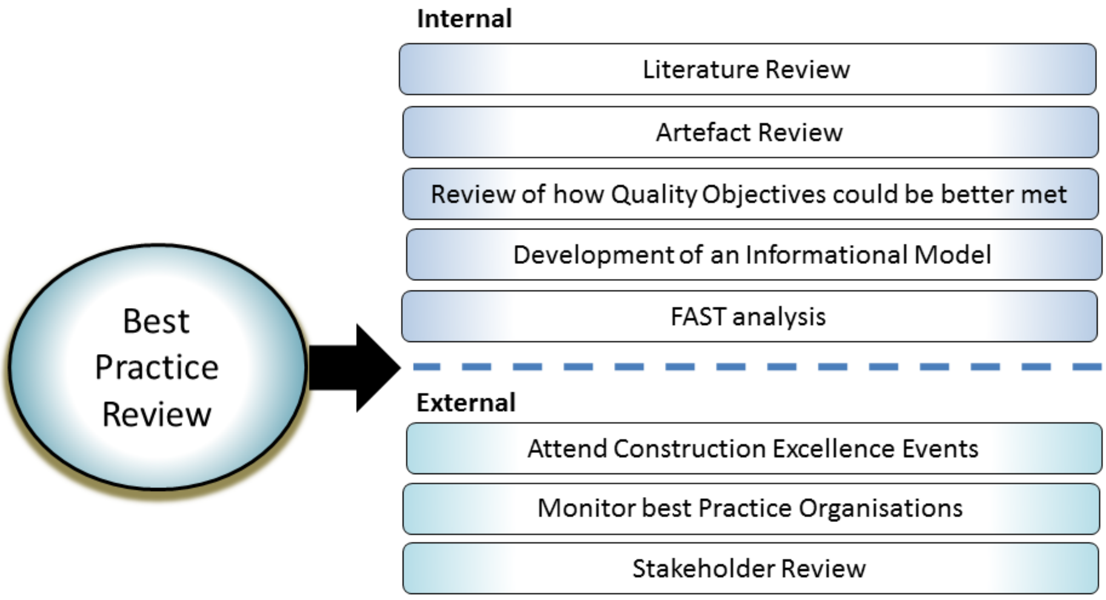


Figure 7.43: Methods adopted to determine best practice

7.9.1 Literature Review to determine Best Practice and benefit analysis

Much of the literature review undertaken as part of the BIM implementation at John McCall Architects is recorded as chapter two and chapter three of this thesis. These documented many aspects of best practice. Best practice is a feature of accredited management standards such as ISO 9000 and ISO 14000. ISO 9001 2008 documents quality system requirements. Although, there are arguments for adopting a proactive rather than a reactive approach. John McCall Architects were registered against the ISO 9001 standard. This allowed them to bid for certain projects were ISO 9001 was a precondition.

ISO 14000 is a standard for environmental management. ISO 14001 sets out the criteria for an environmental management system against which it is possible to be certified. John McCall Architects at the time of the research were not registered against ISO 14001 but were considering becoming registered. This lack of registration in no way indicates a lack of concern and knowledge in the area of sustainable issues, which were fundamental to the designs and their method of production in the company. The company had adopted many of the methods and practices necessary for ISO 14000 certification.

Lean and lean engineering also represents an area of developing best practice. The relation of BIM, best practice and lean has been documented in chapter three. This area of research provided many pointers on how an effective BIM system should be developed. This was documented in chapter three of this thesis.

The researcher was also able to bring his own experience of best practice and not so good practice having historically worked for several other architectural firms.

7.9.2 Artifact Review

Adopting an artifact centric approach enables rich, natural communication among diverse stakeholders about operations and process (Cohn 2009).

Artifacts are defined by the following properties:

a) Physical or virtual form

b) Shelf Life and time of influence

c) Accuracy

d) Objectiveness (addressing an issue) and the fit for purpose:

e) A Creator or Developer

f) Perceived recipient and method of communication

g) Codes and Standards

h) Ease of creation

i) Responsibility

j) Operate as a Stepping stone

k) Standalone Value

l) Static and responsive artifacts

m) Orphaned or connected: sometimes an artifact is an orphan and sometimes it remains connected to its source

In order to start to understand architectural practice we can look at the artifacts it produces. The traditional practice in small architectural firms is using a file based system not a data based system. The use of CAD is often the main tool of graphical production. The output tends to be drawings and documents as artifacts. An artifact is one of many kinds of tangible by-products produced during the building development. Artifacts often represent how information and concepts are transferred in the traditional architectural process. Below shows the artifact review of drawings produced on Edith Street at John McCall Architects (see figure 7.44).

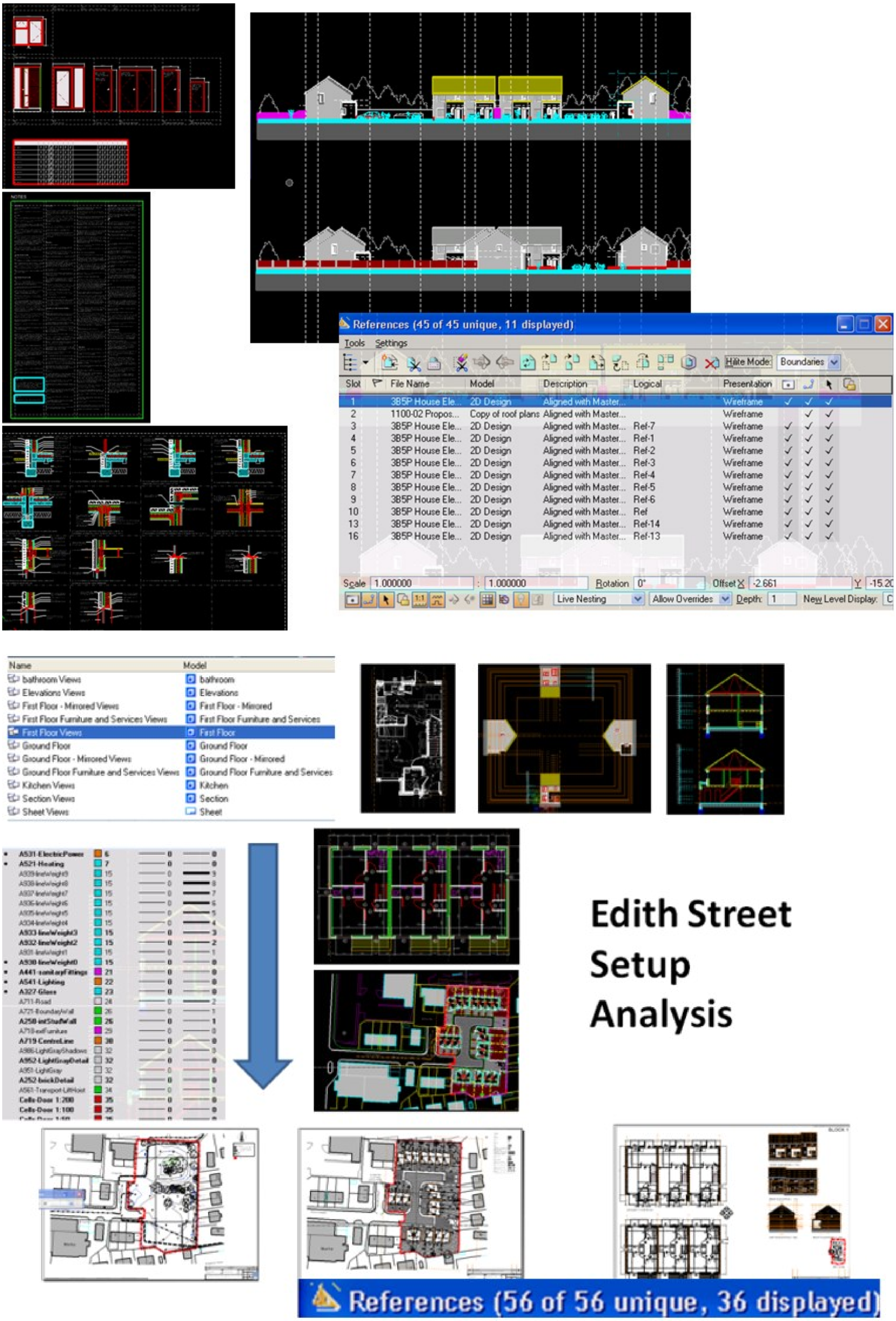


Figure 7.44: Records taken of the artifact review of the Edith Street Project

Often artifacts are also boundary objects and need to be suitable for the needs of several parties. Boundary objects allow different groups to collaborate on common tasks (see figure 7.45 and 7.46). Using an open-systems perspective, boundary theory assumes that an organization depends on its environment for critical resource inputs, as well as for the disposal of its outputs (Aldrich and Herker 1977). From this perspective, a central challenge for organizations is to manage their boundaries with other organizations. An organizational boundary represents the domain of effort in which an organization interacts with its environment to survive (Aldrich and Herker 1977).

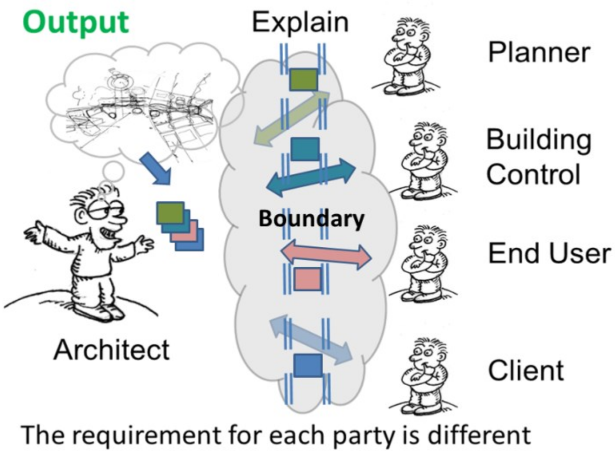


Figure 7.45: The architect providing different model output to different parties

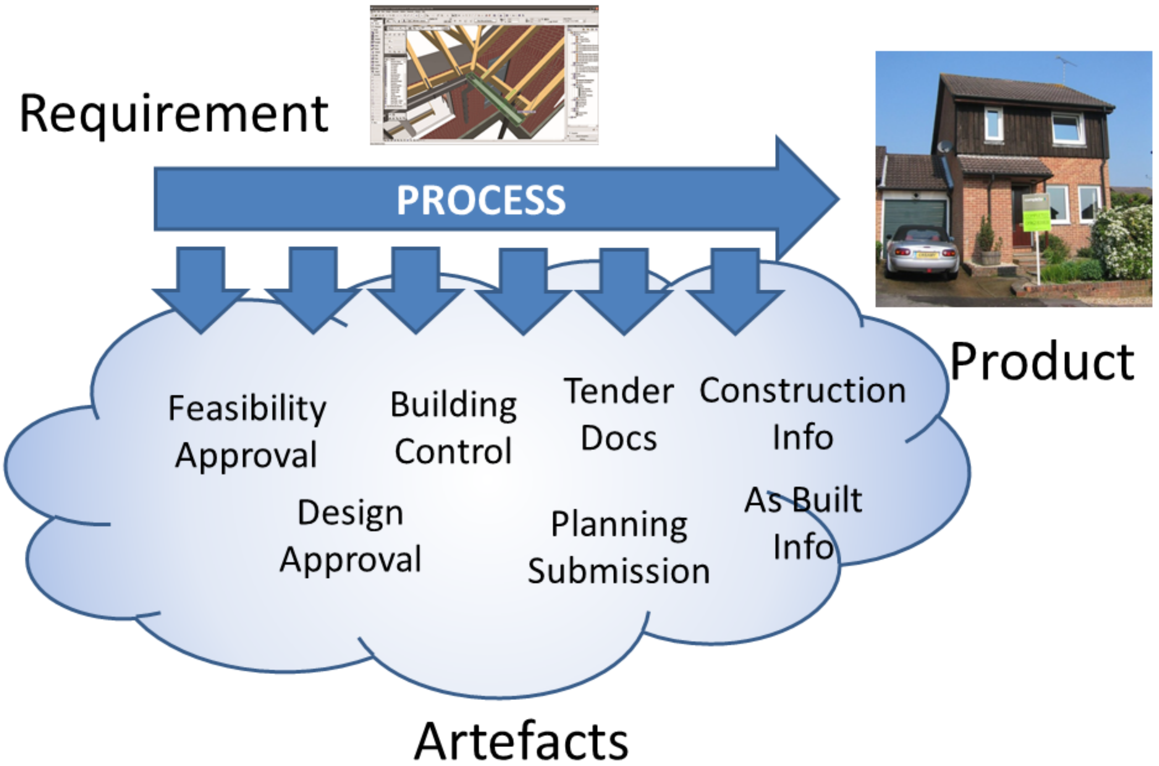


Figure 7.46: Artifacts produced during the architectural development process

Research into the artefacts produced at John McCall Architects involved review of historic documents and engaging in a dialogue with architects working within the company. Artefacts created and identified at John McCall Architects included models, sketches, sample boards, videos, drawings, specifications, bills of quantities, outline and full planning submission documentation (see figure 7.47), building control submissions, CDM submissions, contracts, programs and construction plans of work and as built documentation. These are generated manually or by a range of computer programs. The specific artefacts required depend on and are determined by the project and method of procurement.

Figure 7.47: Shows a typical planning submission drawing set produced using CAD by John McCall Architects

This is why BIM may not be fully adopted without the development of new BIM aligned methods of procurement. The professional bodies are currently developing these new procurement methods.

Artefacts are often used as milestones and are often used as approval points on projects. Delivery of artefacts can also relate to the points at which invoices are raise to the client.

The format and contents of the artifacts produced is potentially determined by recipients and the client. This would provide an artifact aligned to the recipient requirement. Sometimes the formats are prescribed at the outset in the terms of agreement. Surprisingly little definition of the form the artifacts are to take is stipulated by external parties.

An example of this is how building control or planning documentation can be completed in many different ways. Although the Town and Country Planning (General Development Procedure) Order 1995 sets out a statutory list of information that is required to accompany planning submissions.

These are all properties that need to be built into a BIM information management system so artifacts can be appropriately managed. These facets are dealt with by B.S. 1192.

Architects produce two major types of artifacts:

- Artifacts developed to gain approval
- Artifacts developed to facilitate construction and the work of others

Breaking down the informational silos and enabling multiple disciplines being able to work more effectively together is one of the stated roles of BIM (Varkonyi 2009). Arno Schlueter proposed that the biggest obstacle for architects to adopt BIM methods is the tentative use of BIM by other industry partners such as engineering firms (Schlueter and Thesseling 2009). An organization can only truly know if it is implementing BIM in an appropriate way when the information it is place into models and the models themselves are being effectively used by other disciplines.

Table 7.01 shows the differences between non BIM, BIM and intelligent BIM artifacts.

Artifact	Non BIM Artifact	BIM Artifact	Intelligent BIM Artifact
Feasibility Report	Hand sketches, basic costing from areas.	Massing Model, basic costings generated from the model	Bidirectional model and costing information with decision support system
Preliminary Sketch Design	Sketchup model, material lists and costings from areas	3d database, with areas volumes and materials and costs	Multidiscipline collaborative models with intelligent feedback
Final Sketch Design	Sketchup model and plans in powerdraft, material list and costings from areas	3d database, with areas volumes and materials and costs	Multidiscipline collaborative models with intelligent feedback
Planning Design	CAD drawings created from 2d representations, materials noted on drawings	3d database, with areas volumes and materials and costs, with non-required information removed, planning specific info added	Models that can be placed in context allowing review in virtual reality
Detailed Design	Plans, sections, elevations and details produced as 2d representations and outline specification, colours, finishes and buildability	3d database – details extracted and worked up in 2d, schedules generated direct from the database	Links to product information databases and supplied specification and direction. Link to sustainability database and design for manufacture considerations
Production Information	Plans, sections, elevations and details produced as 2d representations and full specification, full details	3d database, all representation connected reducing inconsistencies, automated BOM	3d database – all information in 3d, shop drawings generated direct from the model, construction support system
Construction Documentation	Plans, sections, elevations and details produced as 2d representations and full specification, full details and shop drawings and construction sequence drawings	3d database usable by the contactor	Models indicating sequence of construction, and method of construction
As Built Drawings – Life Cycle Info	2d representations of what has been built	3d database of what has been built	Intelligent identifiable objects with attached maintenance information

Table 7.01 Non BIM, BIM and Intelligent BIM Artifacts

When adopting BIM it is important to identify the old non BIM artifacts and manage their transition to BIM or intelligent BIM artifacts. An example of this would be a planning application. Lessons learnt doing the first planning application using BIM should be feed through to subsequent planning submissions. Ideally as part of this development process the recipient should be interviewed to understand his or her specific needs. Arguably more time should have been spent on planning the transition of specific artifact and understanding their specific requirements at John McCall Architects.

7.9.3 How quality objectives can be better met

In order to determine current best practice questions were asked how John McCall Architects could develop a better product using new methods and technologies. The questions asked loosely followed those criteria set out in the ISO 9001 quality standards. The questions asked and the answers given are listed below (see Table 7.02).

How can John McCall Architects using BIM better ensure that projects are delivered on time?	Delays can be avoided by ensuring the architectural production is correct and coordinated with other disciplines. This can be indicated by a reduction in requests for information. (Clash detection) also using rule based checking.
How can John McCall Architects better assure projects are delivered on cost through the use of BIM?	At a basic level BIM models have the potential of instantly generating net and gloss floor areas from these building costs can be estimated using meter rates. BIM models have the potential to product bills of materials. BIM information. As of yet these potential benefits have not be utilized at John McCall Architects but it is hope that on future project this capability will be exploited.
How can John McCall Architects ensure that the projects are more fit for purpose by using BIM?	To ensure projects are more fit for purpose the compliance with the brief needs to be monitored. This can be automated using output data from BIM model into checking tools.
How can John McCall Architects better communicate with the client by using BIM?	Clients may or may not be able to read and understand traditional architectural drawings. But by using BIM 3d models certain design issues can be more easily understood
How through action research new process maps and a systems approach be developed?	The architectural production process is a complex activity fulfilling a wide range of needs, criteria and regulatory requirements. Through the investigation undertaken as part of the KTP it was possible to reveal the overall process and many of the issues faced.
The ways in which John McCall Architects staff can be integrated into new BIM projects?	Training Development of company standards
How can the staff trained to use the new processes?	Setting up a system of peer group training can help spread an understanding of the new process as can providing user manuals
How a more factual based decision making process was developed?	Building Information Models allow more intelligent building analysis for both the architect and other disciplines.
How can supplier relationships be developed?	Supplier relationship can be developed by attending BIM user group events.
How continual improvement can be integrated into John McCall Architects?	Setup of a BIM review committee

How can John McCall Architects Contract Review process was amended by the adoption of Lean principles and BIM?	At the outset of a project how a project is to be achieved needs to be determined. Having a BIM protocol in place can help define project requirements.
How can John McCall Architects Design control process was amended by the adoption of Lean principles and BIM?	Design control can be broken down into three areas. Control of the development of the concept and its ability to meet the stated and perceived needs set out in the brief. A projects ability to meet the technical criteria, those considerations that mean that appropriate methods of construction are adopted. Then there are statutory considerations. How the project complies with the building and other regulations.
How John McCall Architects Document Control process be amended by the adoption of Lean principles and BIM?	One of the major concepts of BIM is of a unified informational database. This is certainly not the case at John McCall Architects and is unlikely to occur for the foreseeable future.
How John McCall Architects Purchasing process be amended by the adoption of Lean principles and BIM?	The major influence John McCall Architects has on purchasing is when the company is able to decide which other consultants are employed as part of the project team. This is usually not the case. The decision of who is on the project team is more often made by the client.
How John McCall Architects Control of supplied product process could be amended Lean principles and BIM?	Design review procedures can be setup
How John McCall Architects Product Identification and Traceability process be amended Lean principles and BIM?	An important part of any quality system is audit trails. This is the information which enables faults revealed by the auditing system to be traced back to source. Audit trails may consist of many different types of information stored in many different formats.
How John McCall Architects Inspection and Testing process be amended Lean principles and BIM?	With the adoption of BIM the roles of inspection and testing change. Using models inspection can be undertaken by a member of staff or the process can be automated.
How John McCall Architects Inspection, Measuring and Testing of Equipment process be amended to Lean principles and BIM?	It is important to ensure that BIM tools work with the accuracy required. When setting up the template files in ArchiCad modifications were made to ensure the correct GFA and NFA were automatically generated.
How John McCall Architects Control of non -conforming product process be	Through the automatic generation of schedules from BIM models it is easier to

amended Lean principles and BIM?	check for duplicate incorrect information.
How can effective transfer of information be developed?	The effective transfer of information depends on having a BIM protocol in place.

Table 7.02: Review of how better quality objectives can be achieved at John McCall Architects

7.9.4 Development of the Information Model, Information Structuring and compliance

Some of the issues related to the development of the informational model and information structuring have already been dealt with in part, in the analysis of data handling section in this chapter.

Historically John McCall Architects has relied on hardcopy filing of letters, documents, faxes and hardcopy drawings were also retained. Old projects were stored in the basement in plastic boxes.

Different concepts and taxonomies exist of how project information should be created, used and stored. Currently John McCall Architects stores its electronic project information on a restricted network server or in hardcopy. Other than the John McCall Architects FTP server none of the information on the server is accessible to external parties without formal issue. Information is issued by email attachment or on a CD. These issues of documents are recorded in various forms by members of staff. The FTP server allows parties with the necessary access privileges to upload and download large files placed on the FTP server from John McCall Architects.

The server or in hardcopy files reside in many places and many formats. The primary classification at John McCall Architects is by project number. Information can be classified by whether it resides on the computer network or whether it resides outside the computer network. John McCall Architects also has its own unique office filing / numbering system. A copy of this filing system is available on the practices intranet copy of the quality management system.

At John McCall Architects there has been a move to ensure all information resides on the computer network. This is achieved by scanning project information that is received as hardcopy. Moving all information to the computer network has several advantages. The information is backed up so this gives the information extra security. This procedure was documented using the A3 method (see figure 7.35).

The information once on the network is easily accessible to all members of staff. Although the accounting section of the server had restricted access. Staff may access the information on the server from both in the office and remotely via a VPN (virtual private network) connection. Information is only of value if it can be found and be readily accessible. If we look at the directory structure adopted by John McCall Architects this is oriented around project numbers and names. These numbers and names are John McCall Architects specific and have limited meaning outside John McCall Architects. Information concerning projects is also stored in several databases serving a range of functions. These databases again can be accessed by all members of staff.

Data may be regarded as of high quality "if they are fit for their intended uses in operations, decision making and planning" (Juran 1951). Much of the data at John McCall Architects was not high quality and “making do” (using data that does not meet its needs) is a regular problem.

Informational Structuring is central to the efficiency and effectiveness of any architectural practice and at a wider level project (multi-disciplinary) efficiency.

First how John McCall Architects structured its letters and other documents was investigated. Then how John McCall Architects structured it drawings and the files and representations that go to make John McCall Architects graphical production information was reviewed.

The main organizations providing standard building data are companies owned by the Royal Institute of British Architects. NBS Services publishes the National Building Specification, which is widely used, and has developed a new classification system, Uniclass, to integrate CI/SfB with other classification systems used in the UK, in a series of faceted tables. RIBA Information Services publishes the Product Selector which is currently classified by CI/SfB

The size of the UK industry, and the differences between the professions, have resulted in several different classification systems: CI/SfB, mainly used by designers and for product literature, Common Arrangement, organized by work sections in a previous attempt to unify classification, and the Standard Method of Measurement used by Quantity Surveyors for bills of quantities. Uniclass which has been advocated as part of COBie in the UK aims to integrate these classification systems but has not been widely promoted yet. Semantic linking is currently developing between uniclass and other classification systems.

7.9.5 SWOT and PESTLE Analysis

SWOT (Strengths, Weaknesses, Opportunities and Threats)(see figure 7.48) and PESTLE (Political, Economic, Social, Technological, Legal and Environmental factors) reports (see figure 7.49) focusing on BIM were developed at John McCall Architects. These are well documented approaches to business analysis. The important issue here is that such analysis should taking into account both existing and potentially new clients and internal and external factors. These reports were presented to the directors and feedback sort. In hindsight the business model generation process has relevance here and this activity was undertaken after the main research and is also illustrated here.

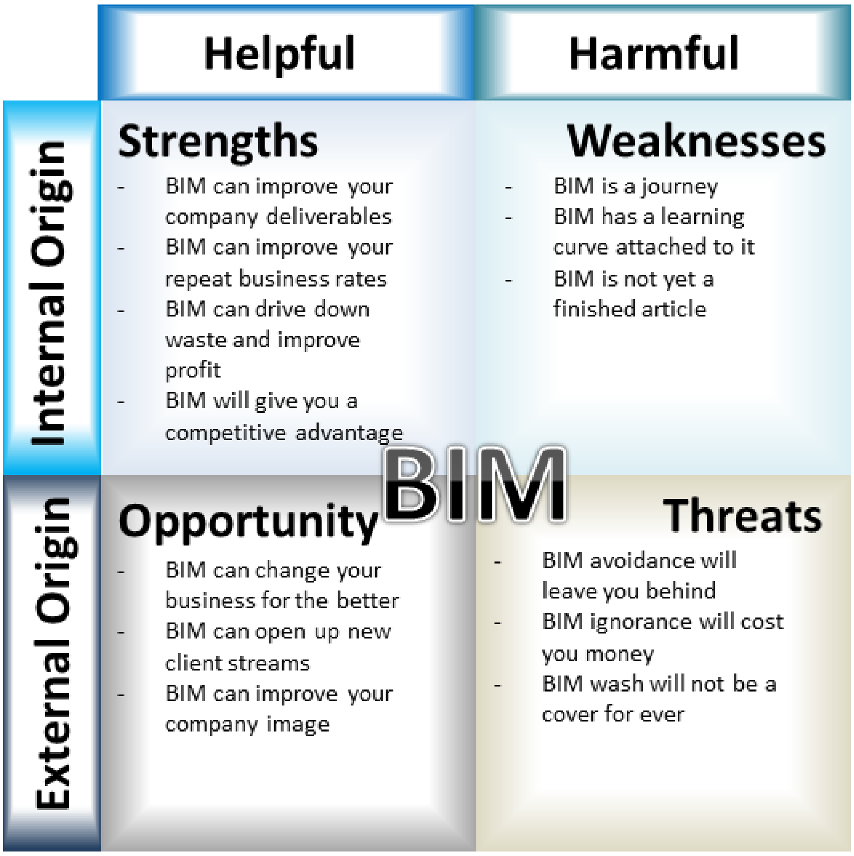


Figure 7.48: The different areas of SWOT analysis (adapted from BIM Sphere 2013)

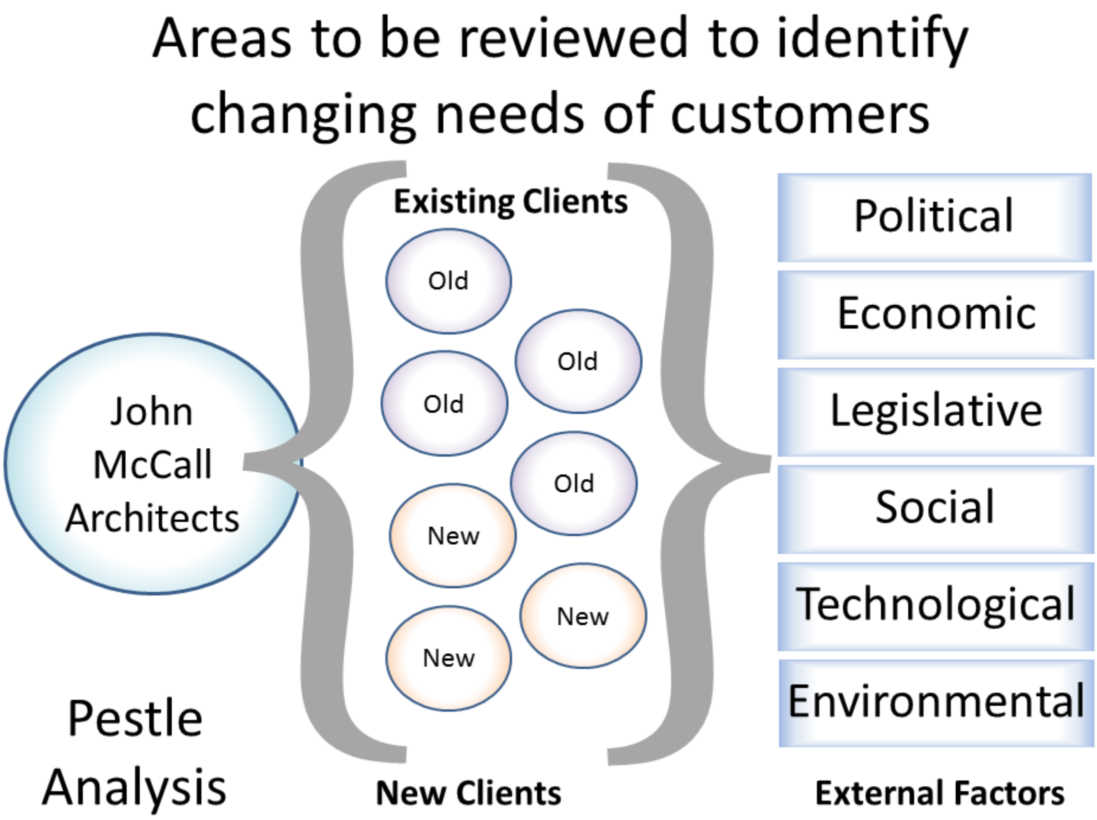


Figure 7.49: A diagram of those issues covered in the PESTLE analysis at John McCall Architects

SWOT analysis needs to be done as part of the BIM implementation for the following reasons:

- The SWOT analysis indicates the business factors which will form the backdrop into which the BIM implementation project will need to integrate.
- The SWOT analysis looks at the external as well as the internal factors effecting the business.
- The SWOT analysis considers changes in the practices structure, processes and IT
- The SWOT analysis gives a more holistic view of the organization.
- The SWOT analysis will form a reference to refer back to while undertaking the BIM implementation
- PESTLE analysis on the other hand focuses purely on external factors.

These external factors were covered in Chapter two of this thesis.

7.9.6 Monitoring of Best Practice Organisations

In the UK the RIBA takes the responsibility for spreading best practice to architects and architectural practices through its CPD (continued professional development) program. In 2012 the RIBA provided two and a half hour BIM CPD sessions in various locations around the UK. Construction Excellence is also an organization in the UK that encourages best practice among construction disciplines. (Results from this research have twice been presented at construction excellence forums during the period of the research.

These presentations offered an opportunity to gather thoughts and to get feedback from the wider profession. Presentations were also made at “Construct IT” and CIBSE both forums promoting construction best practice.

More recently BIM Hubs have been set up in the UK to help people and organizations better understand about BIM. These have been arranged by the Construction Industry Council and provide a useful insight into BIM developments.

7.9.7 Visit to companies to witness best practice

To better understand BIM the lean concept of “genchi genbutsu” or go see for yourself was adopted. As part of the investigation into BIM best practice for John McCall Architects it was decided for the researcher to visit Helsinki as the Sennate Properties “BIM mandate” was set up in Finland in 2007. Finland is seen as a leader in BIM use. As part of this visit it was decided to visit both software vendors and organizations using BIM. The software vendor visited included Tekla, Solibri, Riqq Innovations. Through visiting these organisations it was possible to understand their vision for BIM and also some of the issues relating to BIM. A meeting was also arranged with the chairman of building smart in Finland Tomi Henttinen of Gravicon Oy.

The interviews were also carried out at Aalto University, with academics studying and developing BIM. The interviews were carried out in an semi structured manner, as each company and institution had unique experience of BIM and varying viewpoints on their activities. The semi structured approach to the interviews was adopted in order to capture their uniqueness as well as commonalities in their BIM experiences. However, all the interviews had the same aim and goal, which was to understand their views and strategies for BIM use and implementation in practice.

Also as part of the visit it was possible to visit Helsinki Music Centre. This was a major BIM project that was being built on site. There the issues of BIM were described from a contractor’s point of view. What became clear was that the software tools commonly adopted in Finland were not those commonly adopted in the UK.

Of particular interest were the range of BIM tools used and how BIM was used to solve problems on site. The Finnish engineering firm Vahanen employed Allplan software for the design and structural planning of the Helsinki Music Centre. Responsible for designing all the ventilation systems, Granlund Oy used MagiCAD's integrated sound calculations.

Now with further developments of BIM in the UK it should be possible to undertake such research into organisations with BIM experience, without the need to travel abroad. Also as the UK further defines its own BIM expectations through the development of standards research in the UK for UK practices adopting BIM becomes more appropriate.

7.9.8 Stakeholder Review

Central to achieving best practice in an architectural organisation is defining and understanding the process stakeholders and their needs and requirements. A list of key stakeholders was provided to the researcher whilst working at John McCall Architects. The major sets of key stakeholders are illustrated (see figure 7.50).

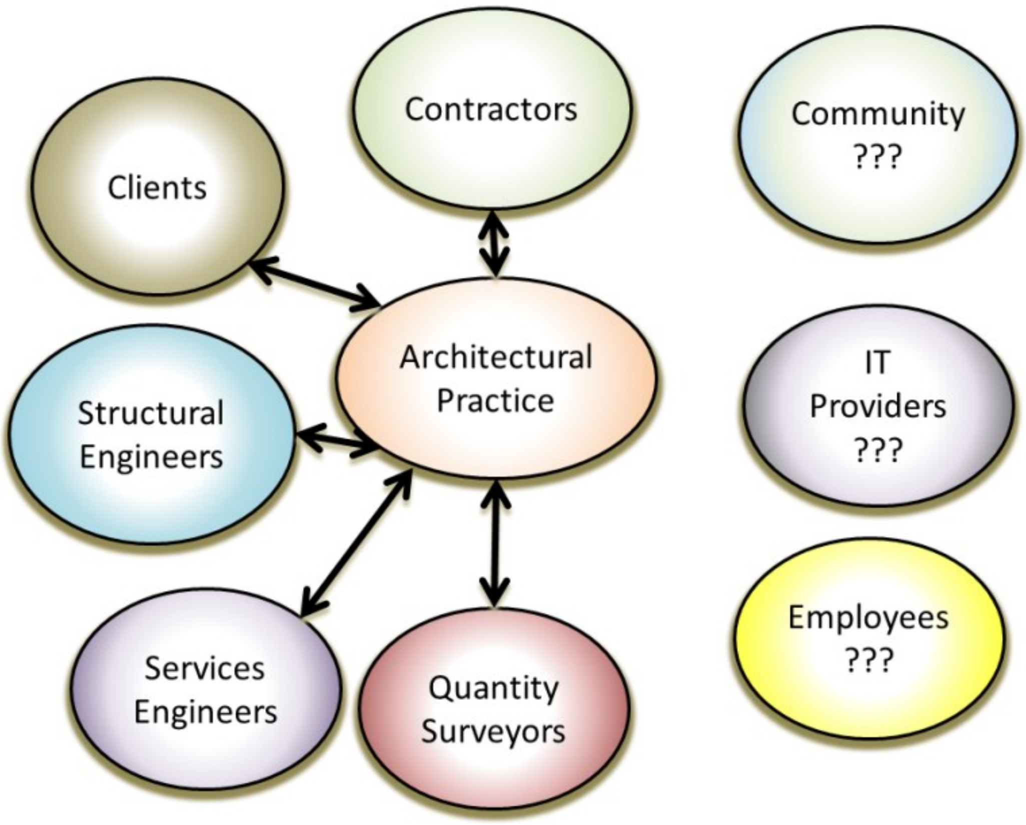


Figure 7.50: External stakeholder diagram for an architectural practice

The actual stakeholders and stakeholder types vary from project to project. It is this change in stakeholders which makes it difficult to develop capabilities across project teams. Frameworks where teams build repeat projects have a better potential for team development.

An understanding of clients can be gained from reviewing bid requirements. Also a review of previous project feedback may show where customer requirements are not being met.

The initial understanding of John McCall Architects stakeholder requirement was achieved through review of their websites. The problem with reviewing websites is that they have a certain marketing bias. This were possible was followed up by interviews. The ideal method of understanding and meeting stakeholder requirements is documented (see Figure 7.51).

Figure 7.51: The process of meeting stakeholder requirements

At John McCall Architects a questionnaire was prepared to be sent out to the company's clients. Unfortunately the questionnaire was blocked by the company directors.

Presentations on the implications of adopting BIM were given to clients, engineers, quantity surveyors and FM managers to illicit discussion. These discussions in part helped to formulate an understanding of the needs of the John McCall Architects stakeholders. Where sufficient client feedback is gained affinity diagrams can be used to reveal a hierarchy of common issues (Brassard 1989) (see figure 7.52).

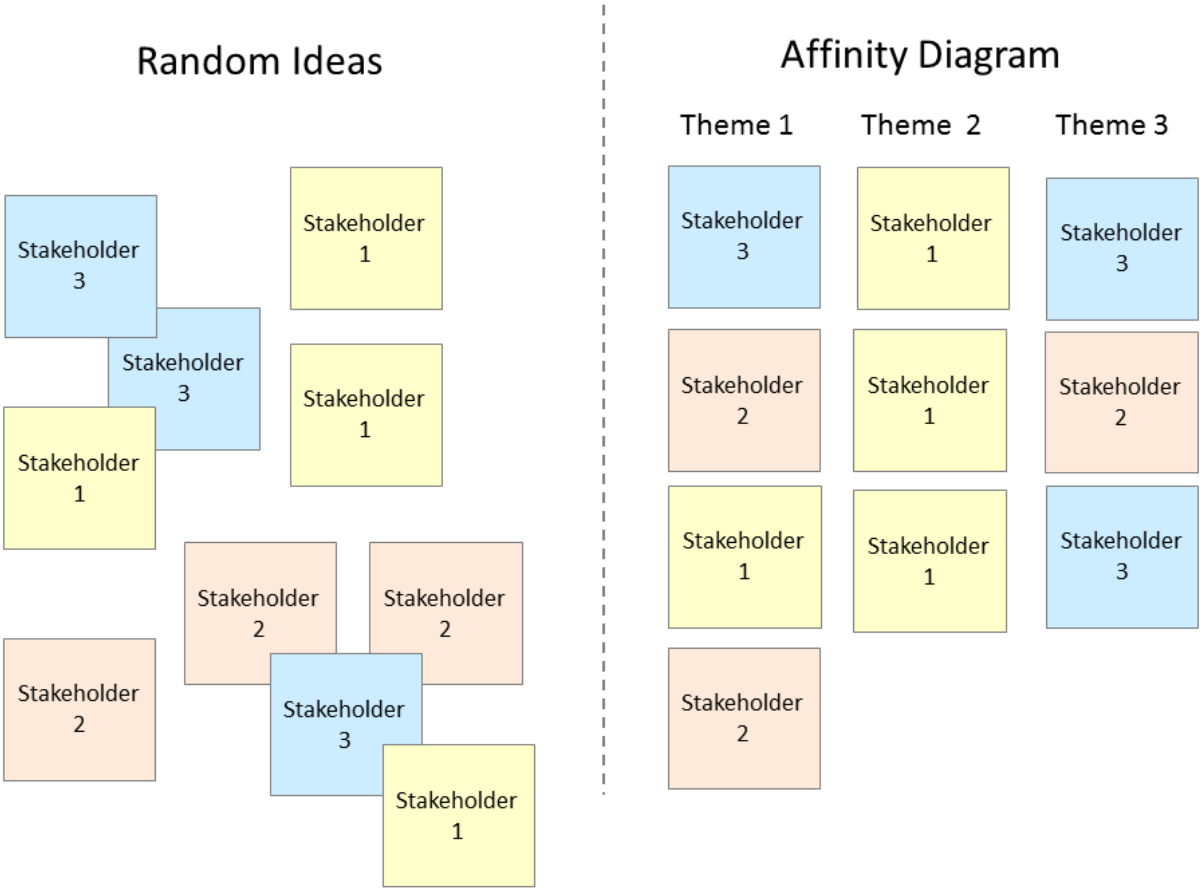


Figure 7.52: Showing how affinity diagrams can be generated from stakeholder feedback

7.10 BIM Tool Review / Selection

7.10.1 BIM Tool review - Introduction

Technology is a tool and like all tools it should fit your hand when you pick it up, you shouldn't have to bio-re-engineer your hand to fit the tool.

(Snowden 2011)

When considering BIM technology several conditions should be applied:

- Use the most current software version /release

- Use the most current version of Industry Foundation Classes (IFC) file format. (Although the IFC capability was not used on the projects undertaken at John McCall Architects during the period of this research).

- Use the most current version of collaboration software providing interoperability between the software applications

Only commercial of the shelf (COTS) BIM software solutions were considered at John McCall Architects as the company did not have the skill set to create BIM software systems.

A tool is any physical item that can be used (by someone) to achieve a goal. Success comes from selecting the right tool and determining how someone must use it. The alignment of tools to operators, tasks and outcomes is a critical part of the BIM adoption process. The implication of the tool selected may go beyond the practice that uses the tool to the wider building team and stakeholders.

BIM authoring software is an example of an information and data manipulation tool. Many BIM softwares can be regarded as multi-tools. A multi tool is a tool that incorporates several tools into a single entity. BIM tools usually have the ability to store data and provide visualizations two very different functions and many other functions beside. Websites such as “Find the Best” can be used for a quick but invalidated comparison of the major BIM tools available. Where considerable investment is concerned it is important that appropriate specific practice oriented research is performed and the right BIM tool is chosen.

Architecture remains first and foremost about design (Laiserin 2010). Therefore the design capabilities of the BIM authoring tools adopted are critical. Whether design occurs during the use of BIM tools or BIM tools merely record the result of the design thought processes is debatable. Design involves selection and judgement. Therefore the better the understanding of the proposal i.e. in 3D, the easier it is to make the decisions.

ISO/IEC 9126 is an international standard for the evaluation of software quality (see figure 7.53). The areas identified form the areas that were later tested.

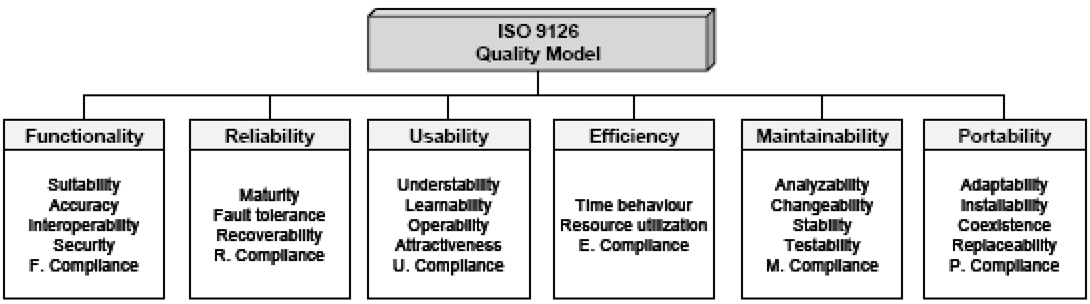


Figure 7.53: The ISO 9126 Standard to evaluate software quality

When considering BIM the most important areas where identified (see figure 7.54).

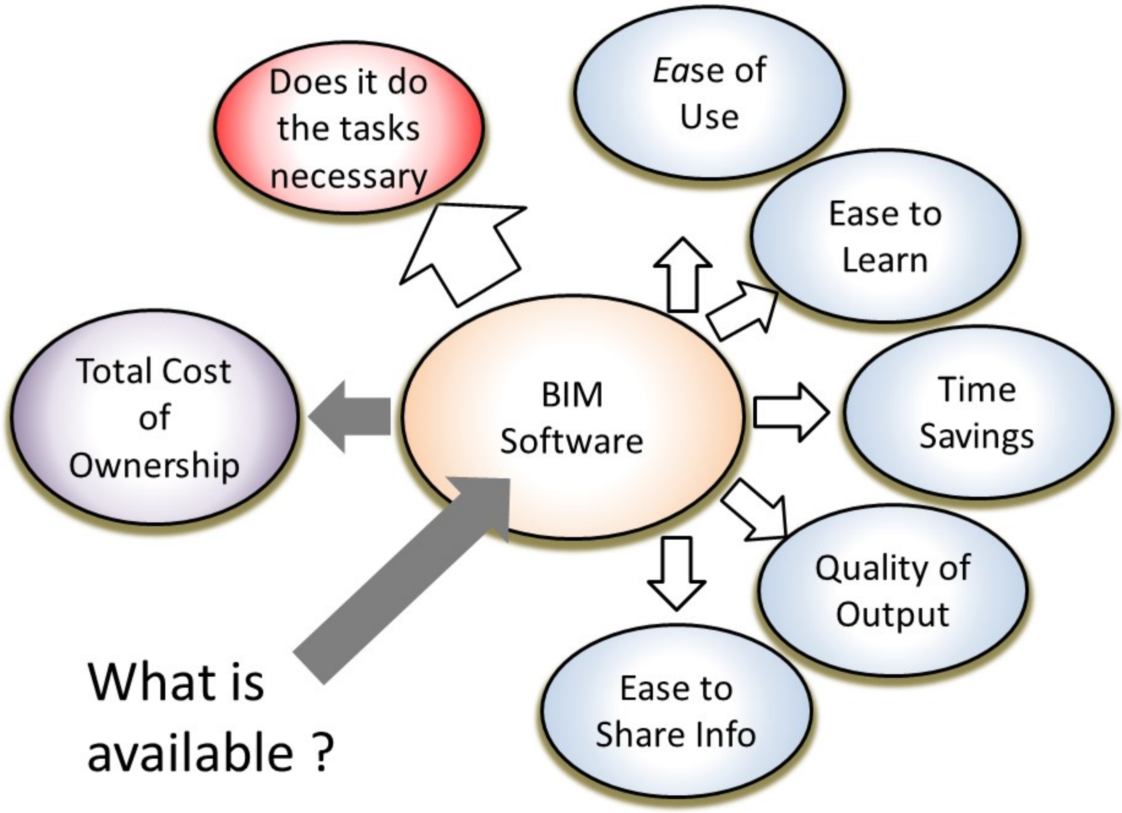


Figure 7.54: Major areas of consideration when selecting a BIM tool

Each one of these consideration areas identified in the illustration was be dealt with in turn.

Some practices may adopt a single BIM platform. Some architectural practices may have a range of BIM authoring tools. But having a range of BIM tools is prohibitive partly because of the cost and partly because of the skills necessary to use multiple BIM tools effectively. Having a range of BIM tools can be beneficial because it allows interoperability to be tested and also the practice may be eligible to acquire a wider range of projects. For a small architectural practice the aim is likely to become proficient using one both tool rather than inexperienced at using many. This was the approach adopted at John McCall Architects.

It is unlikely that the expertise will already exist within the organisation adopting BIM to make the appropriate software tool selection. Even experienced users tend to be knowledgeable on one rather than multiple BIM tools. Therefore it is recommended that a software selection procedure should be adopted to define the best software to use. The recommended selection process is as follows:

- Identify the critical capabilities required of the software tools

- Identify a range from the vendors of the tools that have the appropriate capabilities

- Arrange presentations and demonstrations from vendors

- Set standard tasks for expert users to perform and evaluate the tasks against predefined criteria

- Undertake a SWOT analysis and cost of ownership analysis of the different BIM tools

- Confirm software to be used and adoption strategy

A considerable investment in time, training and system development relating to the BIM tool selected is required. If the wrong tool is selected this is not a decision that is easily changed without wasting most of the investment that has already been made. In large architectural companies using multiple BIM authoring tools becomes a more feasible option.

7.10.2 BIM Tool Review - Requirements

What is required from this activity is to determine the appropriate BIM tool or tools to be used in the architectural practice. This may sound a simple task but it proved to be an emotive subject at John McCall Architects.

7.10.3 BIM Tool Review - Activities undertaken in the case study company

A range of activities were undertaken at John McCall Architects as part of the BIM tool review and selection process. These are shown (see figure 7.55)

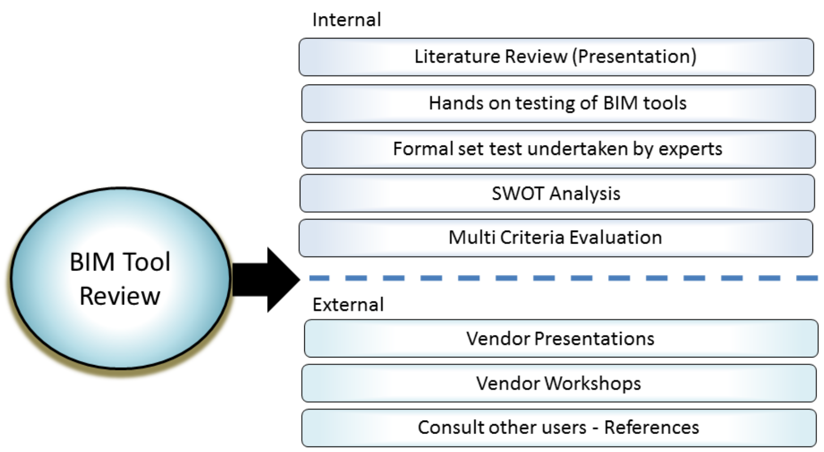


Figure 7.55: Internal and External components of a BIM tool review

Some of these activities were conducted within the company other activities were undertaken outside of the company.

The first thing that needs to be decided as part of a BIM tool reviews, is which are the BIM tools to be reviewed. Building Smart certifies BIM tools and this may be referred to. A survey was conducted by the NBS of CAD and BIM software. This was provided in their 2013 report (see figure 7.56).

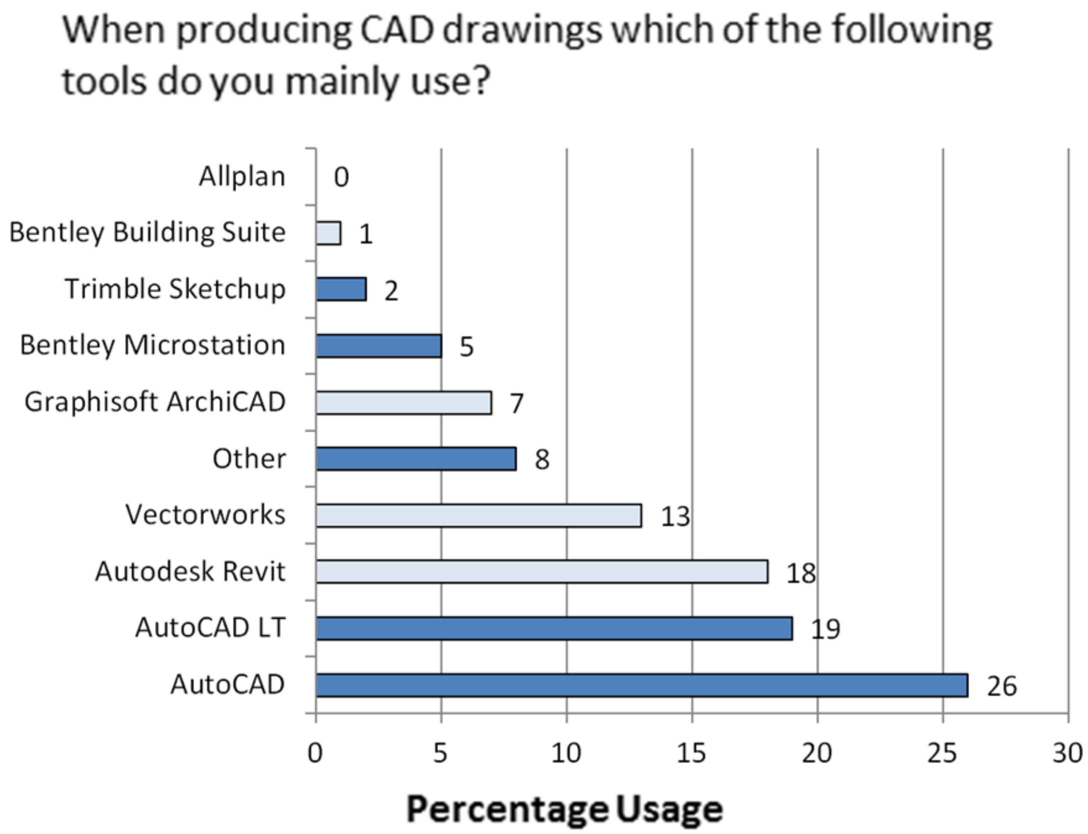


Figure 7.56: Comparative usage of CAD and BIM software (NBS 2013)

The BIM tools available and their capabilities will change overtime. Two immediate filters are cost and operating system. A list of BIM tools is currently maintained by Georgia Tech (see figure 7.57). A list of BIM tools is also available on the CAD Addict website (Broquetas 2012). This is also linked to the BIM tool vendors' websites. Although this list is by no means comprehensive.

Preliminary Tools

> Preliminary Space Planning Tools

Facility Composer	Requirements-based facility modeling
Trelligence Affinity	Architectural programming, Schematic design, Plugins for Major BIM tools
Vectorworks Fundamentals	Drafting, technical drawing and 3D modeling

> Preliminary Massing and Sketching Tools

3dVia Shape	3D Sketching
bonzai3D	3D Sketching Tool
FormZ	3d modeling, Radiozity rendering
Rhinoceros 3D	NURBS-based 3D modeling
SketchUP	Intuitive and flexible 3D surface modeling

> Preliminaty Environmental Analysis Tools

Ecotect	Environmental analysis
Green Building Studio	Web based building energy analysis, gbXML
IES Virtual Environment	Building performance analysis

> Preliminary Cost Estimation Tools

Dprofiler	Project budgeting in early design stage

BIM Design Tools

ArchiCAD	Surface & solid geometry modeling, Parametric CAD, BIM modeling
Bentley Architecture	BIM-enabled Architectural design, solid modeling, model-based drawing generation, 3D visualization
Revit Building	Parametric modeling, Quantity Take off, Rendering
VectorWorks	Parametric BIM Tool

Structural Design Tools

Information on "Structural Design Tools" is not collected yet.

BIM Construction Tools

Tekla Structures	Structural 3D modeling

Fabrication Tools

Information on "Fabrication Tools" is not collected yet.

Figure 7.57: Screen shot of the BIM Design Tool List from the Georgia Tech BIM Wiki (Georgia Tech 2012)

This provided a base list of BIM softwares to be investigated. Magazine articles can also form a useful initial point of reference at this stage. When we talk about BIM tools for an architectural practice we a talking about tools that can create and manipulate building objects. There is also the question of how BIM tools can assist with the process of design. Use of the objects to be tested in other BIM softwares may be required. Other types of BIM software that may be used in architectural practice are viewing softwares and model checking softwares. The issue of eco BIM tools is considered later in this chapter.

Another consideration is the other tools the BIM software will have to interact with. This is both inside and outside of the architectural practice. There is also an issue of legacy information (old drawings files) which should be considered at this stage.

At John McCall Architects it seems likely they will maintain the old Microstation CAD software and the skill necessary to operate the legacy software for some time. This is to be able to access old and historic projects undertaken by the company in dgn or dwg format.

The first question when analysing a BIM tool is does it do the tasks necessary? If the concept is that the BIM tool replaces existing tools, then the critical functionality of the old tools need to be supplied within the new BIM tool. So writing a critical function list of the legacy methods of operation will form a good checklist to evaluate part of the capabilities of the new BIM tools. This having been said the deliverables and the methods may change as a result of using the new tool. New capabilities are likely to be made available by using a BIM tool. Understanding these new capabilities required can be understood through discussion with experienced users.

A list of factors a practice may try to determine to better understand its needs was developed (see figure 7.58). These can be evaluated using a MoSCoW scale (must have, should have, could have and won’t need) (Clegg 2004). The list can be divided into BIM tool questions, cost model questions, legacy system question, business process questions and external collaboration questions.

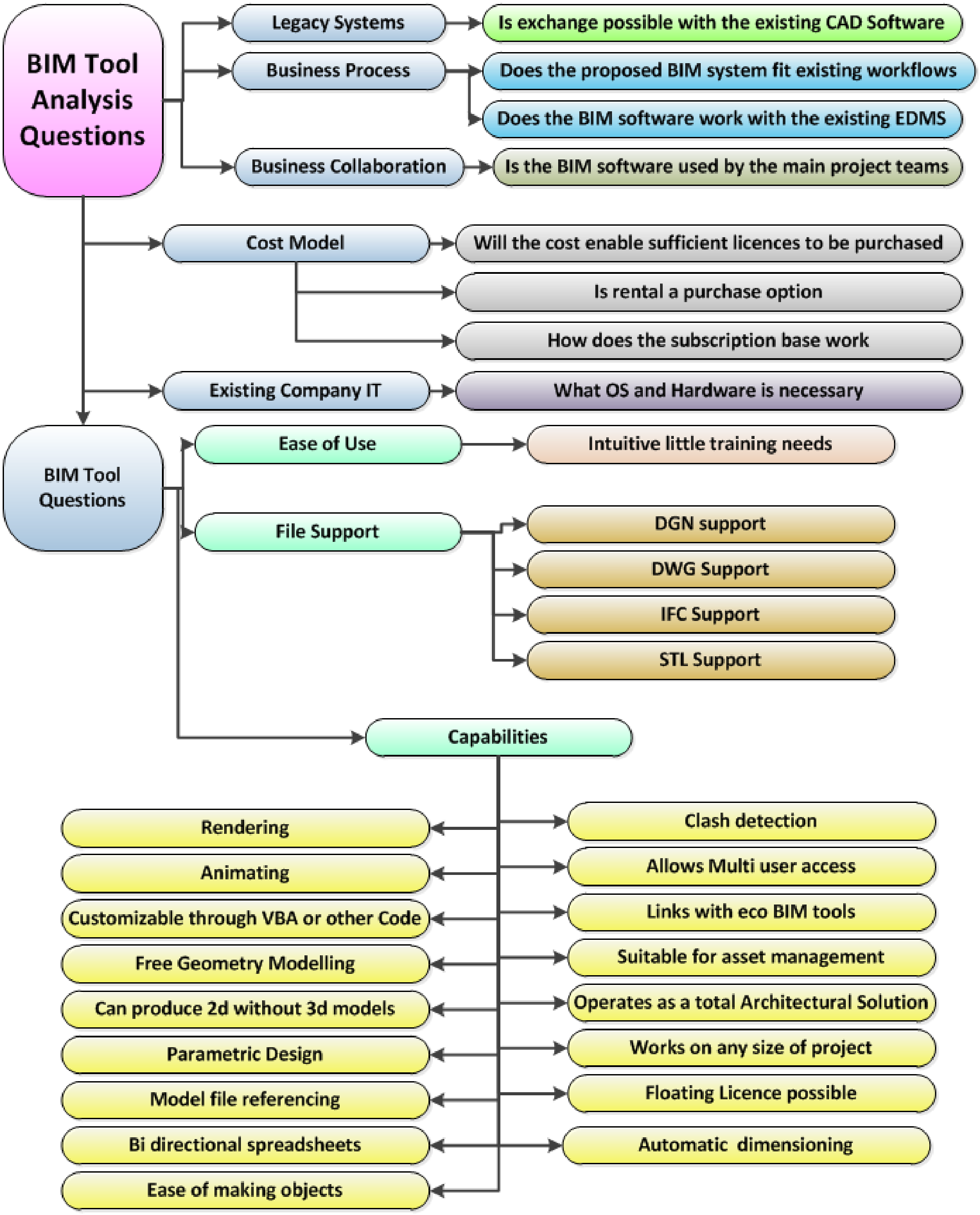


Figure 7.58: Questions to be asked when analysing an BIM tool for Architectural Practice

One of the major problems of BIM tool review is the people available to review the tools do not have sufficient knowledge to review the tools. If a CAD user or CAD manager is used to review BIM tools their perspective is flavoured by their historic experience using CAD. While BIM has some similarities with CAD it has many more issues and capabilities that need to be evaluated. The evaluation of BIM tools must take on board previous experience but also understand the future potential of the tools being reviewed. It must also be remembered that a successful BIM implementation is as much about organisation productivity as it is about the productivity of the individual users.

At John McCall Architects members of staff where asked what BIM software had they heard of and what BIM software they had used before. Some members of staff had used BIM software at University while others had used the BIM software at other companies. At John McCall Architects it was decided to review four possible BIM authoring tools. These tools were Revit Architecture, Bentley Architecture, ArchiCad and Allplan. In hindsight because of the amount of interest in Vectorworks in the UK (see figure 7.59) it might also have been justified to review Vectorworks software as this currently offers a particularly cost effective BIM solution.

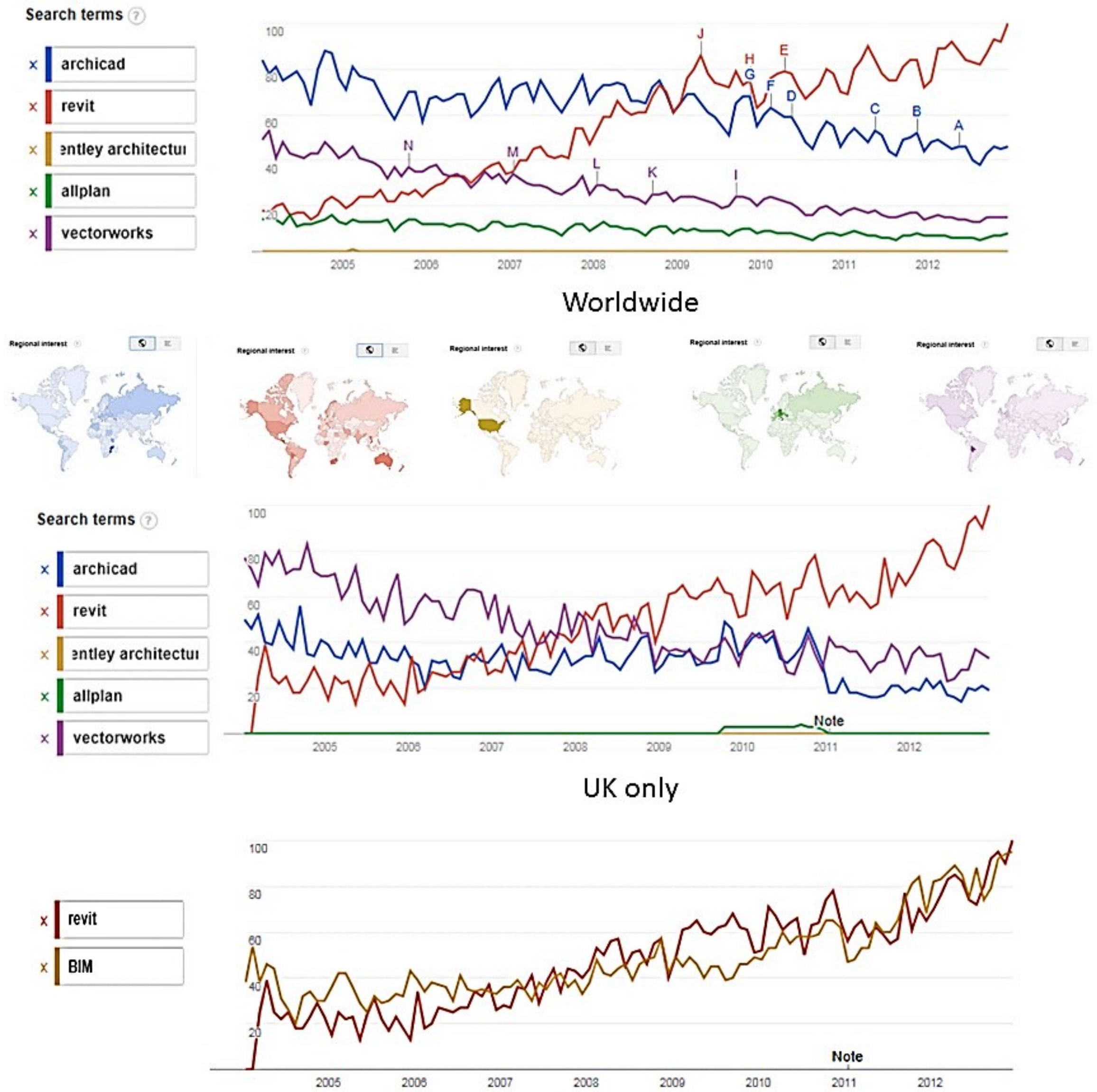


Figure 7.59: An example of a review of different BIM authoring tools (information from Google Trends 1/12/2012) and the related growth of interest in BIM and Revit software in the UK (information from Google trends 1/12/2012)

The version numbers of the BIM tools reviewed changed over the review period. Most BIM tools are on an annual upgrade cycle. The major consideration here is when change of file formats is involved.

Each of these BIM tools was selected for a different reason. Revit architecture was selected because of its known market position and its association with the market leader CAD software AutoCad. Revit is also part of a suite of software used by a wide range of disciplines. This in theory should enable better transfer of data between Revit related softwares using proprietary formats. Bentley Architecture was selected because John McCall Architects as a Microstation user company had a long association using Bentley products. Bentley Architecture is also part of a less widely used suite of products. Bentley Architecture is not a standalone tool it sits on top of the Microstation software. Archicad was chosen as it was known as a long established BIM 3d tool. Allplan was chosen because it was the particular favourite of one of the members of staff at John McCall Architects. Allplan is a BIM software that is widely used in Germany, but at the time of review there were only an estimated 400 licenced copies in use in the UK (according to the UK distributor).

During the investigation it was decided not to progress the investigation into Bentley Architecture. Although vendor presentations were given of this product. This was partly because it was the most expensive solution (although introductory offers were made) also Bentley Architecture needs to sit on top of Microstation to operate. The two software approach was not considered as a good solution. At the time of writing Bentley Systems is bringing out a new product Aecosim Building Designer v8i. Again as new products come on the market a revaluation is necessary.

7.10.4 The literature review for the BIM tools

A report by Khemlani (2011) covers the evaluation of Revit Architecture 2010 from Autodesk, Bentley Architecture V8i, ArchiCAD 13 from Graphisoft, Allplan Architecture 2009 from Nemetschek AG, Vectorworks Architect 2010 from Nemetschek and Digital Project V1, R4 from Gehry Technologies.

A review of the internet was also undertaken to ascertain the popularity of the repective BIM software (see figure 7.56). Webinars also proved to be a useful source of information about BIM software tools.

Where references of other practices using BIM were given these were investigated over the phone. The telephone investigations were conducted as semi structured interviews. This provided particularly insightful information of how the BIM tools were being used in practice and what features the users considered important.

The output of the literature review was a presentation which compared the different BIM tool capabilities (see figure 7.60, 7.61 7.62). This presentation was given to the directors of the practice. On the presentation slides the capabilities of the BIM tools were placed side by side to allow easy comparison of the features.

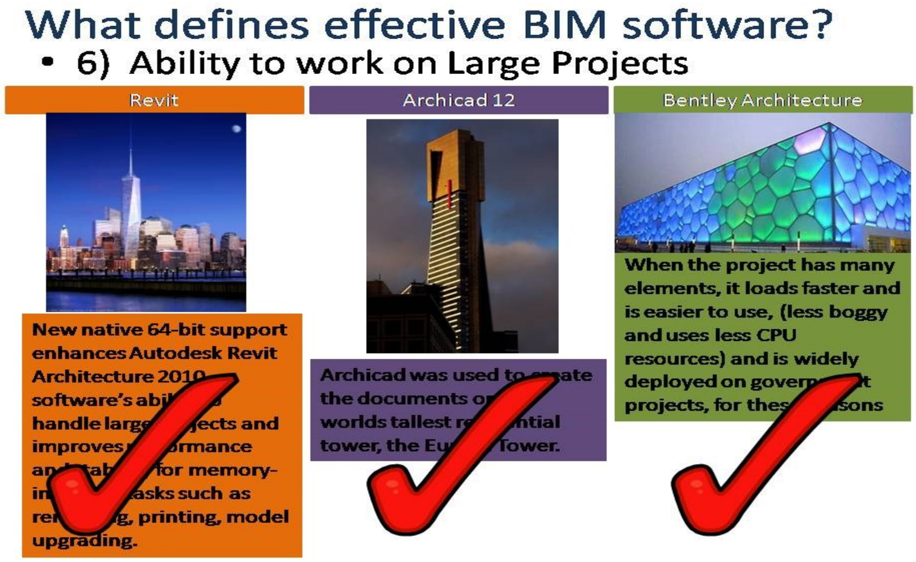


Figure 7.60: Part of a PowerPoint presentation analysing the capability of different BIM software's

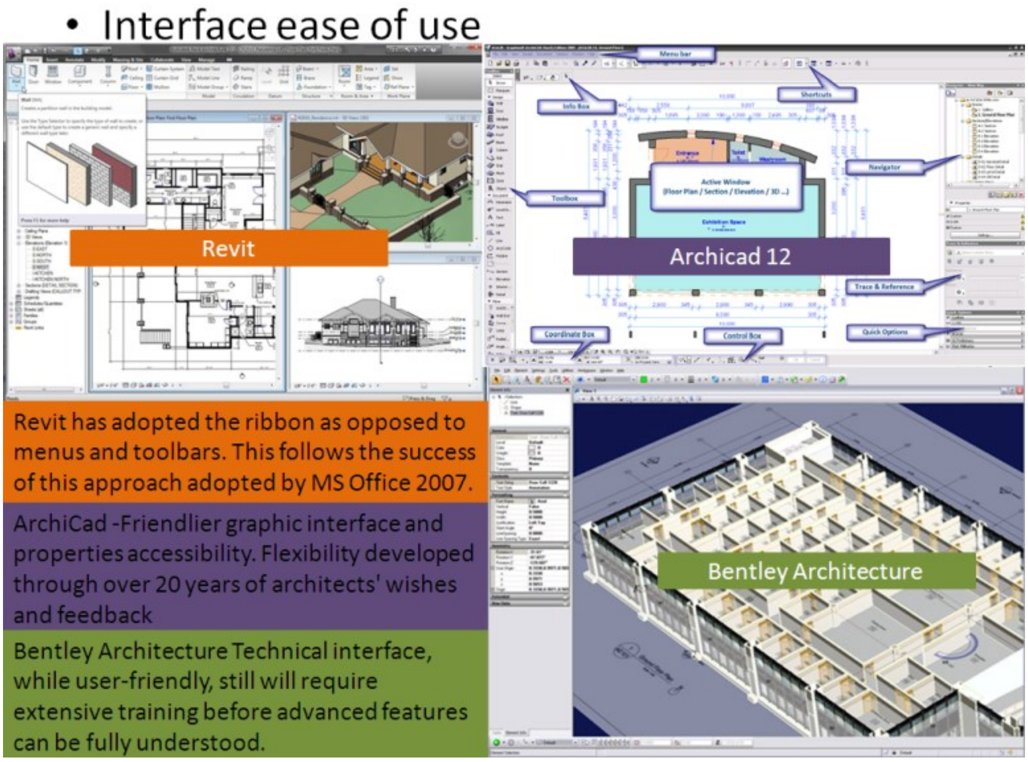


Figure 7.61: Part of a PowerPoint presentation reviewing the different interfaces of the BIM software reviewed

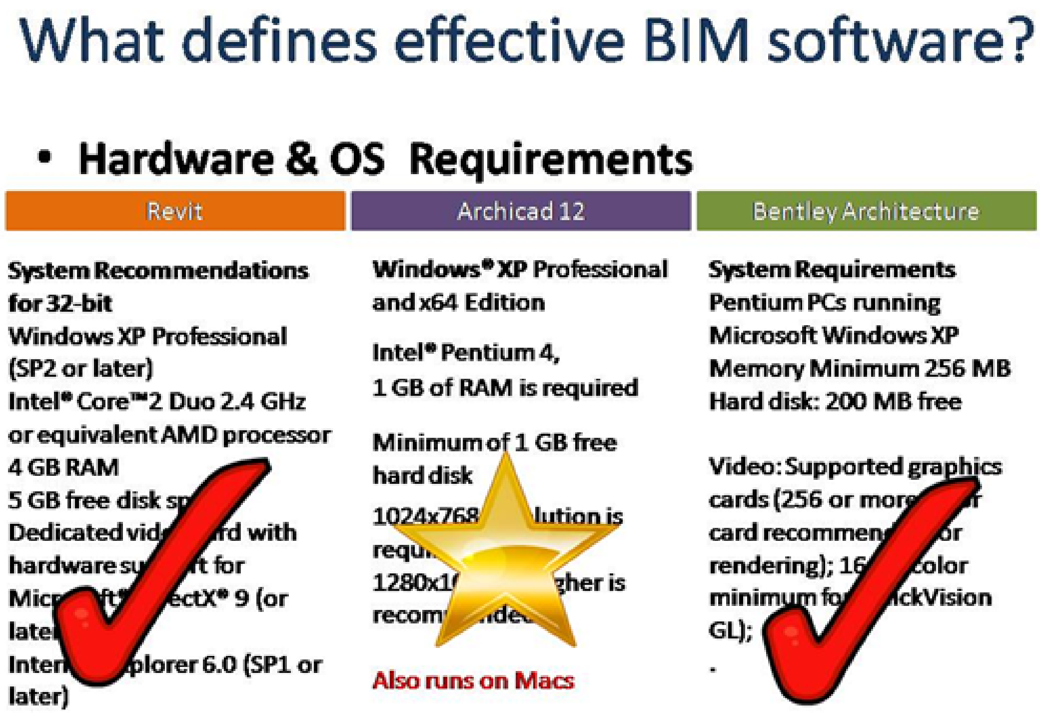


Figure 7.62: Reviewing the hardware and operating systems needed by different BIM software

In some cases the BIM vendors offices were visited to see demonstrations of the BIM software. In the case of Bentley Systems a webinar also took place where John McCall Architect's staff could ask questions to the Bentley Architecture development team in the USA.

As part of the BIM tool review future predicted developments of the specific BIM tools should also be noted. Although these future capabilities may or may not manifest themselves in future versions of the BIM tools.

7.10.5 Hands on testing of BIM tools

The BIM tools evaluated were downloaded as trial educational versions. Although in some cases there was limitation placed on the use of such trial softwares. Trial ArchiCad at the time operated in a different file format from normal ArchiCad. The BIM tools were downloaded on to a standard PC and preliminary experimentation was undertaken by the researcher.

A simple house design was developed using the different BIM softwares. Trying to achieve the same output from different tools enabled direct comparisons to be made. This was helpful because it enabled more informed questions to be formulated and be asked to the software vendors.

Using the BIM tool without specific training is a good test to see how intuitive the software interface is. At the time of the research Revit one of the BIM tools evaluated had recently changed its interface to the new ribbon format. This is the format adopted by all Microsoft software programs.

At a personal level the researcher found the ArchiCad software the most intuitive to use.

Testing the software in this way also allows its ability to perform on equivalent hardware and operating system to be evaluated.

7.10.6 Formal set tests undertaken by expert users

At John McCall Architects it was decided to put to the test Revit, ArchiCad and Allplan using experienced BIM operators supplied by the software vendors. The elements of the tests are shown (see figure 7.63 and 7.64). The BIM operators were given a standard task of generating a small number of terraced houses using BIM. This was a task that might be expected of any BIM operator working at John McCall Architects once the software was provided. Modifications were asked for as the designs progressed as might occur in a typical project.

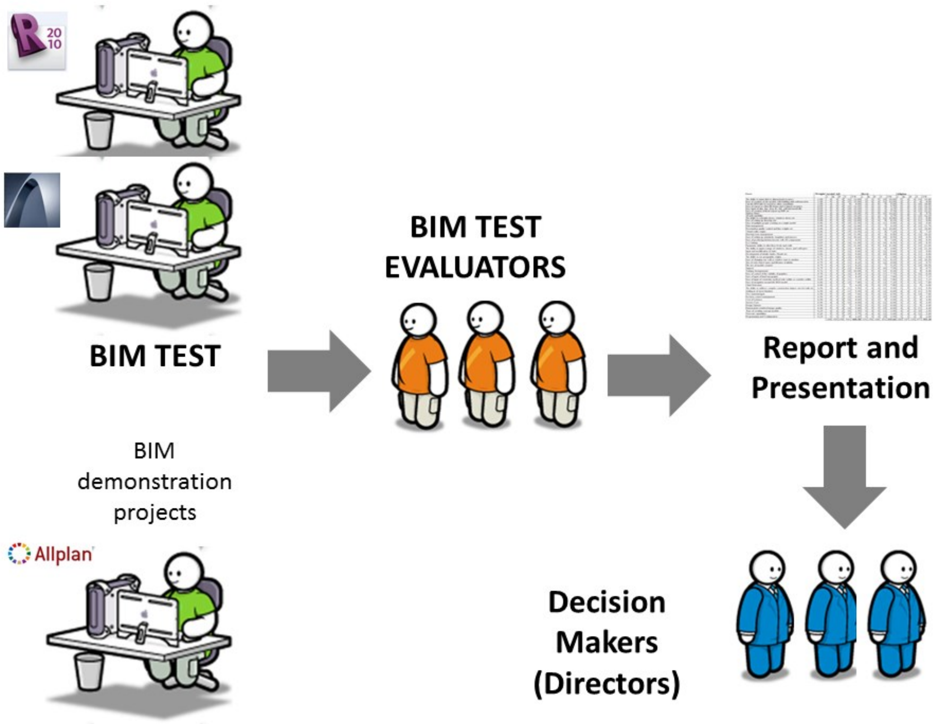


Figure 7.63: The BIM authoring tool test process used at John McCall Architects

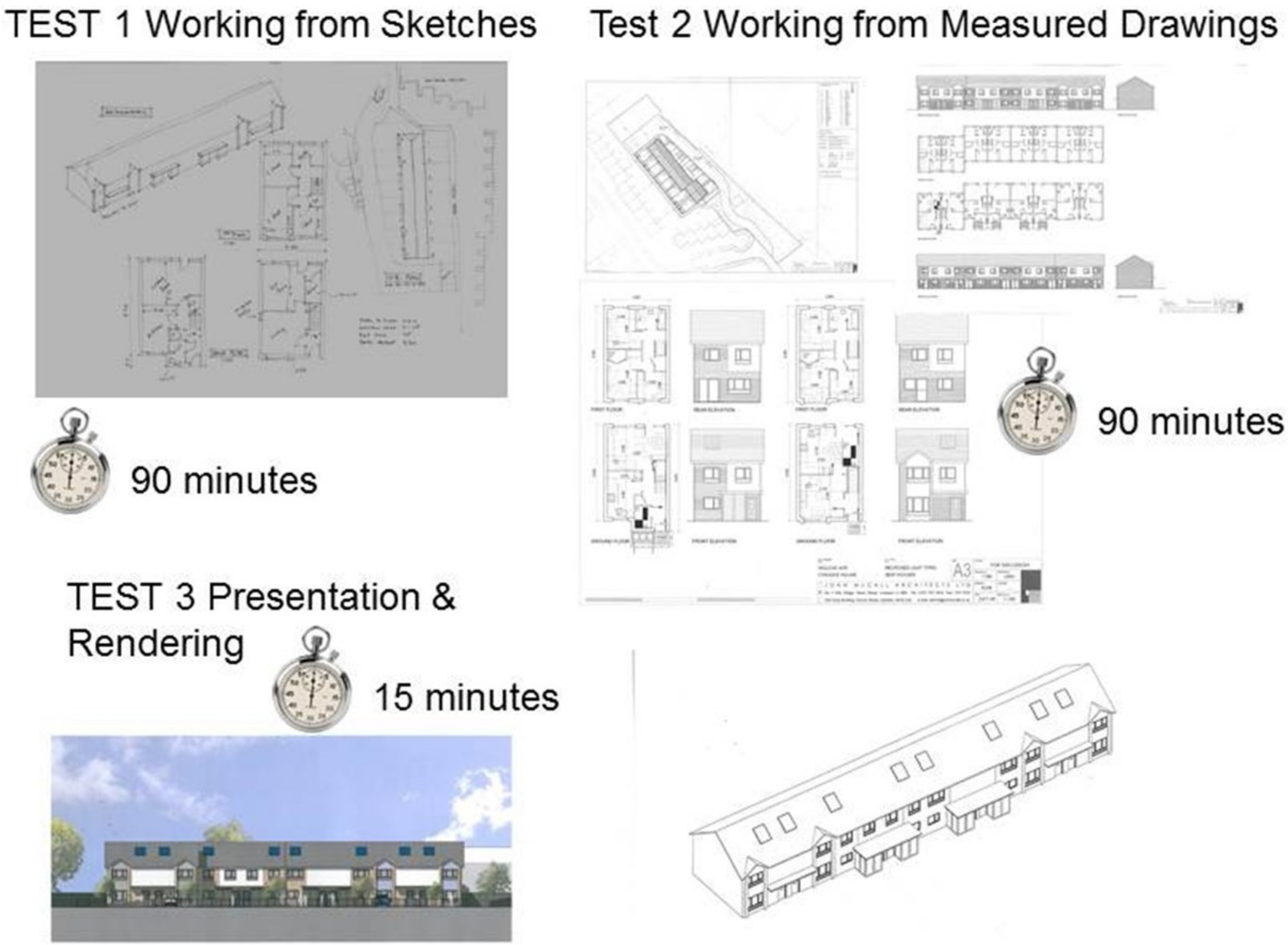


Figure 7.64: Test undertaken to evaluate the BIM System to select

The BIM authoring tools tested had no special customisation, libraries or templates preconfigured. Although the expert users had been told in advance that it was a domestic project to be undertaken.

At John McCall Architects it was decided as part of the demonstration project the following capabilities should be tested:

1) Ease of creating concept models (to be demonstrated)

2) The ability to input a range of windows, doors, and wall types in line with John McCall Architects requirements

3) Ease of changing one wall or window type to another either as a distinct entity or all elements of a particular type (tested through changing the design as part of the test)

4) The ability to input data to dimensional accuracy (snap codes, accudraw etc)

5) The ability to use geographic origins and input site plans

6) The ability to address complex construction shapes curved walls etc. (Not often a requirement at John McCall Architects)

7) The ability to schedule doors, windows doors etc. (in fact any object type)

8) Parametric ability to alter floor levels and walls (ideally when the floor height alters the wall height should automatically adjust).

9) Easy of setting up drawing sets

10) Ease of navigation around the BIM model

11) New material input

12) Ease of input of land topography

13) Ease of multiple people working on a single model

14) Ease of creation of site models with building units referenced in

15) Ease of control of the visibility of graphics

16) Ease of input of constrains eg fixed stair widths or corridor widths

17) Ease of export to other file forms and re import accuracy

18) Easy input of dgn, skp, dwg, ifc, dxf and model files

19) Ease of creation of fixed export eg PDF etc

20) Drawing issue management

21) Print management and Automation (batch printing)

22) Revision control management and Clash detection

23) Presentation quality control and line weights etc.

24) Demonstration of size of exist object types and libraries available

25) File size of the models created

26) Ease of setting up standards, templates and macros

27) To demonstrate rendered image quality

One observer monitored the tests at all times. It was the same observer for all three tests. More observers would have been preferable but these resources were not available. As an observer it is particularly important to be impartial at all times.

The test sketch was not revealed until the start of the test within the office. Different strategies were used by the expert users of the BIM authoring tools. The importance of unitizing (breaking the model into smaller referenced models) the housing became clear as the test progressed. Import and export of the site plan, pdf's and ifc files was also included in the tests. The bay windows caused particular difficulty to be created. If the tests had been undertaken over a greater period of time a better understanding of the software capabilities would have been gained. The results of these tests are shown (see figures 7.65, 7.66 and 7.67).

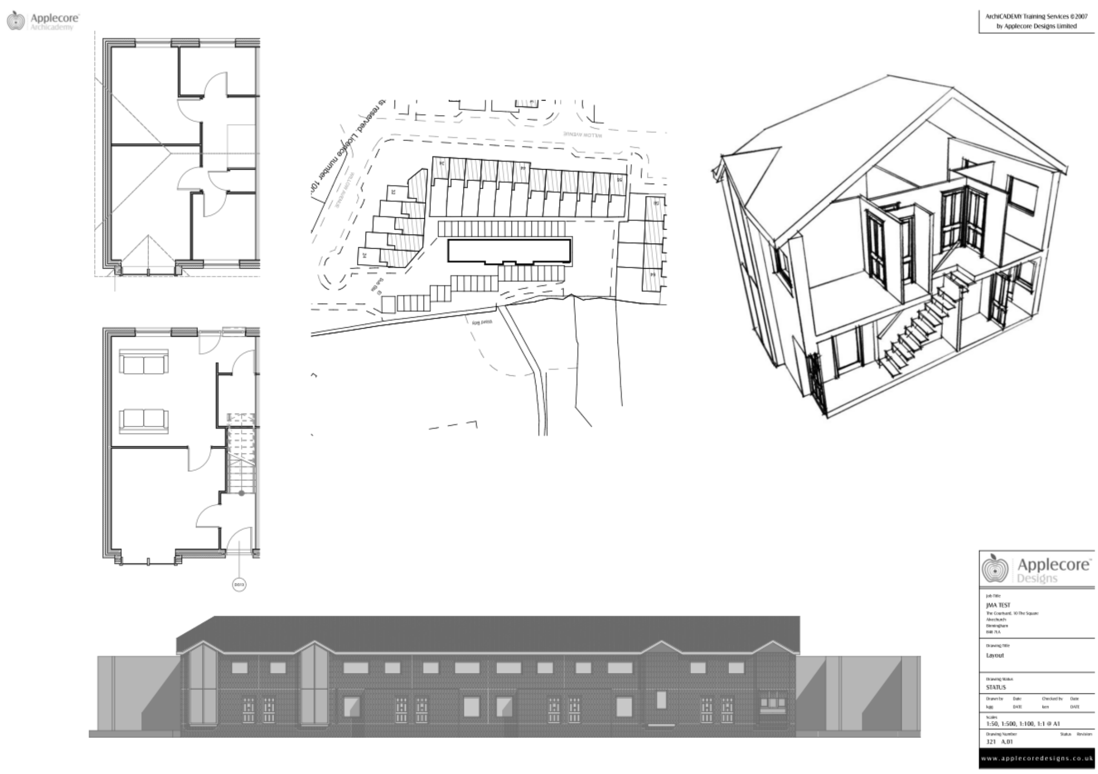


Figure 7.65: The results of the 3 hour test using ArchiCad software

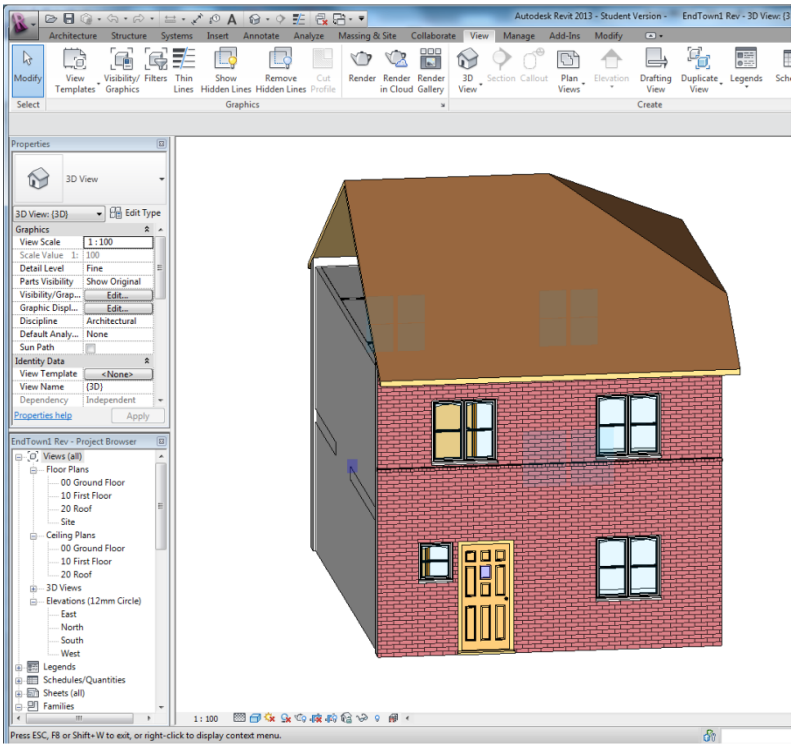


Figure 7.66:Test model produced using Revit software

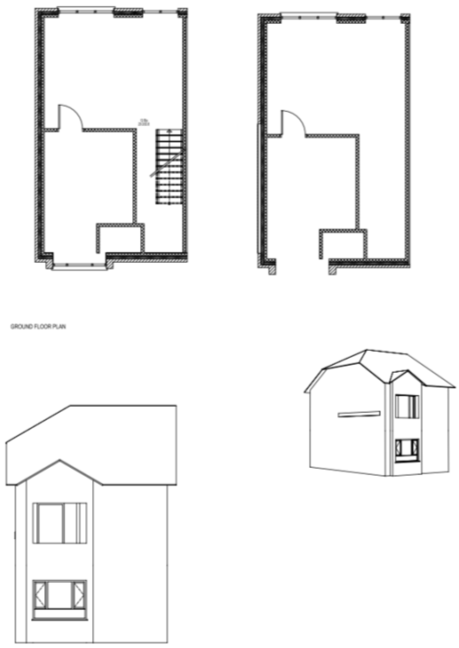


Figure 7.67: Test models produced using Allplan software

What became clear as part of these tests was that expert users could create plans sections and elevations faster using BIM models than by using traditional 2d means. Prints to the John McCall Architects laser plotter were also requested to check the quality of the output. As part of the tests it became clear even expert users have problems when asked to demonstrate features of the software that they do not normally use.

An important element was to decide the weighting of the factors reviewed in the test. A separate meeting with all three of the reviewers was undertaken to determine the weighting of the review factors. All three of the reviewers were from an architectural background and familiar with the deliverables required. The combined figures and weightings are shown below (see figure 7.68). A full review chart is shown (see figure 7.69 Appendix A). The interesting thing here is how different reviewers can see the same thing very differently.

	Facet	Weighting	ArchiCAD					Revit					Allplan				
			J	K	P	T	TW	J	K	P	T	TW	J	K	P	T	TW
a1	The ability to input data to dimensional accuracy	1.00	4	4	4	12	12.00	2	3	5	10	10.00	5	4	4	13	13.00
a2	Ease of creation of site models with building units referenced in	1.00	5	4	4	13	13.00	4	4	4	12	12.00	2	2	2	6	6.00
a3	Can the BIM info be issued to other consultants	1.00	4	3	2	9	9.00	2	2	5	9	9.00	5	3	2	10	10.00
b1	Ease of export to other file forms and re import accuracy	0.95	4	5	4	13	12.35	2	2	2	6	5.70	5	4	4	13	12.35
b2	Easy input of dgn, skp, dwg, ifc, dxf , pdf and model file	0.95	5	5	4	14	13.30	1	2	2	5	4.75	5	5	4	14	13.30
b3	Ease of creation of fixed export eg PDF etc	0.95	5	5	4	14	13.30	1	3	2	6	5.70	5	4	4	13	12.35
b4	Market Share	0.95	4	4	3	11	10.45	5	5	5	15	14.25	3	2	1	6	5.70
b5	3D pdf capability	0.95	5	5	5	15	14.25	1	2	2	5	4.75	5	5	3	13	12.35
c1	The ability to schedule doors, windows doors etc	0.90	5	5	4	14	12.60	3	4	5	12	10.80	4	4	3	11	9.90
c2	Easy of setting up drawing sets	0.90	5	5	4	14	12.60	3	2	4	9	8.10	4	4	3	11	9.90
c3	Ease of multiple people working on a single model	0.90	5	5	5	15	13.50	3	4	4	11	9.90	4	4	2	10	9.00
c4	Print management	0.90	5	5	4	14	12.60	1	3	3	7	6.30	4	5	4	13	11.70
c5	Presentation quality control and line weights etc	0.90	5	4	3	12	10.80	4	4	4	12	10.80	5	5	2	12	10.80
c6	Virtual reality engine	0.90	5	5	5	15	13.50	2	3	3	8	7.20	2	3	3	8	7.20
d1	Drawing issue management	0.85	5	5	4	14	11.90	2	2	4	8	6.80	4	4	4	12	10.20
d2	Ease of setting up standards, templates and macros	0.85	5	3	4	12	10.20	3	3	4	10	8.50	4	3	3	10	8.50
d3	Ease of producing kitchen layouts with 3D components	0.85	5	3	3	11	9.35	3	3	3	9	7.65	4	3	3	10	8.50
d4	Eco Linking	0.85	5	5	4	14	11.90	3	3	4	10	8.50	4	3	3	10	8.50
d5	Parametric ability to alter floor levels and walls	0.85	4	5	4	13	11.05	4	5	5	14	11.90	5	5	3	13	11.05
e1	The ability to input a range of windows, doors, and wall types	0.80	4	4	4	12	9.60	2	2	2	6	4.80	5	5	4	14	11.20
e2	Input and modification of stairs	0.80	5	4	3	12	9.60	4	4	4	12	9.60	5	4	3	12	9.60
e3	Development of details Jambs, Heads etc	0.80	5	3	4	12	9.60	3	3	4	10	8.00	4	3	4	11	8.80
f1	The ability to use geographic origins	0.75	4	4	4	12	9.00	1	1	2	4	3.00	4	4	4	12	9.00
f2	Ease of changing one wall or window type to another	0.75	5	4	4	13	9.75	3	4	4	11	8.25	5	5	4	14	10.50
f3	Demonstration of size of exist object types and libraries available	0.75	4	4	3	11	8.25	3	4	5	12	9.00	5	5	3	13	9.75
f4	File size of models created	0.75	4	4	3	11	8.25	2	2	3	7	5.25	5	5	4	14	10.50
f5	Support	0.75	5	3	4	12	9.00	3	3	4	10	7.50	3	3	3	9	6.75
g1	Training Arrangements	0.72	5	5	4	14	10.08	4	5	4	13	9.36	3	4	2	9	6.48
h1	Ease of control of the visibility of graphics	0.70	4	5	3	12	8.40	3	4	4	11	7.70	5	4	3	12	8.40
i1	Ease of input of land topography	0.65	5	4	4	13	8.45	4	4	4	12	7.80	5	4	2	11	7.15
i2	Ease of input of constrains eg fixed stair widths or corridor widths	0.65	5	4	2	11	7.15	4	4	4	12	7.80	5	4	2	11	7.15
j1	Ease of navigation around the BIM model	0.60	4	5	4	13	7.80	3	4	5	12	7.20	5	5	3	13	7.80
j2	Clash Detection	0.60	3	3	1	7	4.20	4	5	4	13	7.80	2	2	1	5	3.00
k1	The ability to address complex construction shapes curved walls etc	0.50	4	4	3	11	5.50	3	4	4	11	5.50	3	5	3	11	5.50
k2	Adding in of street furniture	0.50	4	4	3	11	5.50	4	4	4	12	6.00	4	4	3	11	5.50
k3	New material input	0.50	5	5	4	14	7.00	4	5	4	13	6.50	5	5	4	14	7.00
k4	Revision control management	0.50	5	5	2	12	6.00	3	3	4	10	5.00	4	3	2	9	4.50
k5	Cost of Licience	0.50	4	4	4	12	6.00	3	3	3	9	4.50	2	2	2	6	3.00
k6	Service Cost	0.50	4	4	4	12	6.00	4	4	4	12	6.00	3	3	3	9	4.50
k7	Design Options	0.50	3	1	3	7	3.50	4	3	5	12	6.00	4	1	3	8	4.00
l1	Demonstrate rendered image quality	0.40	5	5	4	14	5.60	5	5	5	15	6.00	4	4	3	11	4.40
m1	Ease of creating concept models	0.25	4	4	2	10	2.50	4	4	4	12	3.00	4	4	2	10	2.50
m2	Network capabilities	0.25	5	5	5	15	3.75	4	4	4	12	3.00	4	4	4	12	3.00
m3	Programming and Configuration	0.25	3	3	3	9	2.25	3	3	4	10	2.50	3	3	2	8	2.00
			198	185	158	541	**400.38**	133	150	168	451	**319.66**	180	167	130	477	**352.28**
	Review order		1	1	2			3	3	1			2	2	3		
	Nov 11 2009																

Figure 7.68: Review of the three BIM Tools tested at John McCall Architects

The discrepancy of differences in the finding recorded comes because some BIM tools achieve certain functions and some do not. But then some tools achieve similar results using totally different approaches. An example here would be ArchiCad could produce 3dpdfs while Revit produced .dwf files. Should these deliverables be regarded as equivalent?

7.10.7 SWOT analysis of the BIM tools

The strength and weaknesses opportunities and threats of a particular BIM tool does not purely depend on the capabilities of the BIM tool itself. A SWOT analysis of the BIM tools looks at the bigger picture. Issues such as market share and the implications of this were considered. The SWOT analysis of the BIM tools undertaken at John McCall Architects is illustrated below (see figure 7.70). Here again the SWOT analysis relies very much on subjective judgement.

Analysis		ArchiCad		Revit		Allplan
Strengths	1)	Best score in JMA review	1)	Autodesk current recieves 10 times the revenue of Nemetscheck and has 85% of the BIM / CAD market (wikinvest)	1)	Second in JMA review
	2)	25 years in the Market, 100,000 users	2)	Revit Architectural is part of a suite of Revit products and communicates with them	2)	Facilitates the creating of components
	3)	Part of the Nemetschek range of products with data transfer	3)	Marketing with a known brand of software	3)	Part of the Nemetschek range of products with data transfer
	4)	Prefered interface	4)	Product designed arround new concepts built in warnings and clash detection	4)	Experienced user in JMA
	5)	Seems to provide good IFC export	5)	Design option tool and large object libraries	5)	Range of addon programs
Weaknesses						
	1)	Lower percieved market share than Revit	1)	IFC import and export not effective	1)	Only 400 users in the UK
	2)	Can not communicate effectively with Revit suite only with 3d dwg files	2)	Does not import pdfs, need to load pdf driver to print pdfs	2)	Seems not to allow mirrored reference files
	3)	Regarded as an Architectural product	3)	Scored last in JMA review	3)	Marketing with a little known software
	4)	No Clash detection built in	4)	Warnings annoying	4)	Can not communicate effectively with Revit suite
	5)	Limited in setting constrains	5)	Family editor needs training	5)	Limited options for training
Opportunities						
	1)	Better integration with other consultants using IFC products	1)	Better integration with other consultants using Revit / Autodesk products - Small fish in a big pond	1)	Can become the Allplan UK experts - Big fish in a small pond
	2)	Purchase VBE to create virtual reality output	2)	Produced animations of walkthroughs from Revit	2)	Better integration with other consultants using IFC products
	3)	Use Heata software with ArchiCad to produce SAP calculations, Ecodesigner can also be purchased	3)	Link with IES software, Icevision to create VR output	3)	Can produce rendered models
Threats						
	1)	Client or team specifying software required	1)	Client or team specifying software required	1)	Client or team specifying software required
	2)	Inability to hire trained users	2)	Inability to hire trained users	2)	Inability to hire trained users
	3)	Changes in method of usage payment, subscription models, or pay on usage	3)	Changes in method of usage payment, subscription models, or pay on usage	3)	Withdraw support from the UK
	4)	Autodesk take over the market	4)	Competitor development of IFC softwares	4)	Autodesk take over the market

Figure 7.70: BIM SWOT analysis undertaken at John McCall Architects on the BIM tools being reviewed

When considering the BIM tools to adopt the cost of the tools required is likely to be determined by the geometric complexity of the projects undertaken by the architectural practice. Architectural projects are usually relatively geometrically simple when compared with industrial, product and mechanical design. (There are exceptions and extreme geometric complexity is a feature of many of iconic buildings of today.)

While architectural projects tend to be of a medium complexity when compared with ship building and offshore work which can be highly complex. The capability required of the BIM tools to deal with geometric complexity and project complexity is likely to determine the price of the BIM tool required. BIM systems such as Digital Project can handle complex geometry. Digital Project is built on the CATIA Dassault platform and tailored to architectural design. Digital Project now is an architectural design BIM tool commercially distributed by Gehry Technologies. Generative components a Bentley Architecture add on could have provided the ability to undertake dimension driven design. But such abilities are beyond the core requirements of John McCall Architects.

A cost table of the BIM tools compared was also generated (see figure 7.71). This included purchase cost and service costs as well as rental arrangements where available.

BIM cost Analysis	**Archicad 13**						**Revit**				**Allplan**	
No of software licences	Rental	Comment	Rent to Buy	Comment	Purchase	Comment	Rental	Comment	Purchase	Comment	Purchase	Comment
1		3 months = £199.00 per month 6 months = £169.00 per month 12 months = £149.00 per month 24 months = £99.00 per month									£3330 + £450 £3,780	Training extra
2											£6,804 £3,402	10%
3					£10,620 no training	£3,540 each one year support			£10,536 Standalone	£3512 including support Network £950 extra Training extra	£10,206	£3,402
4											15%	
5									£13625 + £2587.5 Standalone	(unit cost £2725 + £517.50) Training extra	15%	
6												20%
7												20%
8												20%
9												20%
10					£32,310 Purchase of 10 over a year	£3231 each £2,799.20 £432 MES						20%
11												20%
12			£43944 £1,831 per month over 24 months 8 days training	(unit cost £3662) Support Included 2 No VBE included							£36,288 £3,024	20%
									Subscription mandatory for first year 3 day training £675		2 days training £1000	

Figure 7.71: Table of BIM tool cost analysis

Actual BIM software pricing consists of two parts: economics and psychology:

Economics

- How much does the BIM vendor need to make from each sale?
- How much does the BIM vendor need to share with others (distributors, royalties, and so on)?

Psychology

- How does a potential customer perceive the software?
- What is the value of the software to the user?

Version management, constant upgradation of softwares has been an issue for architectural practitioners. While most often upgraded softwares allow using data generated from earlier versions, many a times significant changes inhibit these. During the period of research ArchiCad was upgraded from version 13 to version 14.This upgrade had to be managed project by project.

As discussed in chapter three effective transfer of information between BIM enabled tools even with the advent of IFC's can be ineffectual. It is advisable to test out critical transfers of information before confirming which BIM tool to adopt. Some vendors supply a range of BIM softwares. It is more likely effective information transfers will be achieved between softwares from a single vender rather than softwares from multiple vendors.

Now with the instigation of the UK government BIM mandate the ability to generate a COBie deliverable from the BIM tool becomes a consideration.

7.10.8 Review of other BIM Authoring Software

Since the time of the test ArchiCad solo or ArchiCad start edition 2013 and Revit LT (see figure 7.72) have been launched these were not tested at the case study company. But it is believed they would not have provided the functionality required at John McCall Architects. Although, they might offer an alternative to small architectural practices on a particularly tight budgets.

Feature	Autodesk Revit LT 2013	Autodesk Revit 2013
Single, Coordinated Model	X	X
Autodesk 360 Rendering	X	X
Intelligent (Parametric) Components	X	X
Worksharing (Multiuser Environment)		X
Autodesk 360 Energy Analysis for Autodesk Revit		X
Near – Photorealistic Rendering within the product		X
Conceptual Massing, Adaptive Components		X
Exports to gbxml and ifc file format		X
Interference Checking, Copy / Monitor		X
Construction Modeling – Parts and Assemblies		X

Figure 7.72: A comparison of Autodesk Revit LT 2013 and Autodesk Revit 2013 (JTB World 2012)

7.10.9 Review of BIM eco Tools

An important element that could have been taken further was the review of eco software that could be used with the selected BIM tool. We have previously discussed the growing importance of undertaking sustainability analysis as part of the architectural development process. Each eco tool seemed to have a preferred BIM authoring tool and different eco analysis tools had distinctly different capabilities. Some literature research was undertaken to better understand these eco tools (see figure 7.73). Such review should be supported by an analysis and understanding of the existing processes within the adopting practice.

Sustainable Design Features	Weightings (1-10)	Ecotect	Green Building Studio	VE
Energy	6			
Energy Usage		1	3	3
Carbon Emission Calculation		3	3	3
Resource Management		3	1	0
Total Score		**7**	**7**	**6**
Thermal	7			
Thermal Analysis		3	1	3
Heating / Cooling Load Cals		3	1	3
Ventilation and Airflow		3	3	3
Total Score		9	5	9
Solar	2			
Solar Analysis		3	1	3
Right to light		3	1	1
Total Score		**6**	**2**	**4**
Lighting and Daylighting	3			
Daylighting Assessment		3	1	3
Shading Design		3	1	1
Lighting Design		3	1	1
Total Score		**9**	**3**	**5**
Acoustic	2			
Acoustic Analysis		3	0	1
Total Score		3	0	1
Value and Cost	8			
Lifecycle Assessment		0	3	3
Lifecycle Cost		0	1	3
Total Score		0	4	6
LEED	8			
LEED Intergration Tools		0	1	1
Total Score		**0**	**1**	**1**
Total Weighting Score		**150**	**130**	**180**

Figure 7.73: Comparing different types of eco software (Source HCC, Atlanta, Azhar 2009)

7.10.10 Hardware considerations in BIM tool selection

The use of BIM software tends to be more hardware demanding that the use of CAD. This is because BIM uses 3d geometries and there can at times be a considerable amount of data attached. 3d rendering also requires an increase in computer processing power. Therefore a survey of existing hardware including desktops, servers and peripheral devices should be undertaken.

From this a plan can be produced of the new hardware and software that will need to be purchased. To run and effective BIM system similar security and administrative tasks and expertise need to be in place as are required by a traditional CAD system. These considerations need to be built into BIM tool selection.

It is unlikely that existing CAD hardware will have adequate processing power or video cards to run BIM software effectively. At John McCall Architects initially the BIM software was run on existing machines. This proved to be a false economy. Server and network capabilities may also need to be reconsidered when adopting BIM. These costs were born out by the research undertaken at John McCall Architects and more powerful machines needed to be provided.

7.10.11 Output from the BIM software analysis

The findings of all the BIM analysis and exercises were presented to the directors of John McCall Architects. This is documented in the next chapter. It was not a question of what was the best BIM software it was a question of which BIM software could best meet the companies needs and aspirations. Taking all the finding onboard the directors decided to undertake a 50 hour trial using ArchiCad software. This later became the preferred BIM software to be used across the practice.

7.11 Summary of Chapter 7

The diagnosis activities documented in this chapter form the foundation for a successful BIM implementation. The rigor which is applied at this stage is important so the correct actions are defined and undertaken in the following stages.

At the end of this stage ideally a meeting should be held defining the current and future state. The elements of information that could assist at this meeting are documented (see figure 7.74).

At John McCall Architects it was assumed that the workload would increase as a result of adopting BIM (see figure 7.75). If additional time had been spent investigating where the company wished to be in the future it may have been helpful at this stage. Opening up new markets though the adoption of BIM would have been a valuable contribution.

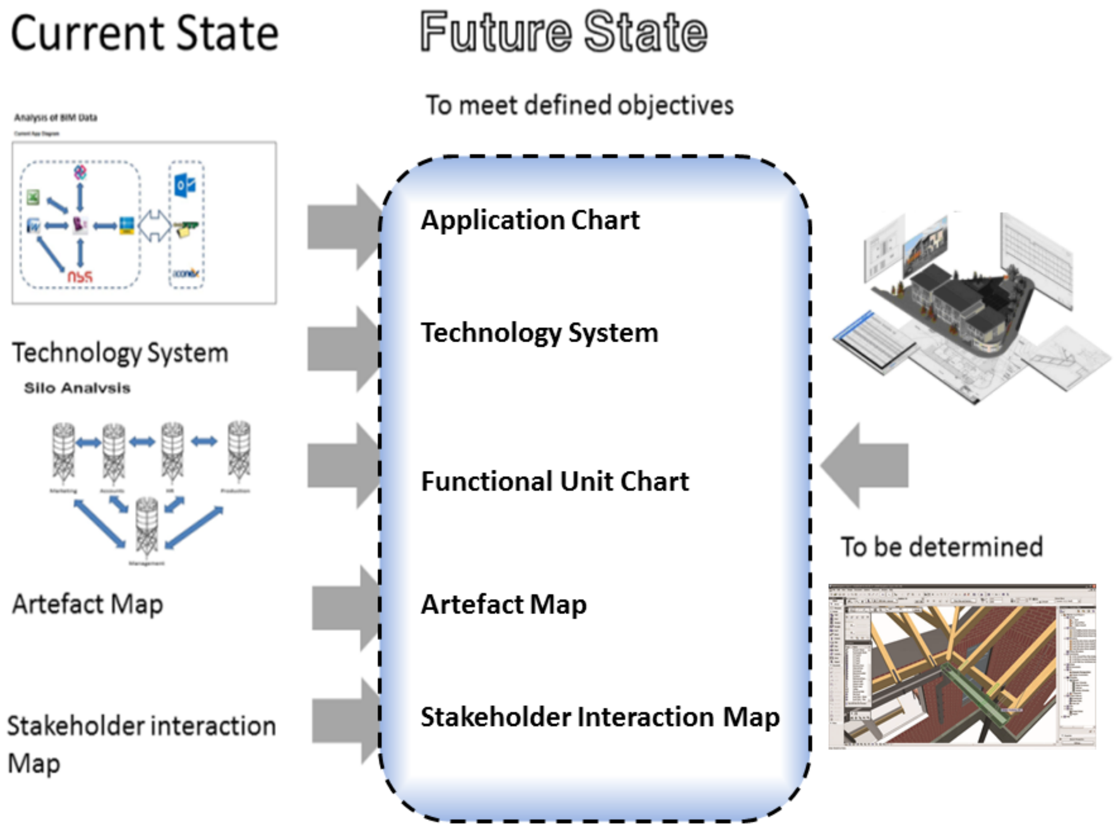


Figure 7.74: Elements to be used to assist in definition of the future state

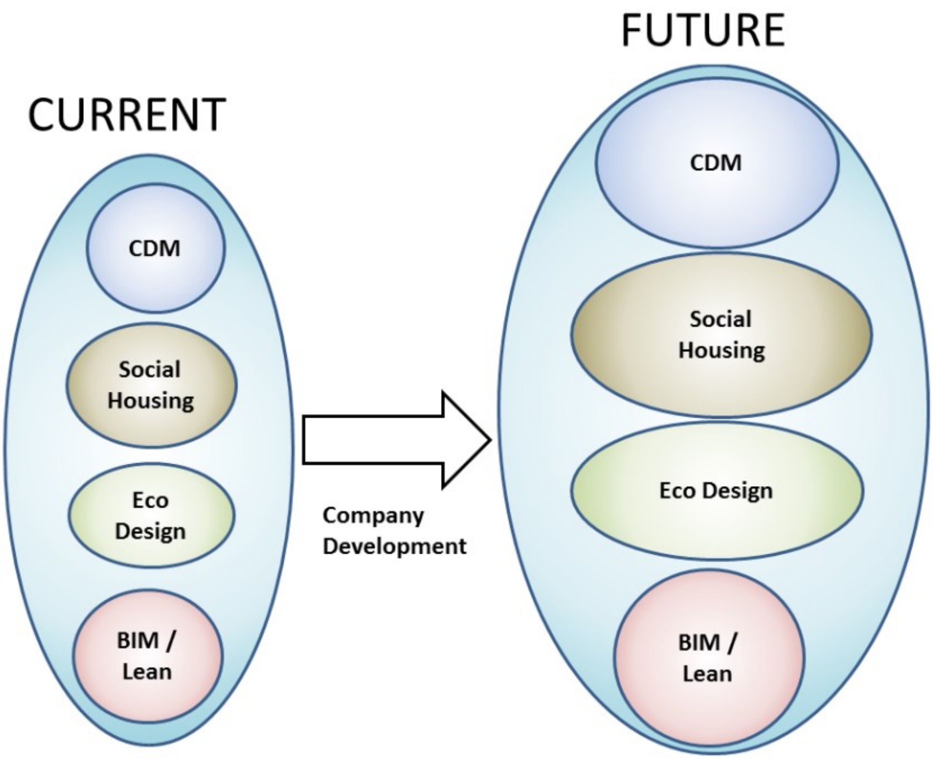


Figure 7.75: Showing predicated company expansion of workload as part of BIM adoption

There are several other strategic management tools which could have been used to help organisations understand their current and future positions. These include the balance scorecard approach, internal factor evaluation (IFE) matrix, external factor evaluation (EFE) matrix and the Boston matrix. Each approach has its advantages and disadvantages. Further analysis using these tools may have given a greater insight into the practice.

Recognising the current state of the architectural practice, its change readiness and purpose for change are all fundamental to the success of a BIM adoption and should be clearly understood by all stakeholders.

What needs to be formally added to this stage is the process of gap analysis. The purpose of gap is to investigate and determine those elements that are currently not available and will be needed to successfully implement BIM. The gap analysis should be undertaken against the objectives defined in the previous work phase. This analysis should result in a written statement on all areas identified (see figure 7.76).

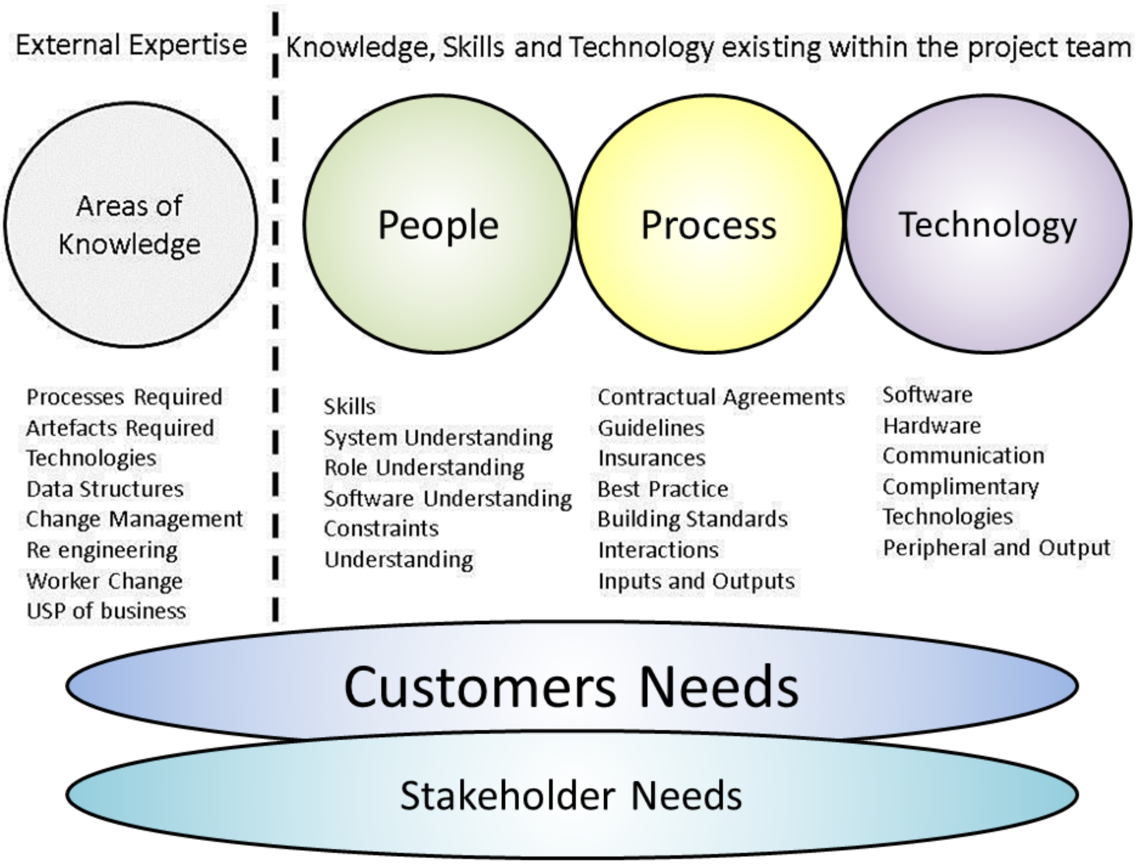


Figure 7.76: Areas which require a Gap Analysis to be undertaken

An important element of the gap analysis is to understand where current practice falls short of meeting customer and stakeholder needs. The expected level of BIM operation will be determined on how successfully these shortfalls are addressed. At the time the research was undertaken the clients of John McCall Architects had no specific BIM requirements they were demanding. Overtime this is likely to change.

When the objectives have been defined a gap analysis needs to be undertaken to establish if there is a shortfall in the knowledge necessary to undertake BIM adoption. This can then feed into the training development.

An understanding of where data should be stored and how it should be used is key to the BIM approach. If this knowledge does not already exist it should be developed within the following stages.

What is also important is for the “unique selling points” or those areas that are critical to success to be determined. If these areas are not already available they should be investigated in the later stages of BIM adoption. When the BIM system is being developed it is vital these issues are addressed and the unique selling points of the company preserved.

Chapter 8

Chapter 8: This chapter explains the action planning stage. This involves defining what is to be achieved, promoting the vision and developing bench marking strategy, developing the BIM implementation plan and mobilizing for the prototype projects.

CHAPTER 8 Explanation of the Action Planning Stage

8.1 Introduction

The purpose of this action planning stage is to confirm direction, determine actions and manage expectations and mobilize to enable the prototype projects to take place. In lean terms this can be considered as the “hoshin” planning stage. The activities in this phase are likely to be context specific to the project and architectural practice.

Through the diagnosis undertaken during the previous stage a greater understanding to the problems and issues faced at John McCall Architects was achieved. In this stage, plans were developed to bring about positive change within the practice. This required the following activities:

- To define what is required
- To promote the vision of what is to happen, particularly those who’s approval is a prerequisite for the project to progress
- To develop project benchmarking strategies
- To develop an implementation plan
- To determine the software and hardware requirements
- To develop a training plan
- To prepare for the prototype projects
- To consider the marketing implications
- The purchase and setup the hardware and software

These activities were distilled from the findings of Tzortzopoulos (2004) documented in section 6.3 of this thesis.

8.2 Defining what is to be achieved from BIM implementation

8.2.1 Defining what is to be achieved – Introduction

It is only after the investigation and diagnosis is completed that the BIM objectives can more clearly be defined. This should be focused around what is desirable, what is viable and what is possible (see figure 8.01).

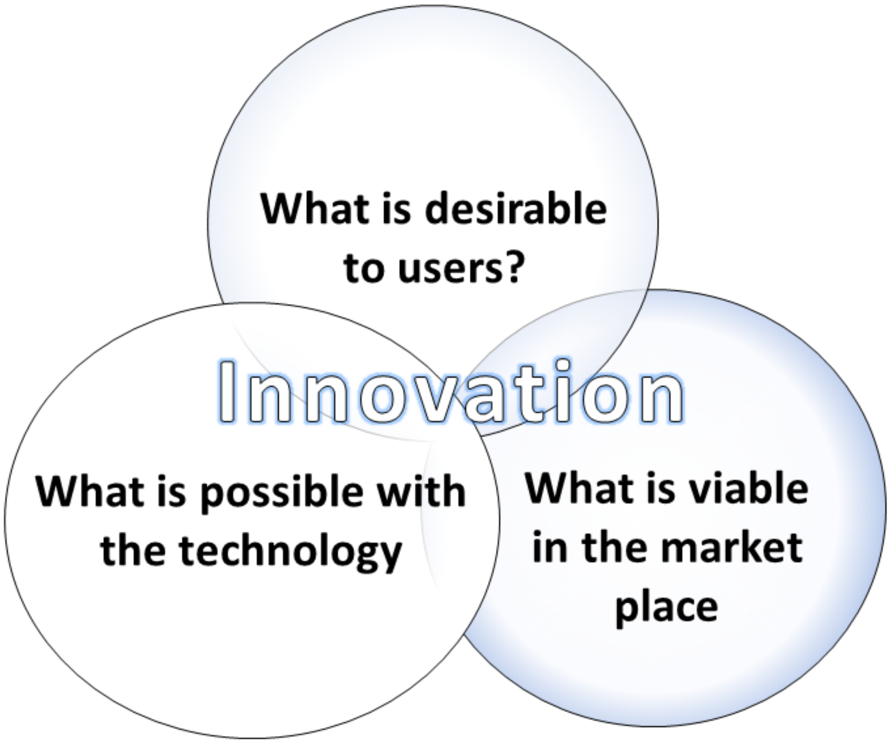


Figure 8.01: Constraints for innovation (Brown 2009)

At this point a value methodology a generic description of what needs to be accomplished without identification of a specific means of accomplishment needs to be defined. Objectives should be considered at project level, practice level and industry level. These can be functional objectives or maturity objectives.

Example lists of BIM functional objectives are now available from various sources. The BIM Project Execution Plan Template Document developed by Pennsylvania State University (2010) is a useful source of guidance here. This execution plan was not available when the research at John McCall Architects was conducted.

Once the functional objectives were determined at John McCall Architects the approach adopted to determine the requirements was the MoSCoW technique (Clegg 2004) (see figure 8.02). The MoSCoW technique offered a simple and quick method to prioritize requirements.

If the time available was longer to prioritize the requirements, additional techniques could have been used such as a Pareto analysis, an Ansoff matrix or a grid analysis. A Parato analysis could have helped to determine the “low hanging fruit”. This would have helped determine the benefits that could have been achieved first with the least effort. The Ansoff matrix would have helped determine those objectives that have the potential to provide the maximum business growth. A fuller explanation of the techniques possible is provided in the Business Analysis Body of Knowledge (BABOK Guide) (IIBA 2009).

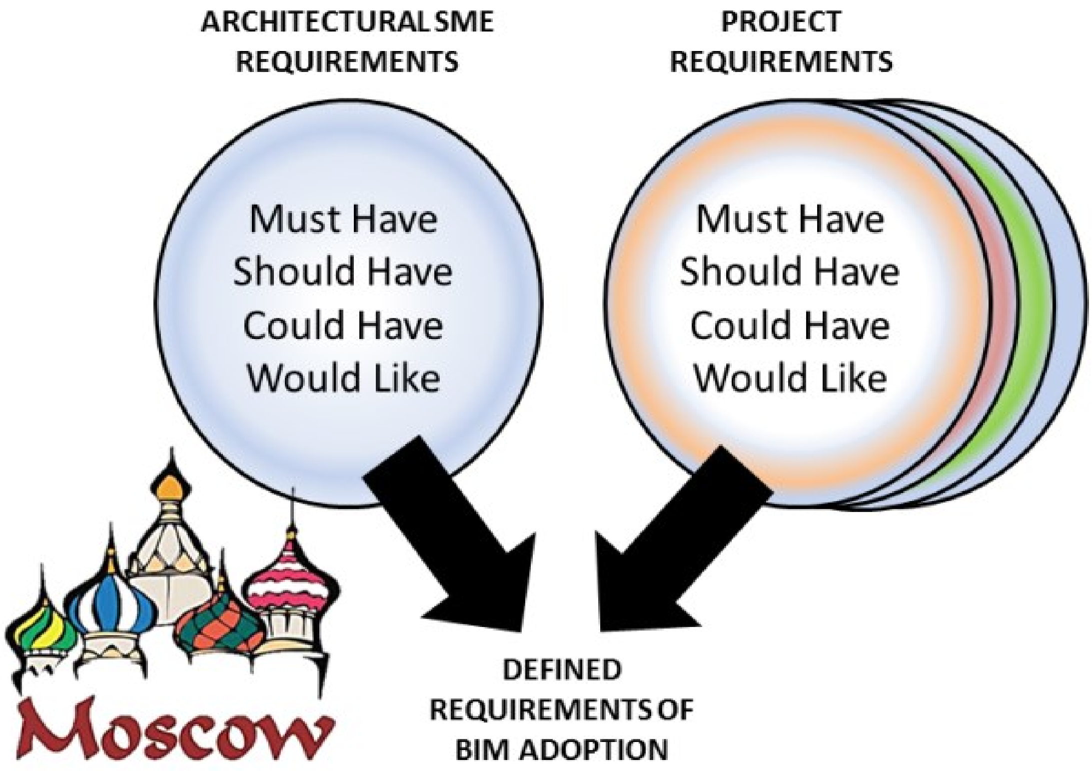


Figure 8.02: Using the MoSCoW technique to define BIM functional requirements

8.2.2 Defining what is required - Actions undertaken at the case study company

Several workshops were held at John McCall Architects to discuss what was required from BIM. Research was undertaken providing the information to define BIM objectives and later to write a formal BIM implementation plan. The primacy of the reasons that justify BIM adoption should influence the decisions and the priorities of the BIM adoption process. The set of reasons is likely to depend on the development stage of the RIBA Plan of work (see figure 6.23). Architects focus on design, therefore they are likely to want benefits in the early project stages.

The maturity of the BIM adoption requirement should also be considered at this stage. Information about BIM maturity can be gained by from the BIM maturity index (see figure 7.06). Although issues of BIM maturity were discussed at John McCall Architects formal reference to BIM maturity indexes did not take place. Using BIM maturity indexes requires some general understanding of BIM that at John McCall Architects was still evolving at that time. In hindsight the use of a BIM maturity index as part of the objective setting process is recommended.

8.2.3 Recommendations on defining what is to be achieved from a BIM adoption

The problem here is that when these objectives are set the people setting the objectives may have a limited understanding of the consequences. To address this problem there is an argument for bring forward the training defining what “what is BIM” to the practice. The exercise of promoting the vision which follows will also help develop a more informed knowledge of BIM as those who participate should start to have a wider appreciation of BIM.

Defining what is to be achieved should ideally result in a formal document that can be reviewed and approved and revisited as the process of adoption progresses. This was not done at John McCall Architects and would be recommended as part of undertaking this stage.

Below is included a desired state checklist to help in deciding how BIM should be implemented (Table 8.01). Using such a checklist would be recommended for future adoptions. Here we use the “MoSCoW” technique. This is used to prioritize requirements by allocating an appropriate priority, gauging it against the validity of the requirement itself and its priority against other requirements.

BIM Objectives

		Must Have	Should Have	Could Have	Would Like
Planning	Existing Conditions Modelling		☺		
	Programming			☺	
	Site Selection			☺	
	Space Planning		☺		
	Preliminary Cost Estimation			☺	
	Phase Planning		☺		
Design	Site Utilization Planning / Analysis			☺	
	Design Visualization	☺			
	Functional Analysis		☺		
	Constructability Review			☺	
	3D Design Coordination		☺		
	Virtual Mock-up			☺	
	Code Checking			☺	
	Engineering Analysis		☺		
	Emergency Evaluation Planning			☺	
	Security Validation			☺	
	Sustainability Evaluation		☺		
	Lighting Analysis			☺	
	Acoustic Analysis			☺	
	Cost Estimation		☺		
	Virtual Testing and Balancing			☺	
	Life Cycle Planning			☺	
	Clash Detection		☺		
Construction	3D Coordination		☺		
	Object Tracking			☺	
	Digital Fabrication			☺	
	3D Control and Planning		☺		
	3D System Design			☺	
	Unit Price Estimation			☺	
	4D Planning		☺		
	Resource Planning			☺	
	Site Utilization Planning			☺	
Operations	Record Model		☺		
	Asset Model		☺		
	Object Tracking			☺	
	COBie		☺		
	Space Management / Tracking		☺		
	Disaster / Emergency Planning			☺	
	Building Performance Analysis			☺	
	Maintenance Cost Estimation			☺	
	Building Maintenance Scheduling		☺		
	Renovation Coordination		☺		

Table 8.01: BIM objectives MoSCoW Chart

The chart was loosely based on the BIM objectives identified by research done at Pennsylvanian State University (2010). This became available after the research at John McCall Architects had been conducted. As an architectural practice most of the “must haves” will be in the design section.

To use this effectively the needs of the small architectural practice and the needs of individual projects must be analysed and then combined into a set of requirements that works both at a project level, organisational level and ideally at a multi-disciplinary level.

An important consideration when undertaking the BIM requirement analysis is not just to take into account the current projects but also predict the projects that the architectural practice will be undertaking in the future. To do this effectively, the practices marketing plan should be referred to (if one exists). The marketing potential of BIM is discussed later in this chapter.

Eco considerations such as building energy consumption or embedded carbon calculations did not register strongly at the outset of the BIM implementation. But when the base BIM capabilities were in place the eco capabilities of using BIM were questioned.

8.3 Promoting the vision

8.3.1 Promoting the vision – Introduction

Through the process of promoting the vision of BIM the aim is to change the people from being resistant to being active passionate contributors (see figure 8.03) and reduced the dissonance to BIM adoption.

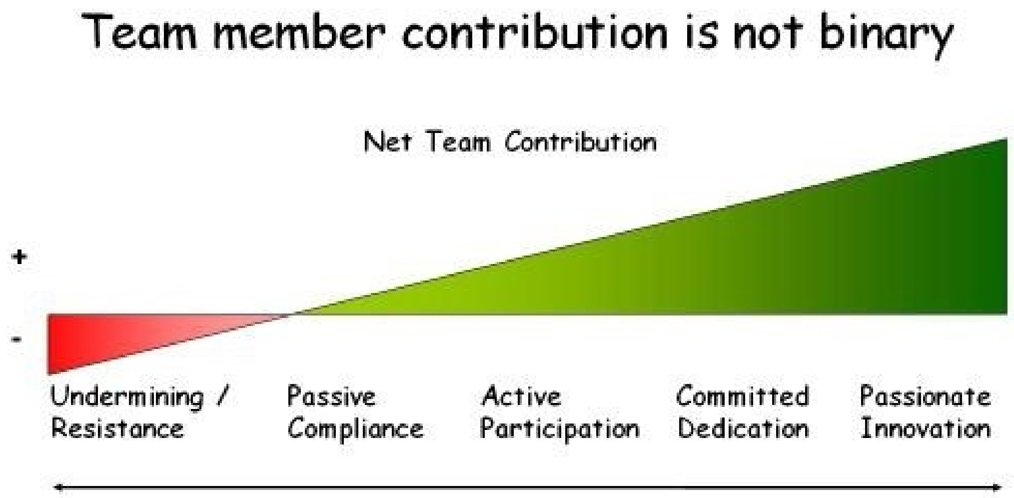


Figure 8.03: Changing the contribution of members of staff engaged in a BIM implementation (Agile 2007)

Here the aim is to change the organisations view of the world. In terms of the Prosci ADKAR model (Hiatt 2006) (see figure 8.04) this is about developing the “desire” of the members of the company to participate and support change.

A Awareness of the need for change

D Desire to participate and support the change

K Knowledge on how to change

A Ability to implement required skills and behaviours

R Reinforcement to sustain the change

Figure 8.04: The Prosci ADKAR Model for change management (Hiatt 2006)

This is achieved by promoting a new vision to the employees and stakeholders within the organisation. A vision is a deeply held picture of where a person or group or practice wants to get to in the future. The vision is a mental picture of what the future state of the practice will be a how it will interact with its stakeholders and provide its services. The elements of a BIM vision contain product, process, profit and direction.

BIM is merely an enabler, it may institutionalize process changes, it does not drive change; People propel organizational changes (Spitzer, 1996).To make the transition what is required is transformation leadership. Transforming leadership is a process in which leaders and followers help each other to advance to a higher level of morale and motivation (Burns 1978). What is desirable is that participants in the change to BIM are changed from being amotivated to be intrinsically motivated (see figure 8.05). Using this motivation organisational change can be brought about more effectively.

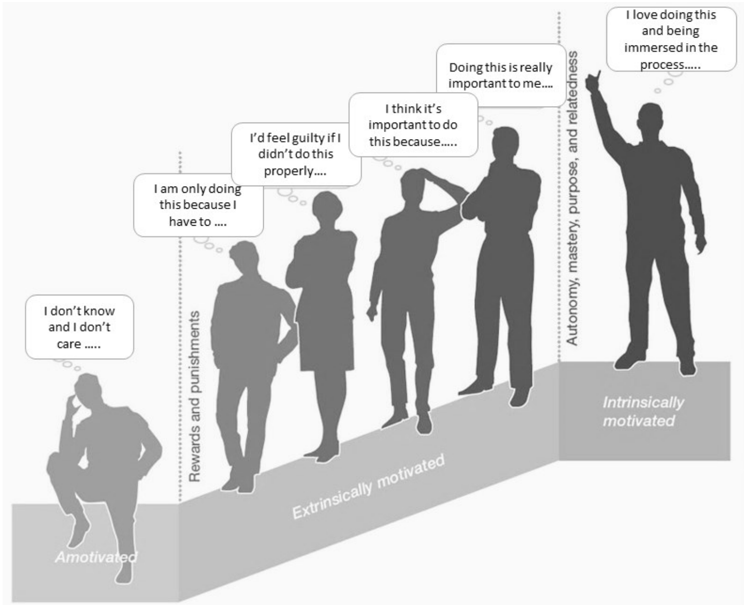


Figure 8.05: The change from Amotivated to Intrinsically Motivated (Bisset 2009)

In chapter three (section 3.3.7) the barriers to BIM adoption were identified. It is these many of barriers that need to be addressed to gain management support, acceptance and commitment. In this section, methods to overcome this resistance "promoting the vision" are documented. The appropriate method to gain management support and acceptance, very much depends on the corporate culture of the company.

The fundamental error that most companies commit when they look at technology is to view it through the lens of their existing processes. They ask, 'How can we use these new technological capabilities to enhance or streamline or improve what we are already doing?' Instead they should be asking, 'How can we use technology to allow us to do things that we are not already doing?' (Hammer & Champy 1993).

According to Cooper (1989) in each period of our history, design and communication have evolved synchronously with the technology of the time. Each new medium has extended our sense of reality and each has looked to its predecessor for language and conventions, referencing and adapting characteristics until its unique capabilities can be explored and codified.

The central to developing a vision is to understand the history, heritage and culture of a practice. Developing the vision requires overcoming the resistance to change. The resistance to change relates to organisational issues and individual psychological factors. Topics include: expressing expected results; and understanding the project in terms of business and organizational objectives, competitors' actions, internal needs, external conditions, customer needs, vendor support, and colleagues' experiences.

Again graphic facilitation was used at John McCall Architects as a tool to help build the vision.

Although the BIM Champion may move the company towards BIM, a BIM implementation is only really successful when it is embraced and seen as the appropriate solution to all the staff involved.

8.3.2 The requirements of promoting the vision

It is important at the outset that those sponsoring and those to be affected with BIM adoption have an overview of its implications and the issues involved. An indication of cost, resources and time should be given at this stage and updated as the project progresses. Such information may be available from others who have already undertaken BIM adoption within the profession. To carry BIM adoption forward a shared vision is necessary. Expectations need to be managed and planning ahead helps minimize stress and ensure a successful BIM implementation.

8.3.3 Activities undertaken to promote the vision

At John McCall Architects a considerable time and effort was spent developing and promoting the vision. This was done at all levels within the company but particularly with the directors. At John McCall Architects it was necessary to overlay their vision of the future with the implications imbued when adopting BIM. An important element here for the BIM Champion is to be particularly knowledgeable about the subject. The major exercise is one of changing the mind-set of the individuals working for the company (see figure 8.06) (Hermund 2009) (Williams 2010). Technology, people and process concerns must all be addressed.

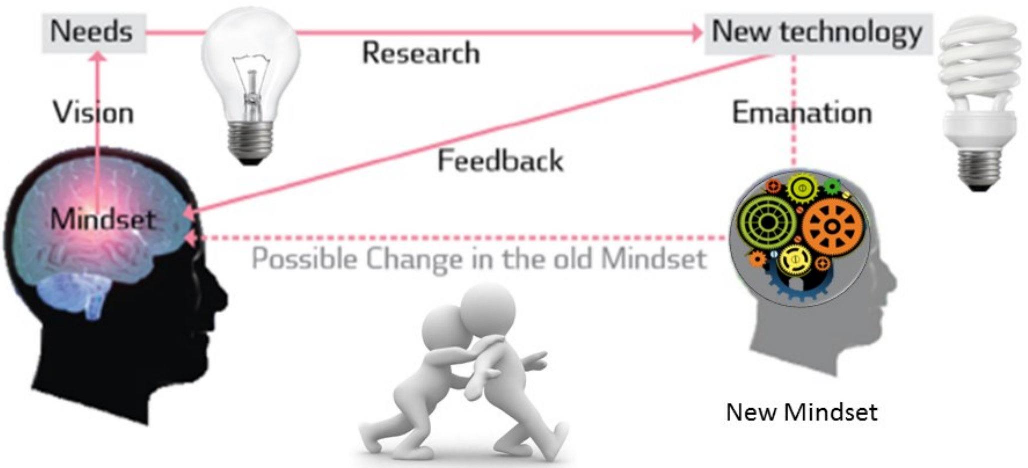


Figure 8.06: Changing the mind set to adopt BIM (adapted from Hermund 2009)

The change required is at the level of the individual but the aim is to get a collective organisational vision of BIM. To do this, the vision needs to be translated appropriately for the team.

When the BIM adoption process was started at John McCall Architects, the directors saw it as a way to be at the vanguard of CAD. This was helpful in some respects because no predefined solutions were expected. Overtime a fuller understanding of BIM was developed showing BIM to offer more than CAD. But the earlier vision of BIM at John McCall Architects was as an advanced form of CAD. This to some extent may have limited what was achieved.

When developing the vision, the focus was mainly on short term and medium term gains. If long term goals are put across disillusion may occur when these are not achieved in the short or medium term.

Short term gains identified were:

- The quality, speed and cost of the services John McCall Architects provides
- Automatic low-level corrections when changes are made to the design through the use of parametric relationship between objects
- Generate accurate and consistent 2d drawings throughout the design
- Visualizations to allow checking against design intent
- Discovering design errors before construction

Medium term gains identified were:

- Information sharing
- Greater flexibility to satisfy customers
- Better financial control
- Simultaneous work by multiple disciplines

The way the vision is put across also depends on the degree of active involvement expected from the members of staff (see figure 8.07). An individual can champion BIM adoption in a small company in a large architectural organisation a team may be required to drive the BIM implementation.

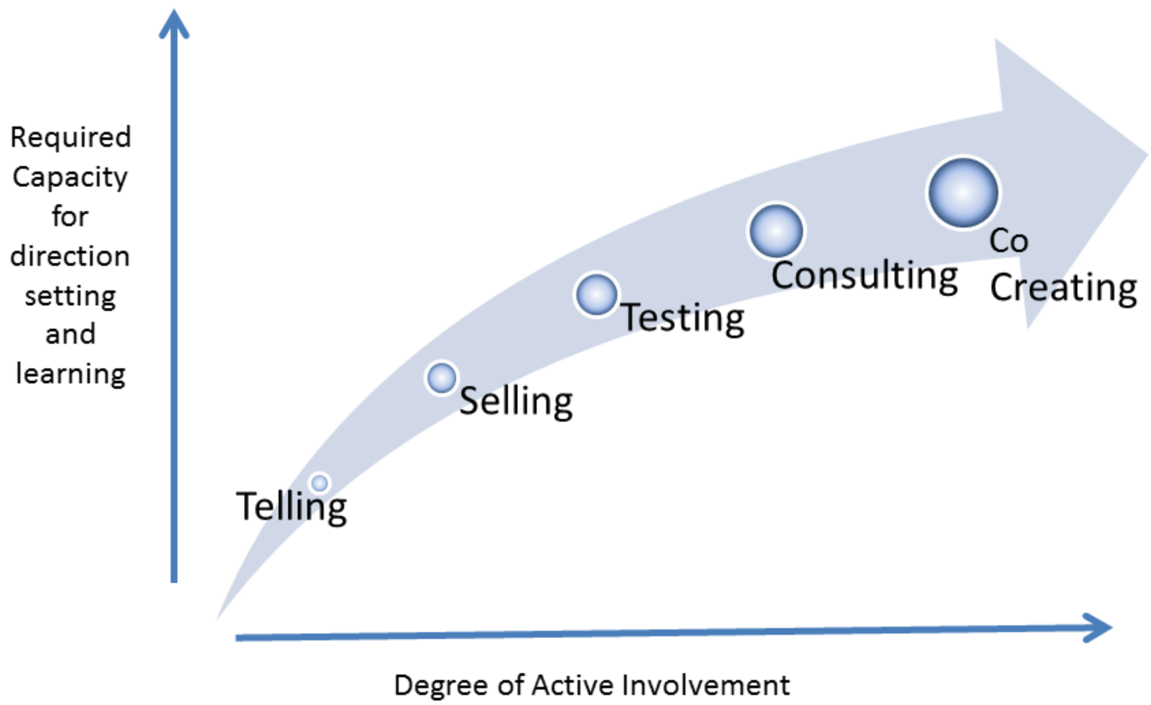


Figure 8.07: The process of building a vision (Senge 1994)

Building a vision can be achieved and was achieved at John McCall Architects through a process of graphic facilitation. This is the approach recommended by BS 7000 the British standard for design management systems part 1 Guide to managing innovation. Graphic facilitation is the art of leading people through a process to agreed-upon objectives in a manner that encourages participation, ownership and creativity from all involved (Sibbet 2011). As part of the soft system methodology (Checkland 1990) rich pictures were used to understand the problems and issues to be resolved. These rich pictures can then also be used for graphic facilitation.

Using metaphors can be a powerful tool when redefining the nature of work (Kensing 1991) (see figure 8.08).

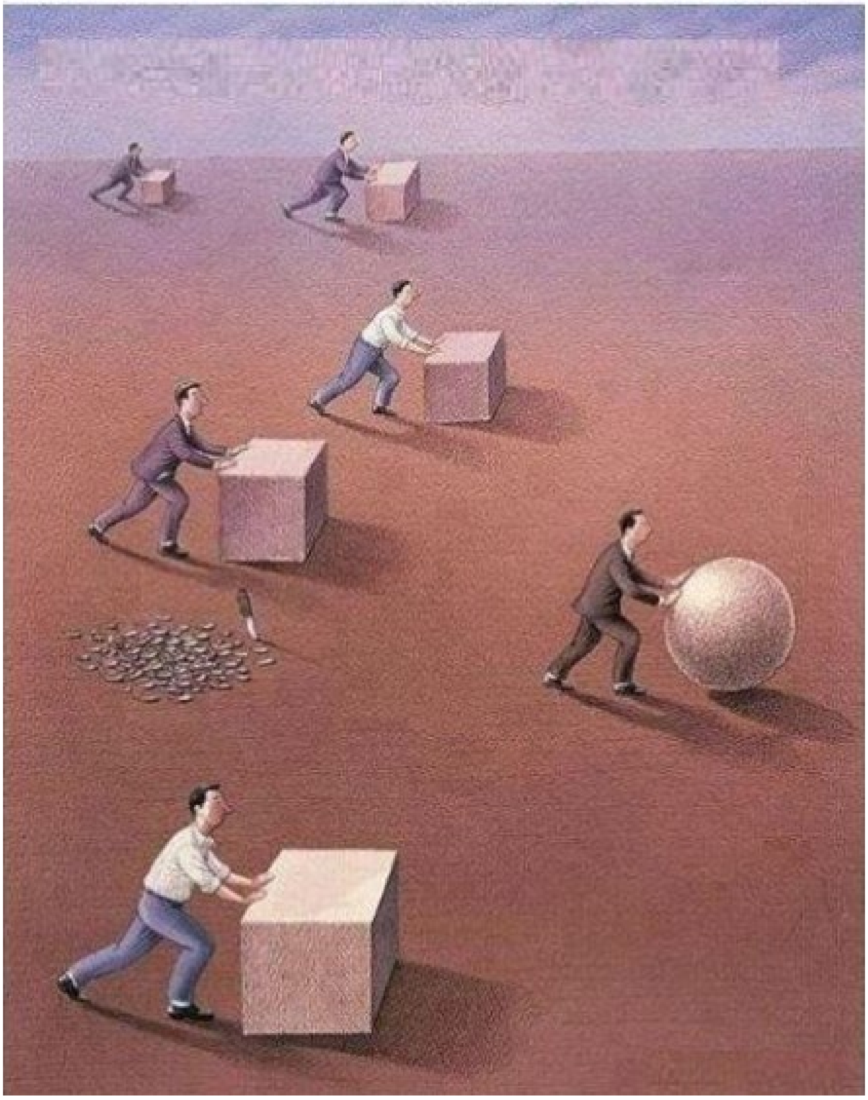


Figure 8.08: CAD vs BIM – A visual aid (source unknown)

Once the message was understood recommended presentation techniques were adopted (Durate 2012). These involved the presentation going through various prescribed phases:

- Reminding people of the status quo
- Revealing the path to a better way
- Setting up a conflict that needs to be resolved

This was the structure of many presentations given at John McCall Architects (see figure 8.09).

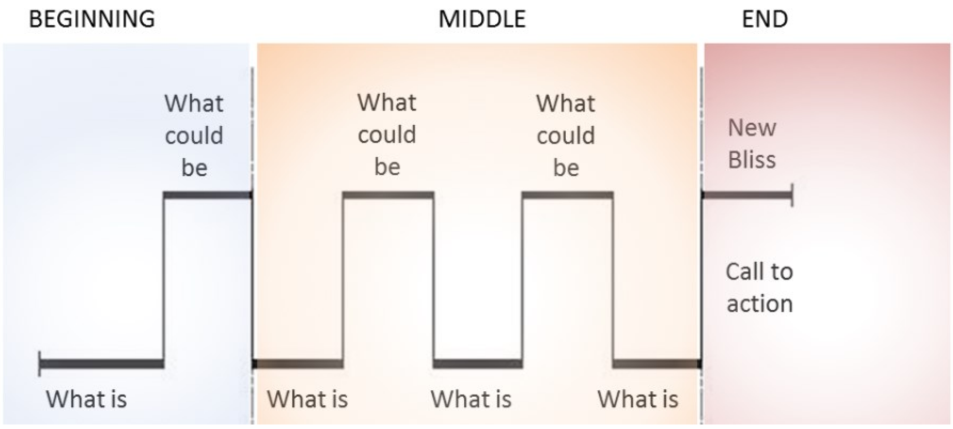


Figure 8.09: The persuasive story pattern adopted for many of the BIM implementation presentation at John McCall Architects (Duarte 2012)

Developing a vision was achieved through numerous presentations (dialogues) involving members of staff from the practice. As part of these presentations numerous context diagrams were discussed to build a consensus among the members of the practice on what could and should be improved through BIM adoption.

Generating discussion was an important part of the presentations. It also provided feedback on how the efforts of promoting the vision were achieving their objective. These presentations focused on the benefits that could be gained from adopting a BIM approach (see figure 8.10). This vision was also put across in many informal dialogues that took place within the office.

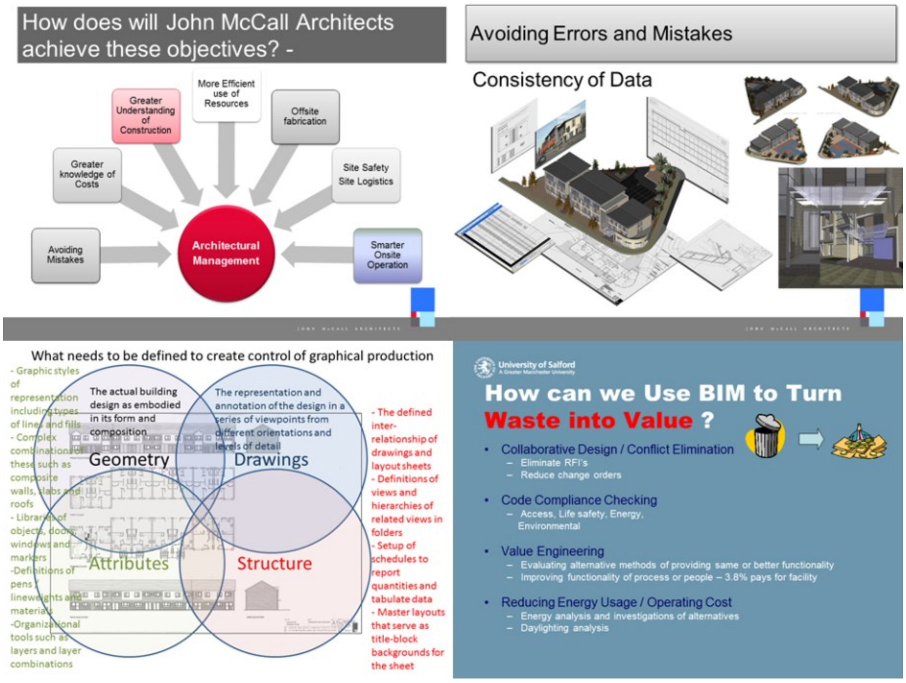


Figure 8.10: Sample slides from vision building presentations given at John McCall Architects

These benefits were put across within a lean perspective and addressing lean wastes (see figure 8.11) to gain greater efficiency. It was shown how BIM could address many of the existing “wastes”. This was time well spent as the enthusiasm and shared understanding were important for taking the project forward in it later stages.

Figure 8.11: Slide from presentation showing Lean wastes as a justification for adopting BIM (GoLeanSixSigma 2013)

The presentations that took place predominately took place at John McCall Architects during lunch time so as not to disrupt the fee earning work taking place within the practice. In order to get staff to attend it was necessary for such presentations to be informative, educational, enjoyable and also to allow time for them to buy sandwiches.

The benefit of this informal setting was that staffs were willing to discuss issues and problems in a way that might not have occurred within more formal meetings.

When everyone in a group thoroughly understands and shares the same vision as was the case for the staff at John McCall Architects they become motivated. They apply their selves to achieve their vision. Throughout the period of research it was possible to generate such enthusiasm among the members of staff. Selling the vision has to do with the human beings and their psyche, and sometimes great effort must be spent on changing the values that people have internalized.

8.3.4 Recommendations to improve the promoting of the vision

The process of promoting the vision did not stop at this early stage of the BIM implementation. It was necessary to continue to promote the vision through whole period of the BIM implementation. Without this continued effort the BIM adoption may have stalled at many points during its development.

Using the lessons learnt from developing the benchmarking criteria could have assisted in the development of the vision. This approach is suggested for future BIM adoptions.

8.4 Benchmarking

8.4.1 Benchmarking - Introduction

Benchmarking is recognised as a valuable tool for the evaluation and contextualisation of organisational performance that leads to superior performance (Cowper 1997). It helps to formulate and frame the right questions and this enables greater focus on priorities for further assessment and better use of scarce resources. Benchmark is also an appropriate tool to evaluate BIM implementation.

Using benchmarking can show the following:

- where are the practices weaknesses
- areas which can be improved
- new or different ways to do things
- strategies for improvement
- what is possible
- where are the strengths are and how to maintain them
- where efficiency can be increased

Benchmarking can be considered in three ways, performance benchmarking, process benchmarking and product benchmarking (Camp 1994). Here the focus is placed on performance benchmarking.

To develop a benchmarking strategy key performance indicators need to be identified. The underlying reasons for benchmarking are to learn how to improve the business process and thereby increase the competitiveness. Thus it is important to develop a benchmarking strategy as part of a BIM adoption. Revisiting the benchmarking at the end of the BIM implementation project is likely to suggest future strategies and actions to adopt.

8.4.2 Benchmarking - Activities undertaken at the case study company

The following attributes are sought for the definition of KPIs (Key Performance Indicators):

- Does the KPI motivate the right behaviour?
- Is the KPI measurable?
- Is the measurement of this KPI affordable (cost-effective)?
- Is the target value attainable?
- Are the factors affecting this KPI controlled by you?
- Is the KPI meaningful?

Some initial investigation into the expected KPI of the BIM implementation should have taken place when the business case was developed.

One of the issues here is that we have to be careful not to just define performance improvement by those KPI's by which it has been historically measured. In order to derive the KPIs, it is necessary to understand the organizational inputs, outputs, and desired outcomes and these KPIs should be as closely linked as possible to the top-level goals of the business. Specifically with BIM, there has been a lack of consistent fiscal benchmarking to evaluate the business improvements and gains from BIM adoption (Gerber & Rice, 2009).

The following steps have been undertaken in the KPI identification.

- Step 1: conducting brainstorming sessions in John McCall Architects and interviewing the external stakeholders John McCall Architects collaborates:
- Step 2: Filling out the KPI design form for all the potential KPIs collated from the brainstorming sessions and the interview with the external partners
- Step 3: Evaluation and assessment of the potential KPIs from step 2 to filter them against the checklist above recommended by Gerber & Rice, (2009)

Using the diagnostic material from earlier stage of the BIM implementation approach led to finalized identification of the KPIs for the evaluation of the business improvement in John McCall Architects and subsequently the assessment and measure the extent of the success of BIM adoption.

Each architectural practice will have KPI which are unique to the practice but many of the KPI will be similar to other architectural organisations.

a) Man hours spent per project - efficiency with cost per project: It is possible to compare the man-hours spent on one project that utilises BIM software with the man-hours spent on the same project using a traditional CAD system.

b) Speed of Development: Turnaround time is important and if handled correctly, it can reduce outstanding work and costs, and improve cash flow. In addition, speed of turnaround also engenders client satisfaction.

c) Revenue per head: Higher revenue per head is achieved when fees increase. Clients will only pay more if they perceive greater value. The potential value of BIM for many clients remains unproven in areas such as facilities management.

d) IT investment per unit of revenue: The use of IT has become a prerequisite of architectural practice and many IT solutions exist. It is important to measure the success of one IT innovation against other potential innovations.

e) Cash Flow: On a daily basis, cash flow is not profitable every day, but setting and achieving a daily margin of profitability is critical to success. Successfully monitoring cash flow allows meeting obligations and protecting the future. By increasing the rate at which product is turned around enables invoices to be raised earlier and liquidity can be maintained.

f) Better Architecture: Whether architecture is better or not is dependent on the individuals' perspective. How to achieve better architecture is critical by making better informed decisions. The use of BIM claims for greater investigation and understanding which has the potential to lead to better decisions and better architecture.

g) A better product: Many facets attributes to BIM have the potential to produce a better product through the reduction of mistakes, clash detection, automated model checking, reduction in build ability issues, reduction in professional insurance costs, etc.

h) Reduced costs, travel, printing, document shipping: Travel expenditure in time and money may be reduced to fewer issues. Printing costs may be saved because less check sets of drawings will be necessary. Document shipping should be reduced when a single multidisciplinary federated model is used.

i) Bids won or win percentage; BIM is supposedly a marketable commodity and helps attaining competitive advantage to win bids, which is based on many different factors. Most of the work gained by John McCall Architects is through framework bids through long term partnerships.

j) Client satisfaction and retention: capturing client requirements and needs and establishing a shared understanding with them on the design and developing a partnering approach are critical and involving them throughout the process to inform and receive feedback from them can be achieved through BIM adoption in order for client satisfaction and retention.

k) Employee skills and knowledge development: staff reaction and acceptance, their cultural attitudes, their skill and knowledge level and related BIM training should be also measured and managed accordingly. Also aggregated competencies across teams should also be considered.

Weighting and normalizing should be carried out once data is gathered on the individual KPI's. Where two KPIs measure similar aspects of performance in different perspectives or contribute to more than one aggregated metric, the KPIs should be weighted accordingly. Although the KPI's were identified at John McCall Architects a full evaluation against the KPI's did not take place.

8.5 Developing the BIM implementation plan

The BIM implementation plan will be determined by the desired state the architectural practice wishes to achieve and in what timescale this needs to be achieved. Here we take the outcomes of the diagnosis stage and the outcomes of step defining the objectives and develop an implementation plan (see figure 8.12). By gaining an understanding of the current situation and understanding what are restrictions and industry best practices, it is possible to develop an improvement plan. The step process of developing the BIM implementation plan is also shown (see figure 8.13). A plan is necessary because:

- It allows more accurate resource scheduling
- It allows project creep or divergence to be spotted
- It allows more effective delegation
- Short term objectives encourage higher motivation
- The plan allow for a shared understanding of the project

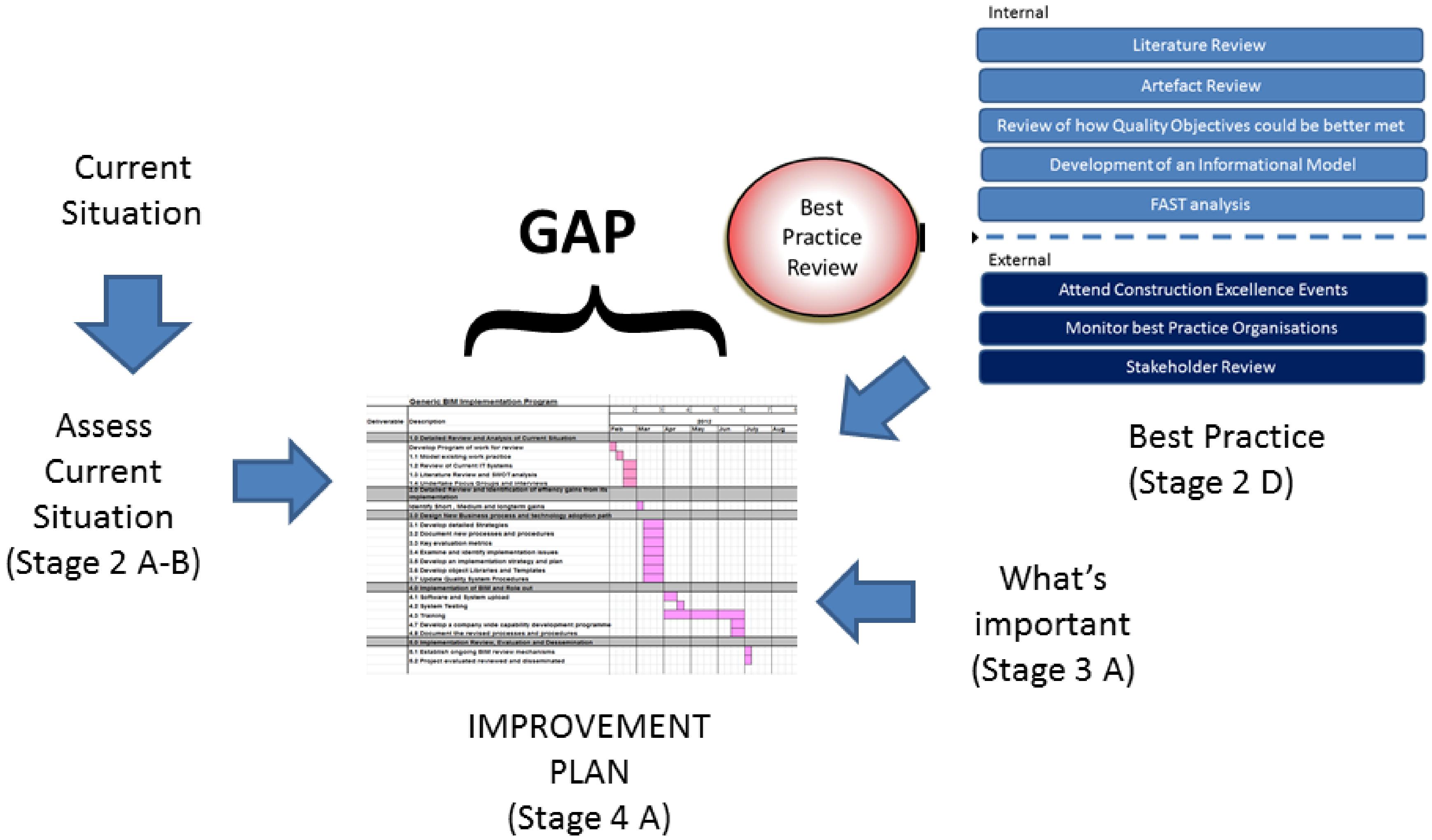


Figure 8.12: Showing how the analysis of the current situation and an understanding of best practice feed into the improvement plan

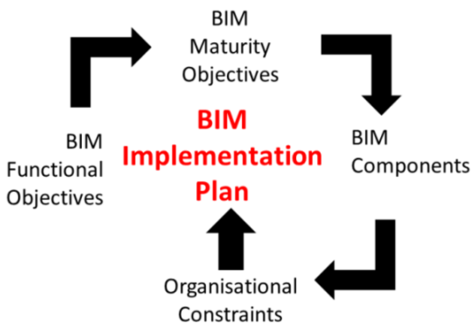


Figure 8.13: The step process to define the BIM Implementation Plan

Several other BIM specific implementation plans templates exist such as the USACE BIM project execution plan (2010). Many of these plans seem too simplified to gain an understanding necessary to undertaken an informed BIM adoption. To correctly implement BIM an in depth knowledge of the participating organisation is required. A proposed structure for a BIM implementation plan is indicated (see figure 8.14).

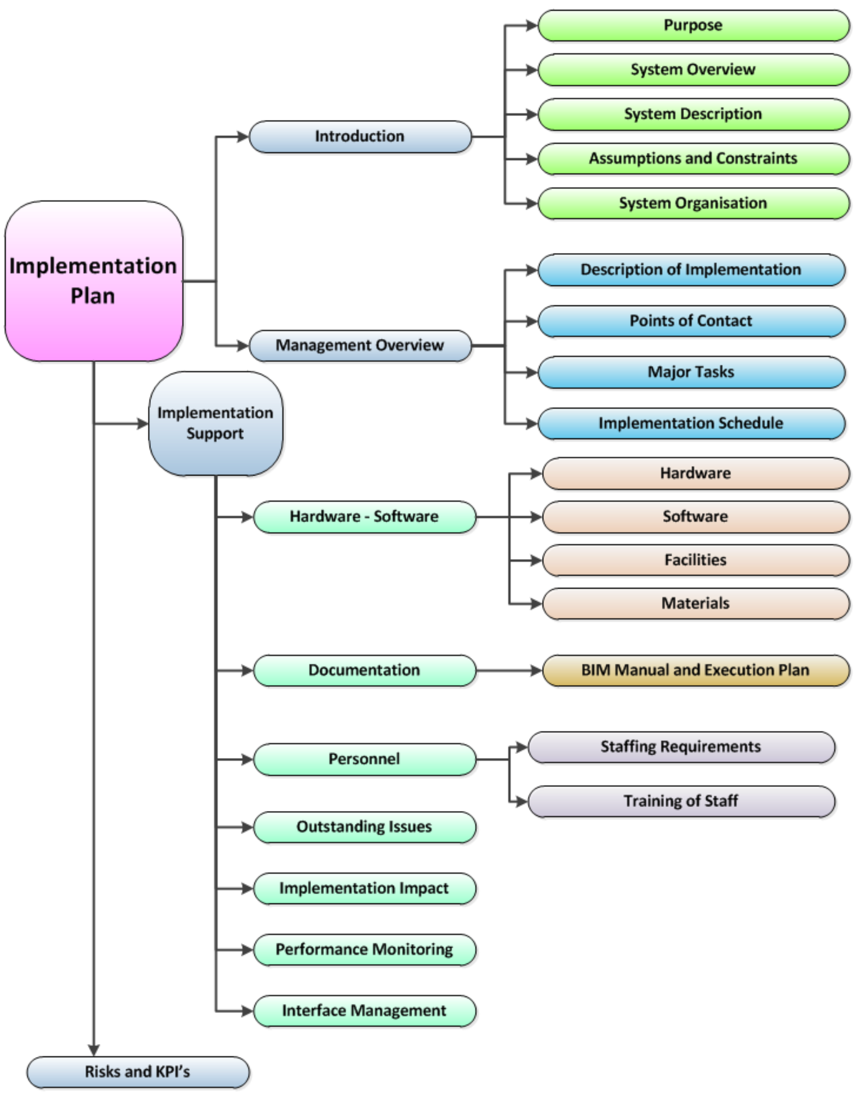


Figure 8.14: Items to be included in a BIM implementation Plan

Using this format for the implementation plan relevant criteria should be documented under each section.

Project planning should include the development and use of schedules such as Gantt charts to plan and subsequently report progress of the BIM implementation project.

As with all technology projects the adoption of BIM is a project that needs to be managed. This is achieved by determining what is required and creating a BIM project rollout program. To determine what is required the objectives of adopting BIM must be understood and agreed upon. When the critical project BIM deliverables are required will determine the dates from the BIM adoption program. From this the activities required to achieve these deliverables can be extrapolated back. Critical dates maybe the agreed delivery of a project in a BIM format to a client or contractor at a specific date. This will give a timetable of activities and expenditures to take place and also a means to monitor the progress of the project. In many cases standards, training and system installation and customisation will be necessary before work using BIM is undertaken. To assist in this process a needs analysis framework was developed (see figure 8.15 Appendix A). Using this, the needs can be documented against the overall timeline of the BIM adoption.

The BIM Execution Plan (BEP) documents the standards and protocols for how the team (Contractors, AEC Firms and others) will work together in the design and construction of buildings maybe required. This is necessary when multidisciplinary BIM is adopted. This was not the case at John McCall Architects. The BEP will define the level of development (LOD) to be modelled, file exchange processes, naming standards, the roles the different parties play in the modelling process and more. The more thorough the BEP is prior to work commencing, the more smoothly the entire project will go. Further information of the development of a BIM execution plan is given in the later section on mobilization to undertake live projects.

By understanding the issues to be addressed and by defining the actions required an action plan can be developed. The action plan places the actions in sequence to avoid waste in effort, to meet external and project requirements and provides a benchmark against which the progress of the BIM adoption can be monitored.

Once the objectives have been defined and also when they are required an outline program should be developed and agreed on. The figure shows a simple outline program for a single discipline roll out (see figure 8.16 Appendix A).

No formal plan was written at John McCall Architects. This in part was a result of the directors of the practice continually changing the direction of the project. The underlining problem was the cost overhead that was to be incurred and at time there was a desire by the directors to shelve the BIM implementation.

At all stages of BIM maturity it must be remembered that the development of the technology, people and process must be aligned. If one of these is not equivalently developed the BIM effectiveness will be reduced and risks or errors built into the system. When considering short, medium and long term goals it is good to think in terms of building foundations onto which future capabilities can be built.

8.6 Determination of hardware and software

The suggestion on which BIM software to select will most likely have been generated as part of the BIM tool review undertaken during the diagnosis stage. This was the case at John McCall Architects. The commitment to a particular BIM tool or collection of tools should only be made once the objectives of the BIM implementation are defined. Such objectives may be for example thermal modelling or cost analysis. Selecting the wrong BIM tool may result in an inability to meet the required objectives. At John McCall Architects the selection of the BIM tool to adopt was a much discussed and argued subject. In the end it was decided to trial ArchiCad BIM software running on PC hardware. This is a critical decision that must be made to allow the project to progress. Hardware used should be in accordance with the software vendors recommendations.

8.7 Development of the staff training plan

Training for BIM can be divided into software agnostic and software specific training (see figure 8.17).

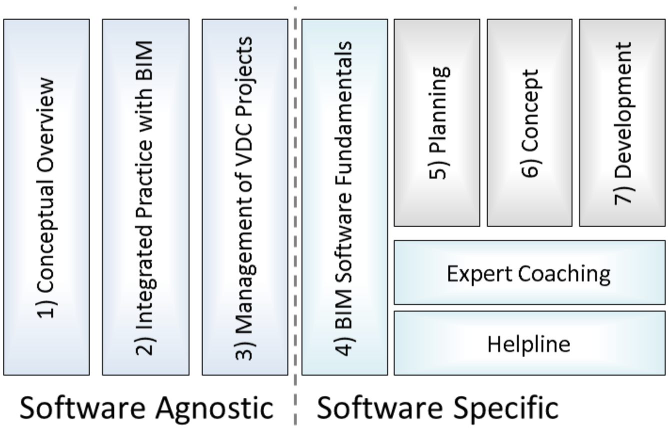


Figure 8.17: Types of BIM training (Rinella 2012 Anshen & Allen Architects)

To operate a BIM environment effectively people with different skills are required with different levels of expertise. The range of skills related to different roles was set out in the AEC (UK) BIM Protocol (2012) (see figure 8.18).

	Strategic						Management				Production	
Role	Corporate Objectives	Research	Process + Workflow	Standards	Implementation	Training	Execution Plan	Model Audit	Model Co-ordination	Content Creation	Modelling	Drawings Production
BIM Manager	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N
Coordinator	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N
Modeller	N	N	N	N	N	N	N	N	N	Y	Y	Y

Figure 8.18: The range of skills required by different role as part of a BIM implementation (The AEC (UK) BIM Protocol V2 2012)

An awareness of peoples' background knowledge is important. It is often the case that people with CAD skills are then used as BIM operators. The concepts behind the two technologies are different so staff will need to be re-educated in BIM. Legacy ideas are possibly one of the biggest obstacles when adopting BIM. It is important to change the vocabulary and change perception. Also to operate a BIM system peripheral staff such as IT support will be necessary from time to time.

There will be many different roles when utilizing BIM some will be management some will be production. Ideally a concept of operations (CONOPS) document should have been developed describing the characteristics of the proposed system from the view point of an individual user. This can then be used as a basis for determining the outstanding training requirements.

Full trainings schedules will be necessary for all staff making the transition to BIM. These schedules were developed at John McCall Architects. There are also people who are not directly involved, but commitment from principals and stakeholders is essential for successful BIM adoption.

Cost figures from David Miller Architects a small practice based in central London show the major investment in BIM is in training (see figure 8.19).These figures include billable hours lost whilst the training was undertaken. Similar cost were incurred at John McCall Architects.

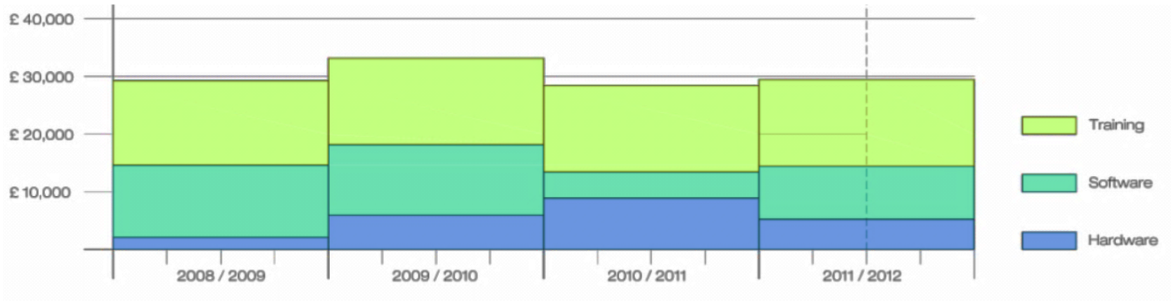


Figure 8.19: Annual investments in BIM at David Miller Architects (Miller 2011)

The high cost of training is in part because to undertake training it involves analysis, design, development, implementation and ideally feedback on the training given.

What is critical is that the best and most efficient and effective forms of training are used. Where possible the training should designed so the material can be reused as required.

To develop a staff training plan several issues need to be confirmed:

- What knowledge is required
- Who needs the knowledge
- When is the knowledge required
- How should the knowledge be delivered
- How should the knowledge be recorded
- How should knowledge delivery be assessed

A BIM-Competent Individual is someone who has adequate BIM skill, knowledge and experience. A BIM-Competent architect will, not only generate a data-rich 3D model, but should also be able to achieve this in a timely manner and according to a high delivery standard (Succar 2010).

Prior to undertaking training of company staff it is important to understand the skills they already have. BIM specific skills can be evaluated through questionnaires or hands on testing. Examples of BIM skill assessment tools can be found at BIM excellence.net and on the Knowledge Smart website. The analysis should provide an understanding of the skills related to the various roles that are necessary. A knowledge of the skills of the staff at John McCall Architects was gain by working with them on a daily basis.

At John McCall Architects the ADDIE model (see figure 8.06) was used to develop the training for BIM. The ADDIE model is actually a frame work that lists the generic process traditionally used by instructional designers and training developers (Morrison, 2010). The five phases—Analysis, Design, Development, Implementation, and Evaluation—represent a dynamic, flexible guideline for building effective training and performance support tools. In this stage the analysis phase of the ADDIE model is addressed. This requires eight questions to be addressed:

- What is to be taught
- What are the teaching objectives
- What defines successful teaching
- Who are the audience
- What do they already know
- What do they need to learn
- What resources are available to help with the teaching process

To implement BIM staff have to learn a range of new skills and adopt several different views of how they should operate. The best training is the one that gives you the answers you need at the time you need them. This is the concept of just in time training. Ideally this knowledge should be imparted by the person sitting next to you or shortly before it is required. This concept of distributed learning was explained previously (see figure 6.11). The next best situation is to be trained shortly before the skills are required. The typical forgetting curve is shown (see figure 8.20). This is why the timing and the focus of the training is particularly important. Learning is reinforced when nit can be applied in practice.

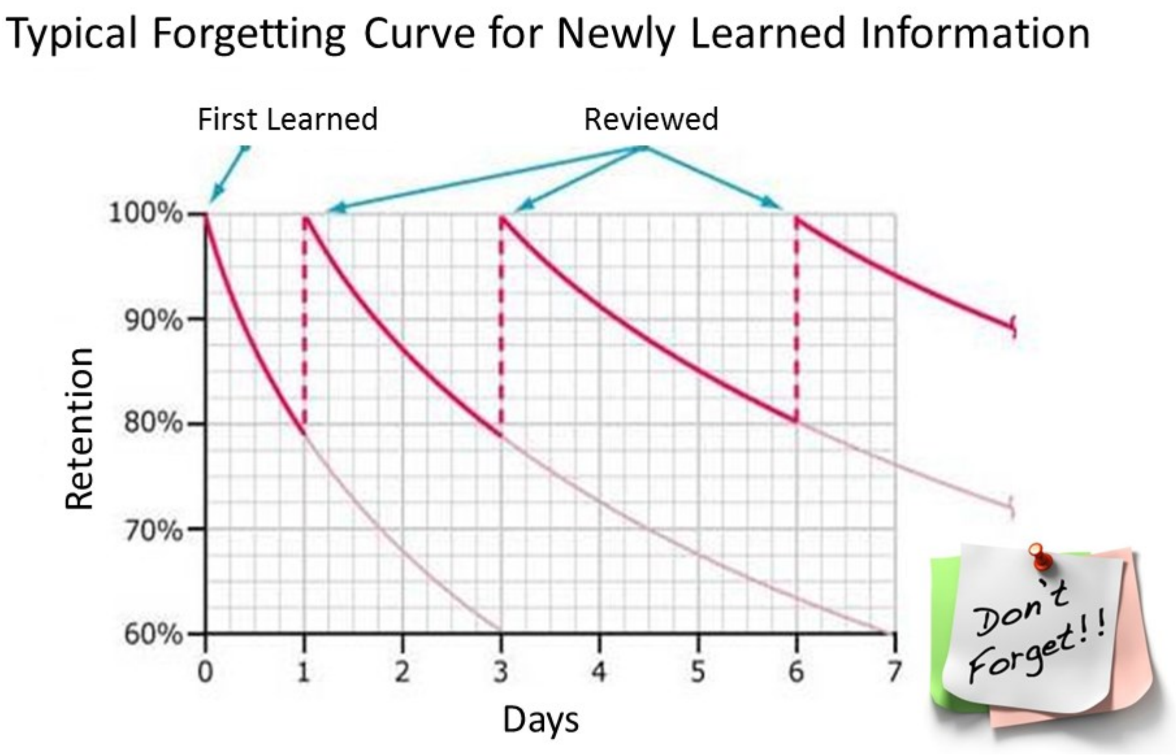


Figure 8.20: The forgetting curve (Ebbinghaus 1775)

At John McCall Architects no formal document was developed covering these questions but the recommendation would be to produce such a document for future implementation. The documents ideally to be developed are:

- The Training Program
- The Training Material
- The Skill Validation methods
- Roles and Job Descriptions

Multiple forms of training may be adopted to best suit the message and the personnel involved. Where possible training should be based on existing knowledge. In John McCall Architects case the existing CAD methods of operation were used as a foundation to discuss the new methods of BIM operation. As the BIM Champion also had a knowledge of the legacy system, Microstation. This proved to be helpful. The similarities and differences between BIM and CAD were explained in a series of lectures. At the outset what users of BIM tools can do will be limited the aim is to increase their ability to take advantage of the BIM tools (see figure 8.21).

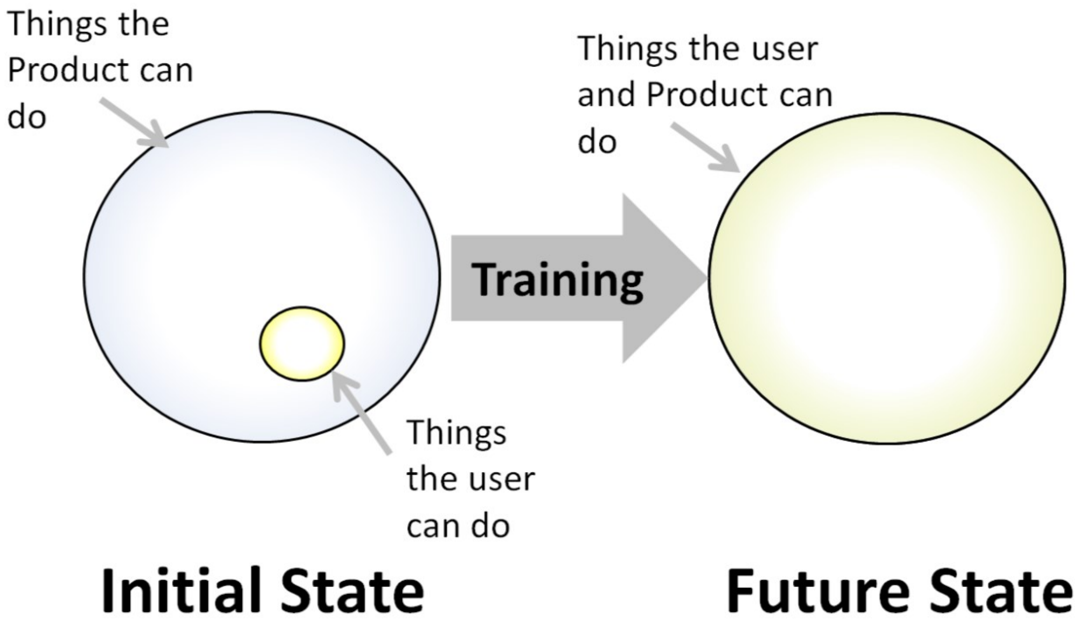


Figure 8.21: The knowledge of the BIM to that needs to be developed (Adapted from Sierra (2006)

One complication in learning new procedures is that there are usually dozens, if not hundreds, of ways to do the same thing. Little details - the sorts of things that sink into the subconscious with practice but are crucial to know for a beginner. These are frequently omitted in casual descriptions or even user manuals. Ideally the trainer should be an experienced user familiar with these pitfalls and road blocks. A trainer who has recently been through the learning experience themselves may be better in this situation.

At John McCall Architects it was decided to train all the staff in the use of BIM (except admin and IT staff). Providing some training to the IT staff would have been a good idea as they were expected to install and maintain the software.

8.8 Determine Pilot or Prototype and roll out projects

Ideally when undertaking the initial prototype project this should be undertaken on a project or projects that have already been undertaken by traditional means. This enables the processes and output of the old and the new methods to be compared and evaluated. Evaluation can be in terms of the time taken or in the quality of the output achieved and the methods used. Secondly a prototype project on a new project is also useful. On a new project there is no prior guidance on how the project should be undertaken. This enables the processes to be implemented without preconceptions being derived from historic methods. Also it is good to undertake a prototype project that demonstrates new capabilities of the new approaches adopted.

If the practice produces new build, renovations and interior designs, it is recommended that each of these types is undertaken as a prototype project. This is because different approaches need to be adopted for each of these project types. Agreeing the prototype projects at John McCall Architects was determined by the company directors.

8.9 Preparation for the Prototype Projects

For the prototype projects many of the items that would normally be in place as part of the BIM support system will not have been created. These items include the BIM object libraries the BIM manual and the support of other experienced BIM users.

During this stage it is important to develop the knowledge so these items can be created and rolled out during the main BIM implementation stage. This makes the prototype project more demanding. In fact undertaking the prototype project can also be seen as also the task of starting to develop object libraries. As part of the preparation further training maybe considered. Also relevant help manuals may be purchased.

The major resource necessary to undertake the prototype projects other than hardware and software is time. As part of the preparation the time scales and expectations and deliverables from the prototype projects should be agreed.

8.10 Managing PR and Marketing of BIM

BIM has a unique marketing potential (Carroll 2009). There is sensitivity when companies adopt new more efficient ways of working. Companies wish to be seen to be adopting best practice or even best in field. But equally well practices may want to make sure they can deliver what is required before marketing the fact.

Two questions that clients tend to ask is will the adoption of BIM affect the quality of deliverable we receive, or will it mean you can provide us with a cheaper service.

John McCall Architects utilized the marketing potential of BIM by taking a stall at the annual Housing Conference at Harrogate. In this way they were able to interact with the clients and collaborators to discuss BIM.

8.11 Purchase of Hardware and Software to undertake the prototype projects

The hardware supplied to undertake the prototype projects should be in accordance with the recommended specification. Hardware specifications for RAM, CPU, hard drive capacity and the video card are all important.

Ideally the prototype projects should be planned that if they prove problematic the software selected can be changed. When purchasing software it may be possible to get a trial period from the vendor or an introductory rate. Software vendors wish to establish their software as the software of choice maybe prepared to enter such an arrangement. This sort of arrangement can help when finances are tight or when the decision, which system run with, has not been finalized.

During the period of the prototype projects at John McCall Architects the ArchiCad software was rented allowing a delayed finial commitment to BIM tool used. Initially the ArchiCad software was provided on a rental basis using an external dongle. The dongle had a 50 hour restriction. After than time a new licence key needed to be upload. This enabled the ArchCad to be loaded onto several PC'S in the office. The problem with dongles is they are removable and have the potential to become lost.

8.12 Initial Hardware and software configuration

Critical decisions such as whether the BIM software should operate at 32 or 64 bit needs to be made at this stage. The initial configuration at John McCall Architects was performed by the computer manager. There were many more items of configuration necessary to ensure that the BIM software operated to its maximum efficiency. What needed to be done was learnt in part by under taking the prototype projects. For further information on software enhancement refer to chapter eight of this thesis.

8.13 Summary of Chapter 8

The purpose of this chapter was to describe the action research undertaken for the action planning and the prototype project mobilization at John McCall Architects. The findings of this research have been reviewed and where appropriate better methods have been suggested.

The important element to consider when employing and utilizing the BIM Champion is the skills that they lack. New skills take time to develop. Until the BIM authoring tool is selected it is impossible for the BIM Champion to develop software specific skills to transfer to others without risking time in abortive work.

The issues of requirement prioritization have been discussed and development of the BIM implementation plan explained. The promoting of the BIM vision has also been discussed at length as managing the human element is critical to a successful BIM adoption.

The benchmarking approach developed has been discussed. Further benchmarking benefits maybe achieved by developing process benchmarking and product benchmarking approaches.

Chapter 9

Chapter 9: This chapter explains the taking action stage. This involves undertaking the prototype projects, undertaking training design and development, mobilization to undertake the live projects and undertaking live projects through the BIM implementation and adoption project undertaken involving the University of Salford and John McCall Architects in Liverpool.

CHAPTER 9 Action Taking Stage: BIM Implementation Role Out

9.1 Introduction

This chapter records and evaluates the undertaking of the prototype projects undertaken by the BIM Champion. The issues related to prototyping are explained in the mind map (see figure 9.01). The researcher personally undertook the creation of all the prototype models and the creation of the objects from which to construct such models. Where new methods and processes were required these were developed by the researcher. After this fee earning projects by company staff using BIM were undertaken. A major element of the work undertaken here was the mobilization and optimisation necessary to undertake the fee earning projects.

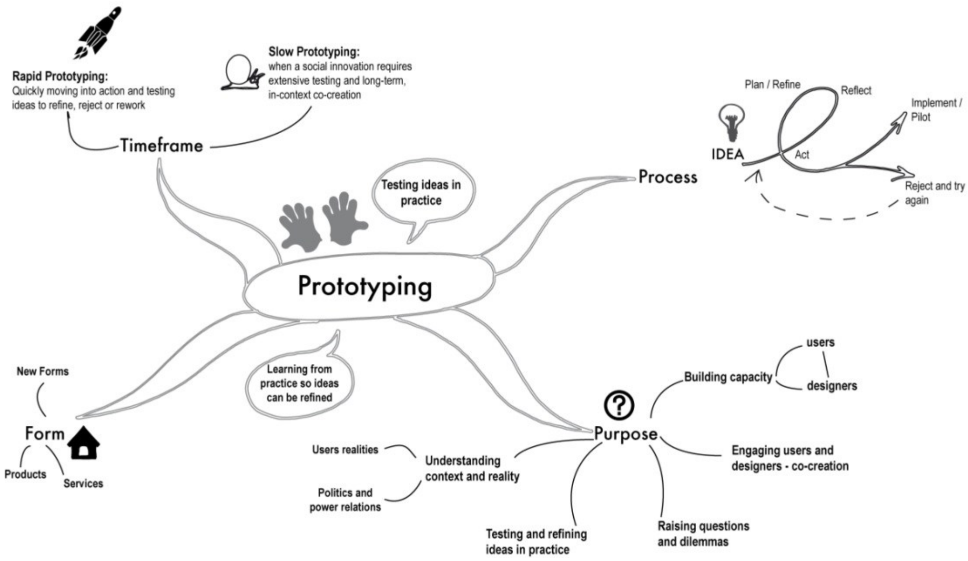


Figure 9.01: Issues related to Prototyping (Hillgren,P. Seravalli, A. Emilson, A. 2011)

The following sections document the prototype projects, what was done and the issues that arose are noted. The findings from these prototypes also formed the basis of internal training given in the practice. But first the training design and development needs to take place alongside the prototype projects.

After the prototype projects had been documented and considered the mobilization elements required to undertake the fee earning projects were documented and considered. These elements were defined by researching into the needs of change management projects. In this case it was the experience of undertaking the prototype projects which provided the knowledge to determine and understand the actions necessary as part of the mobilization stage. These elements include the following:

- Execution of staff training

- Development of project procedures

- Setting up an appropriate working environment within the BIM tools

- Validation Methods

- Setting up the BIM focus group

- Defining roles and responsibilities

- Developing Interoperability

- Ensuring the necessary insurances are in place

After the mobilization is explained the work and activities relating to the live projects is documented. There were several live projects undertaken using BIM during the time of the research. The term live projects, refers to fee earning projects with fixed deliverables. On fee earning projects it is necessary to minimise risk and maximise efficiency and effectiveness of production and of the product delivered. Therefore every effort must be made to ease and facilitate the live projects by addressing people, process and technology inhibitors and constrains. If these projects are not completed to the necessary standard and within the necessary timescales problems and liabilities are likely to occur.

Before undertaking these projects the directors of John McCall Architects had confirmed with the clients that BIM was to be used on these projects. Also it was agreed that the output of these projects, would be the same if not better than, projects using traditional processes. Presentation on “what BIM is” were given to these clients. It was this ability to get client approval and the time when the project needed to be undertaken in the office which determined the selection of these projects as the first fee earning projects to be undertaken using BIM.

In reality undertaking the live projects using BIM is an on-going phase. What is illustrated here is the result of the two months after undertaking the prototype projects. Two projects are illustrated here the Millachip phase 3 project for Arena Housing and the Broomlane project for the Great Places Group. These projects presented projects of sufficient size and complexity in order to show the capabilities of the BIM approach.

An important activity that runs in parallel is the benchmarking of the work that is being undertaken. Also there are many lessons still to be learned from these early BIM projects. This capturing of lessons learnt is documented in the following chapter.

How BIM is rolled out will be determined by the project requirements both from inside and outside of the practice and also the software and staff available.

9.2 Training Design and Development

The analysis of the training requirement took place at an earlier stage of the BIM implementation process. Several options exist to provide training for members of staff interacting with BIM. The training options are, to outsource the training, to conduct internal training, to participate in product related training or to encourage self-training and job shadowing (see figure 9.02). All of these methods were adopted at John McCall Architects to supply different types of knowledge.

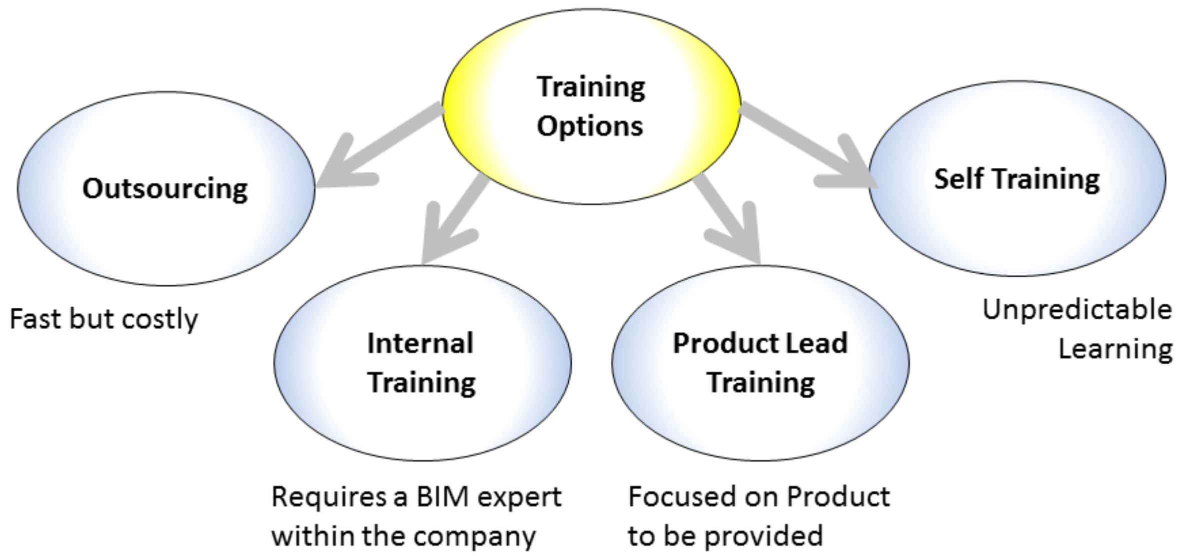


Figure 9.02: Training options for BIM

The different areas of BIM training and knowledge required were identified (see figure 9.03).

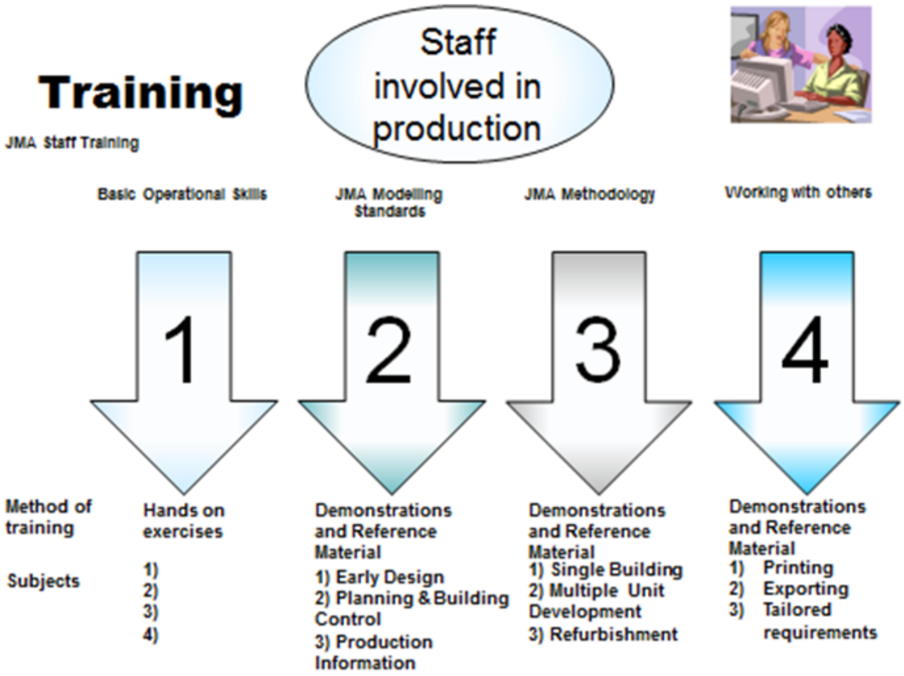


Figure 9.03: Proposed areas of training for Production Staff when adopting BIM

Outsourcing proved to be an appropriate method to provide an enhanced understanding to the BIM Champion. This expertise was then distributed as required through an internal training program. Self-training was facilitated by ensuring participants had access to or knew how to gain access to the software and resources required.

Different training programs should be developed for employees who are to perform different roles. The skills required can be differentiated as follows:

- Basic operational skill
- BIM modelling standards
- BIM methodology
- Working with others

The figure below indicates the areas of training that are necessary for staff involved in BIM production. Also different staff required different skills and different levels of skills (see figure 9.04 and 9.05).

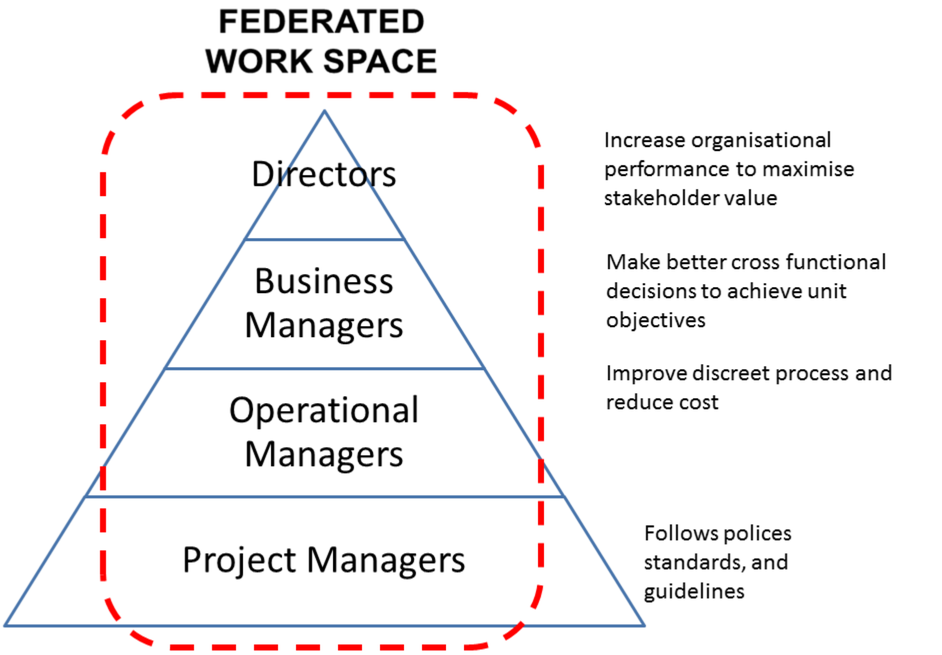


Figure 9.04: Shows the different decision making needs at different levels within an architectural **practice**

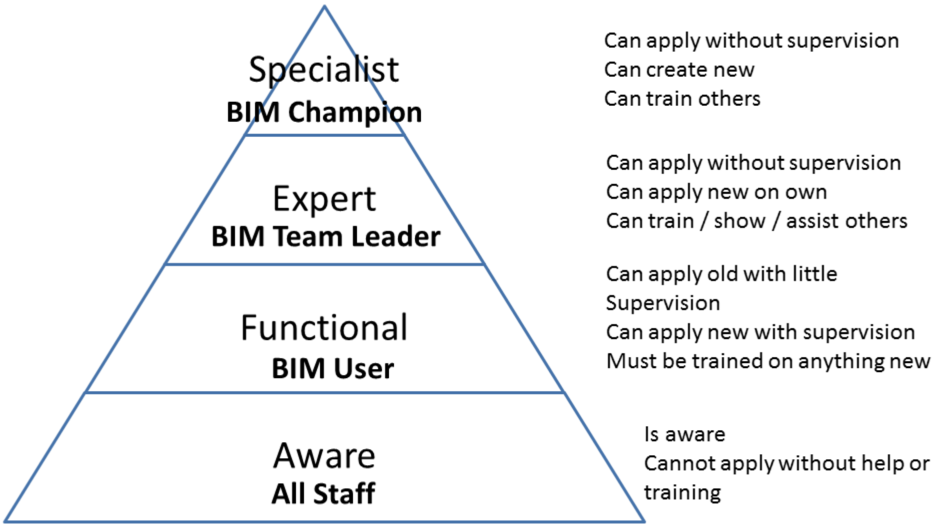


Figure 9.05: Different level of staff ability (This is simillar to Millers Pryramid of Competence 1990)

The whole training process followed the "Addie" model (see figure 9.06). Although this model was not consciously adopted at the time of the research. The originator of the Addie model is unknown but it was developed by Dick and Carey (1996). Each step has an outcome that feeds into the next step in the sequence. What needed to be decided at this time was the best method of training to adopt (see figure 9.07).

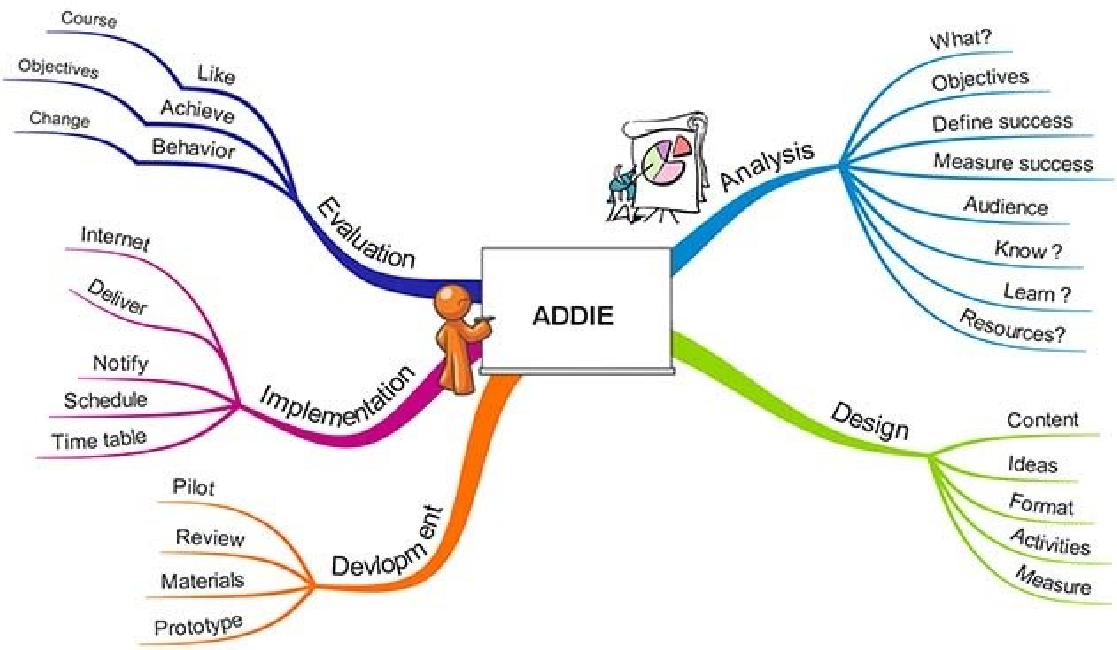


Figure 9.06: The Addie Model (Gupta 2012)

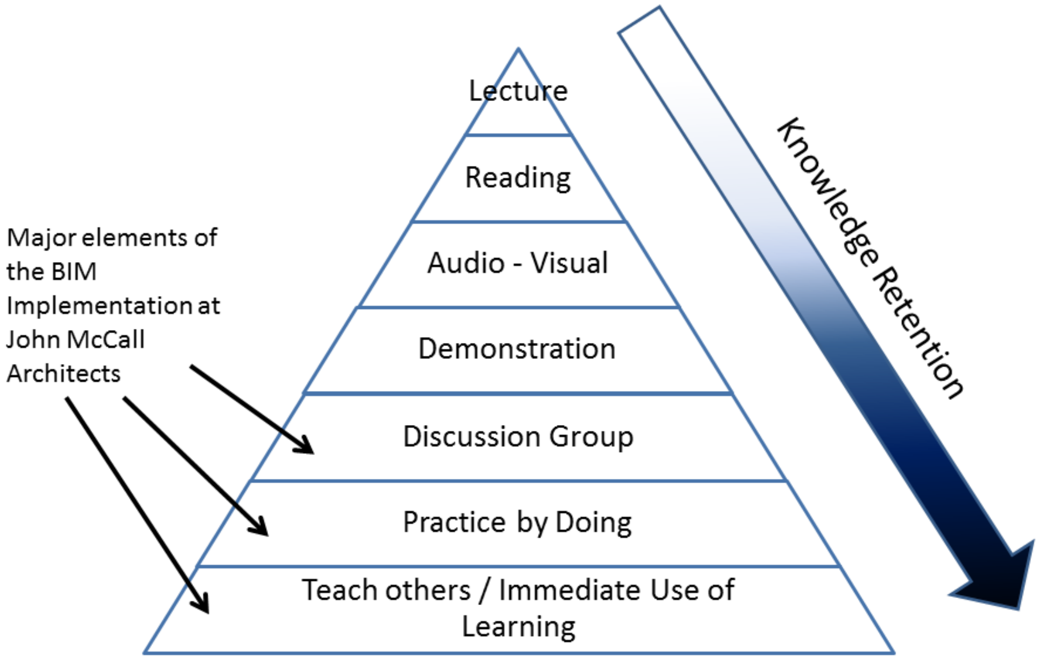


Figure 9.07: Analysis of best methods of knowledge acquisition (Dale, 1968)

It is important that the design and the development of the training takes place during the development of the prototype projects so the training can be given in the mobilization stage for the active or live projects.

A major element was the development of powerpoint presentations (see figure 9.08, 9.09, 9.10, 9.11).

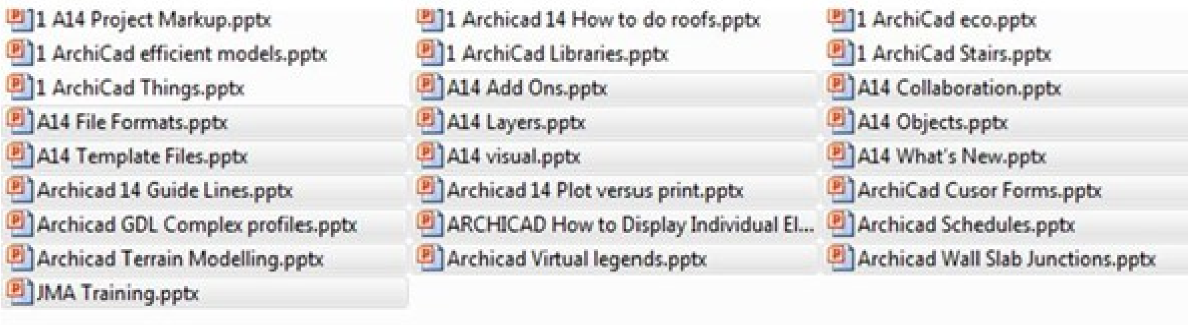


Figure 9.08: Software Training presentations given as part of a BIM adoption

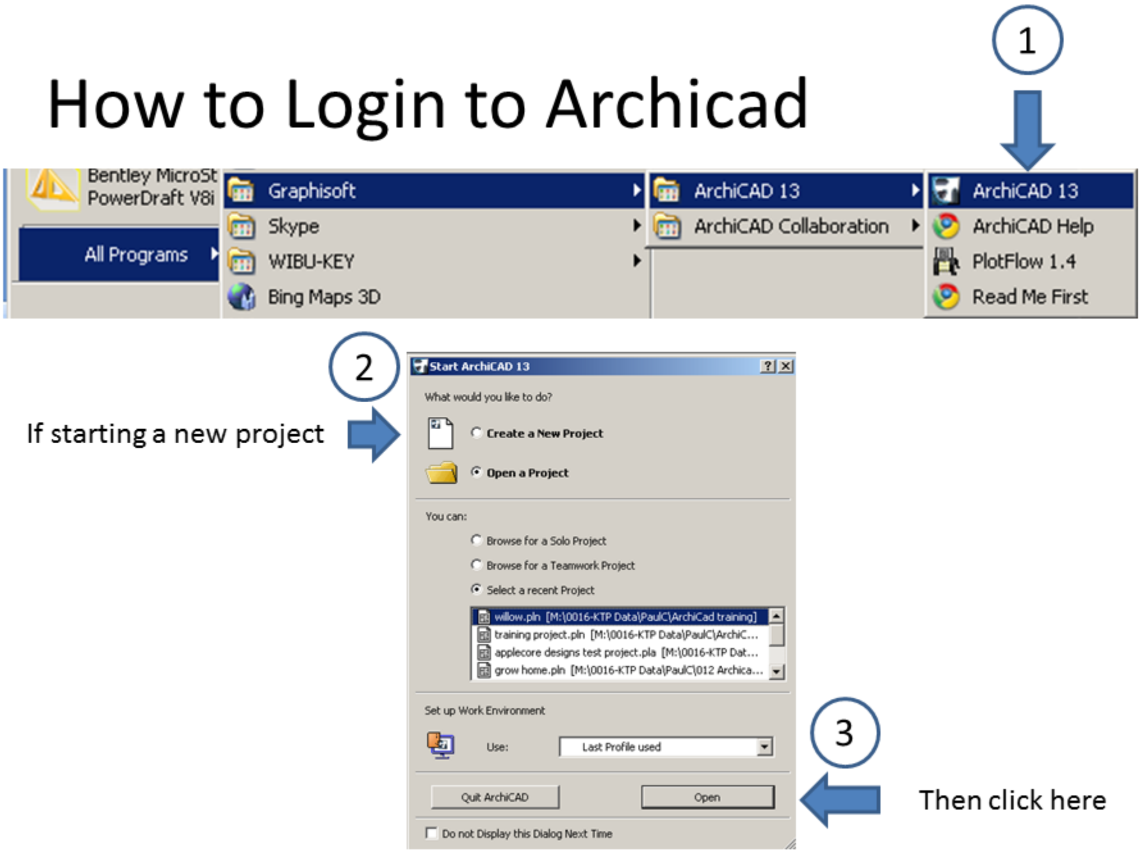


Figure 9.09: Teaching staff how to login to the BIM software

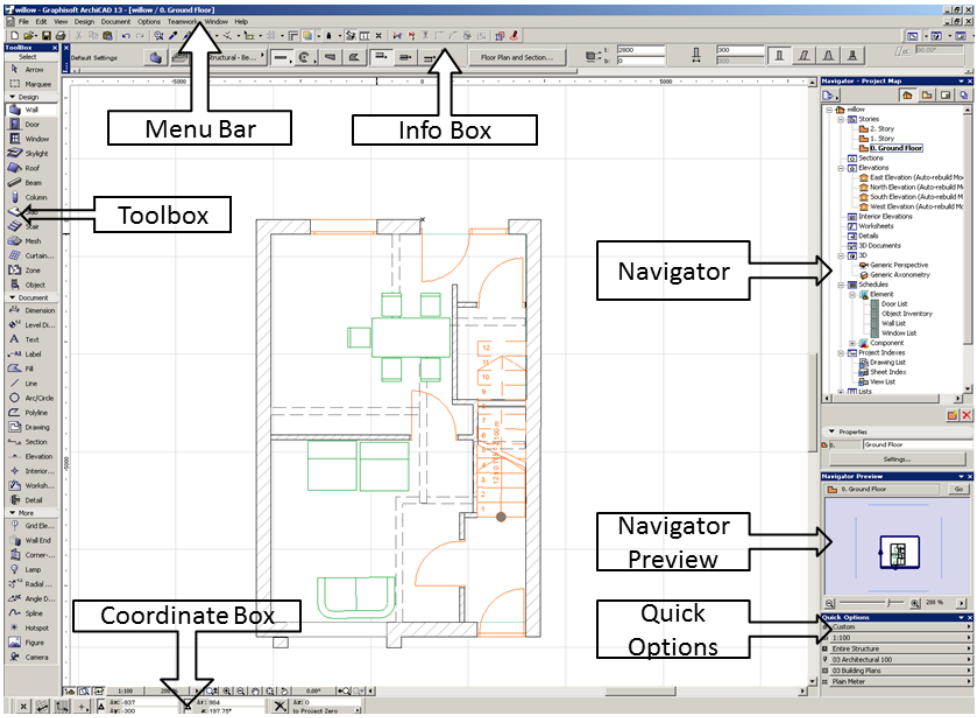


Figure 9.10: Training on the ArchiCad Interface given at John McCall Architects

Native Archicad File Types

extension	Type of File
.pln	Native ArchiCad Document type
.pla	ArchiCad Archive files
.bpn	ArchiCad Backup files
.tpl	ArchiCad Temp
.mod	ArchiCad Module File
.lbk	Plotmaker layout book
.pmk	Plotmaker drawing

ArchiCAD 14 can open projects from ArchiCAD 8.1 and up (8.1, 9, 10, 11, 12 and 13).

Figure 9.11: Training given at John McCall Architects on the different file types used in ArchiCad 13 and when these files should be used

For senior staff, the most important thing to teach them how to do is project markup (see figure 9.12). While for the architects and technicians they need to know how to create models and objects using the software. Architects administrating contracts need to be able to inform and discuss with external parties the implications of adopting the BIM approach.

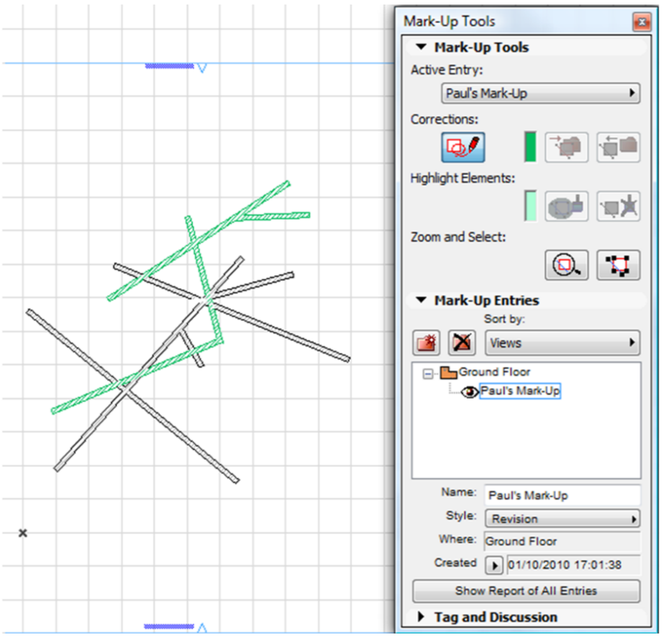


Figure 9.12: A training slide from the project mark-up presentation given to senior members of staff at John McCall Architects

9.3 Training of the BIM Champion

The knowledge development of the BIM champion is a critical part of the BIM adoption process. It is important to develop the BIM champion as much as possible because they are the primary conduit through which BIM knowledge is imparted.

As part of the education of the John McCall Architects BIM Champion the researcher attended the ArchiCad University Summer School (see figure 9.13). This was particularly useful to understand the wider aspects and issues related to ArchiCad operation. At the ArchiCad University it was also possible to raise questions with the developers of the BIM software. It was also possible to talk to other BIM users and gain from their direct experience.

TIME	ROOM	SATURDAY 21st	SUNDAY 22nd	MONDAY 23rd	TUESDAY 24th	WEDNESDAY 25th	THURSDAY 26th	FRIDAY 27th
17:00 - 17:45	SEMINAR ROOM	ARRIVALS	WORKSHOP 1 MESH TOOL ABUSE	WORKSHOP 1 SHELL TOOL	Q&A SESSIONS WITH TUTORS	WORKSHOP 1 IFC EXCHANGE	WORKSHOP 1 ARTLANTIS RENDER TIPS	WORKSHOP 1 COLLABORA-TION
	DINING ROOM		-	WORKSHOP 2 FREEFORM CINEMA 4D MODELING		WORKSHOP 2 USEFUL GDL	-	WORKSHOP 2 ARCHIFORMA
18:00 - 18:45	SEMINAR ROOM		WORKSHOP 3 ARCHICAD LAYOUTS & TEMPLATES	WORKSHOP 3 COMPLEX PROFILES, SOLID ELEMENT OPERATIONS		WORKSHOP 3 BIM SERVER (TEAMWORK)	WORKSHOP 3 BIMx	WORKSHOP 3 OFFICE STANDARDS
	DINING ROOM		WORKSHOP 4 CURTAIN WALL TOOL	WORKSHOP 4 BIM FAST	WORKSHOP 1 BONZAI 3D		WORKSHOP 3 ADVANCED GDL	ARCHICAD TIPS & TRICKS
Dinner 19:00								
20:00 - 20:45		WELCOME & TOPICS VOTE	RENOVATION IN ARCHICAD	CINEMA 4D RENDERING	OBJECTS ON THE FLY	ARTLANTIS PRESENTATION	GRAPHISOFT PRESENTATION	DELEGATES' GALLERY
21:00 - 21:45								DELEGATES' GALLERY
		WORKSHOP LEVELS:			BEGINNER	INTERMEDIATE	ADVANCED	EXPERT

Figure 9.13: An example of the subjects cover at the Archicad University Training schools

Now at a government level the BIM Task Group is not recommending the introduction of a standard or accreditation system for BIM training and education. It is however, producing a description of the learning outcomes that BIM training and education courses should consider. This 'learning outcomes framework' is now being tested with the commercial training providers, professional institutions and academia. It will be published shortly on the www.bimtaskgroup.org website for the industry to use to inform clients and supply chain in their analysis and selection of its staff training programmes; and by training providers to introduce a broad coverage of BIM related courses across strategic, management and technical roles required to up-skill the industry in order to support the Level 2 BIM ambition for 2016.

9.4 Undertaking Prototype Projects - The Build London Live Competition

Before the first practice typical prototype project was undertaken at John McCall Architects it was decided to participate in the Build London Live Competition. The aim of the Build London Live competition was to showcase interoperability, collaborative working and new technology through a cloud based international participatory event. Build London Live is a 48 hour virtual design collaboration competition. The awards available (which indicate the objectives of the competition) were categorised as follows:

- Best overall BIM as voted by the judges
- Best use of BIM for design, drama and excitement
- Best Multi-disciplinary BIM and use of interoperability
- Best use of BIM for sustainability and constructability
- Continuous publication and collaboration
- Judges discretionary awards

The competition was to design a mixed development including housing, commercial and hotel elements. The development was on a triangular site on an island in the Thames estuary. The researcher joined the 3DMD team and produced the design for the residential element for one of the designs (see figure 9.14).

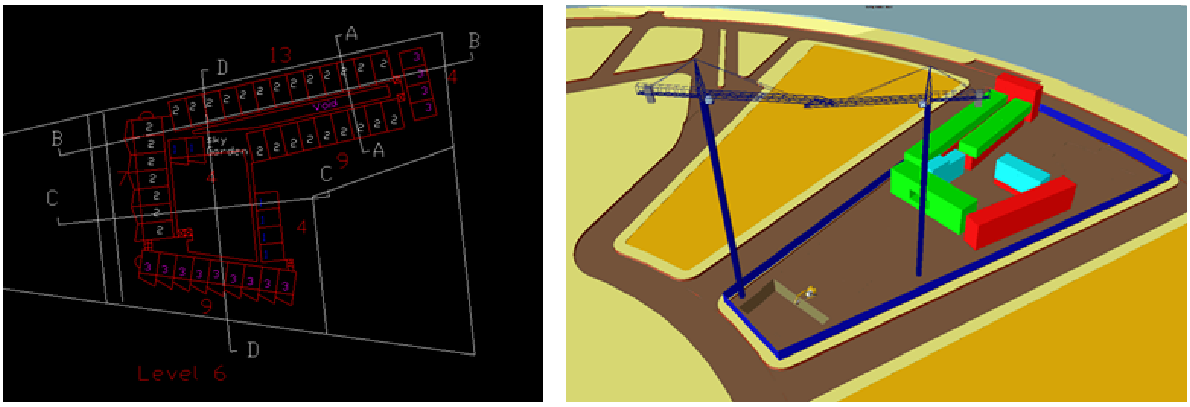


Figure 9.14: A 2d plan of housing development first sketched up in AutoCad software then produced in 3d in Synchro

The team 3DMD was spread over many countries including the UK, Holland and India. None of the members of the team had worked together before. The housing was to coordinate with both a commercial and a hotel also to be placed on the site. These were designed by other architects. Because of the greater possible return from the hotel and commercial elements they were given the prime locations on site. The BIM authoring tool used by the 3dMD team was EliteCad. The housing model was produced using EliteCad (see figure 9.15). The mechanical and electrical design was produced by Magicad. It was through this element that the team received one of the awards from the competition. The timeline for the project was modelled using Synchro software (see figure 9.16).

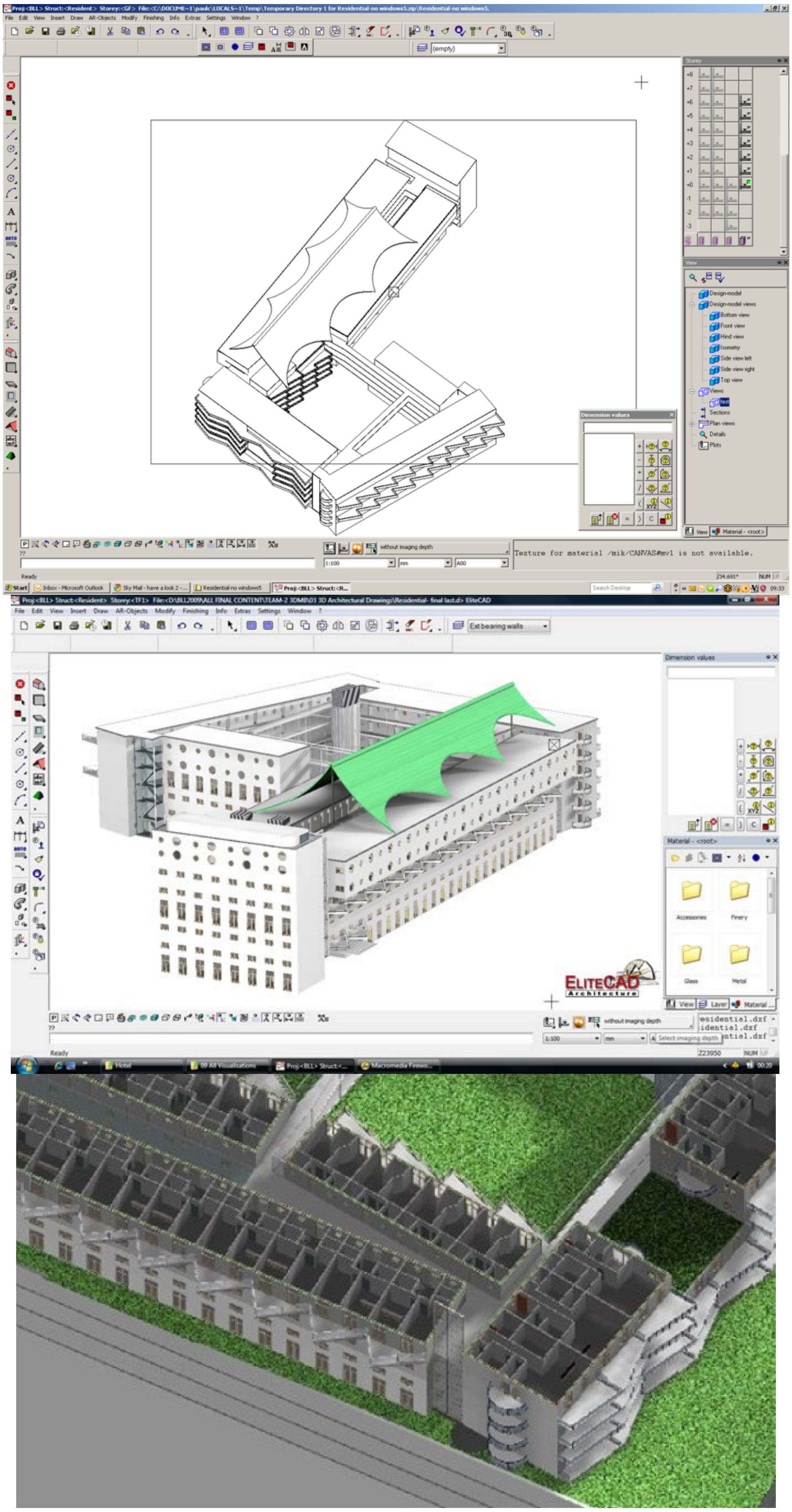


Figure 9.15: Model developed in EliteCad of residential element for the Build London Live Competition

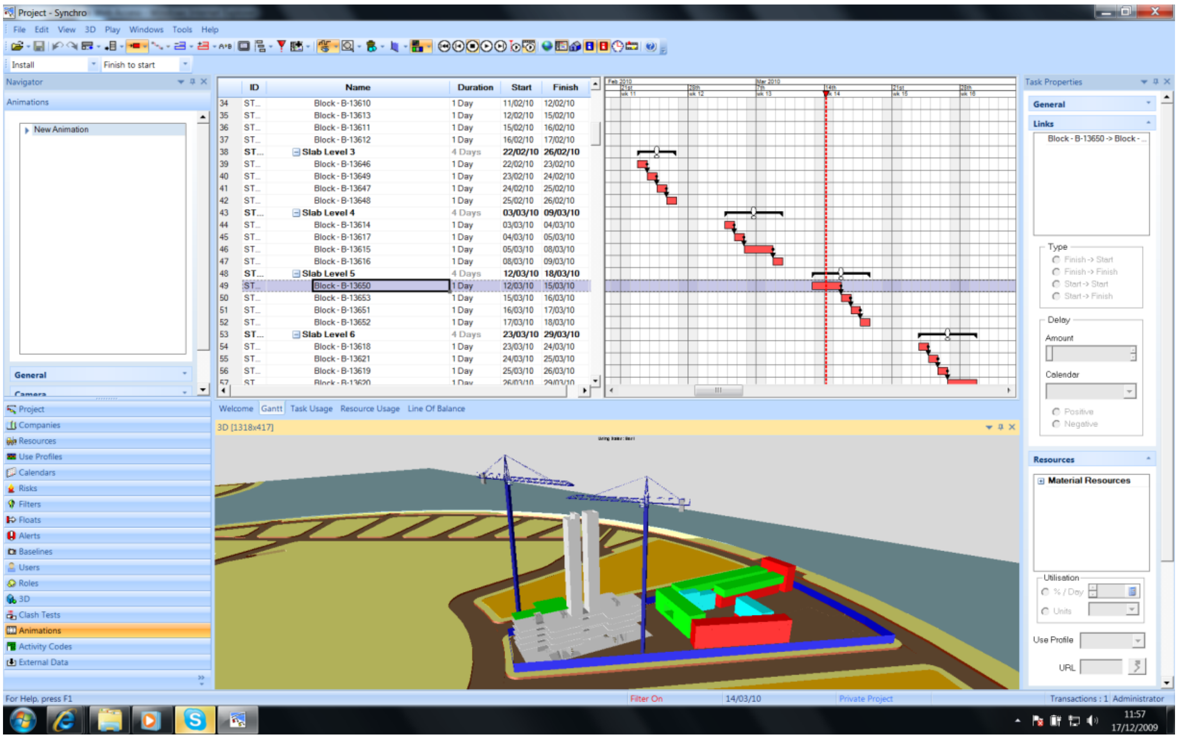


Figure 9.16: The 3DMD site for the Build London Live competition showing build sequence using Synchro software

Becoming involved with such a competition proved to be a good way to understand and demonstrate the power of collaboration utilizing interoperable BIM information. The staff members at John McCall Architects were able to witness the effectiveness of a BIM collaborative project. The interoperability was demonstrated through the exchange of information between the architectural and engineering disciplines.

The output of this completion may still be viewed on the bll2009 website. The lessons learnt from undertaking this competition were particularly about the value of collaborative workspaces such as Asite (see figure 9.17) which was used in the competition. Such workspaces have the ability to help integrate disparate teams using BIM. This is achieved in part by providing a structured channel for communication and decision making.

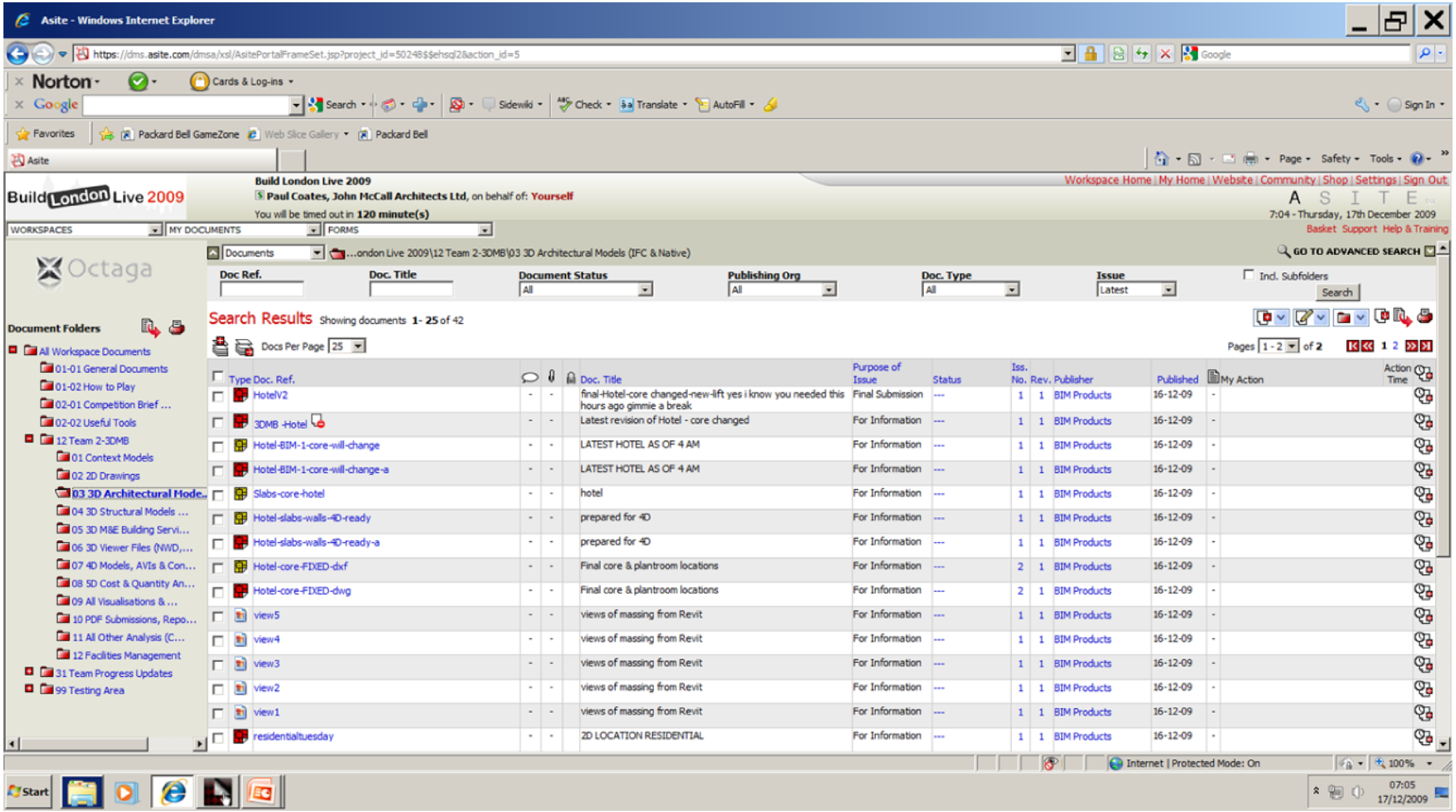


Figure 9.17: A screen shot of the Asite BIM collaboration platform used during the Build London Live competition

Regrettably it was not possible to get any of the members of John McCall Architects to become directly involved in the competition. It is know that one of the teams that participated in this competition went ahead to create a company on the basis of the BIM capabilities demonstrated during the competition.

9.5 Undertaking Prototype Projects - The Grow Home House Design

The major constituent of the workload at John McCall Architects is housing design. So it was appropriate that the prototype task selected was to create a simple house using the ArchiCad BIM software. This was a copy of a house previously developed as part of the “grow home” project / competition (see figure 9.18). The design of the house had been commended for its sustainable features as part of this RIBA competition.

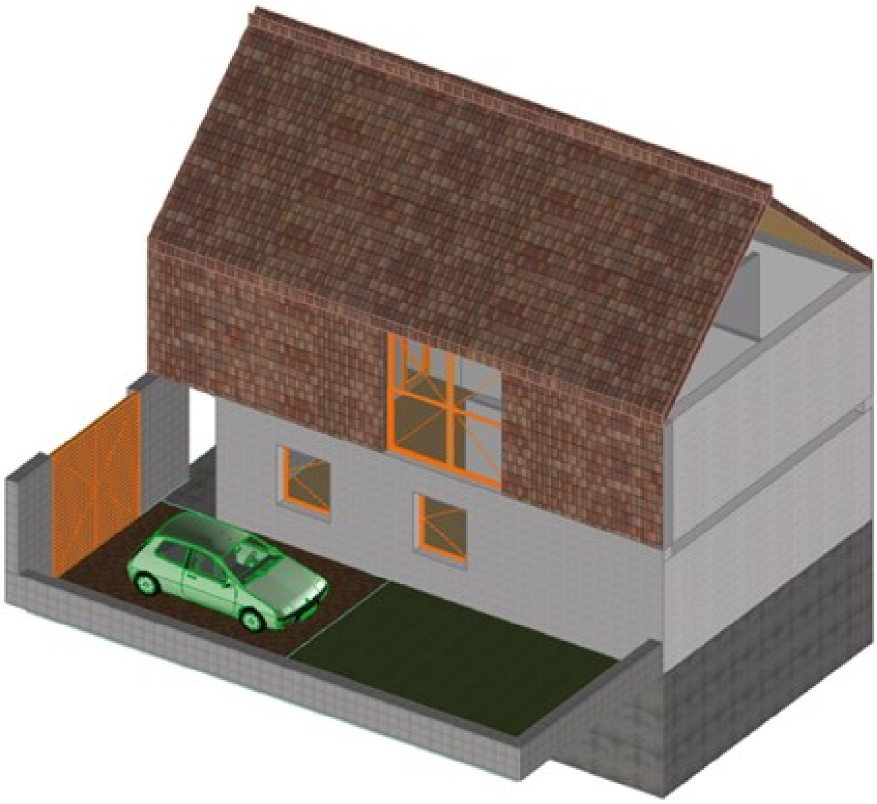


Figure 9.18: The first prototype model produced of the Grow home using Archicad

With this particular house model, questions were raised. When is a wall a wall and when is a wall a roof? The main problem when undertaking the first project in a practice with new software is that there is no one to ask should difficulties occur.

Many of the problems that occurred had simple answers but required research into the online help facility. The house design that was copied did not have its materials specified. This proved problematic when the project was undertaken using BIM where objects input ideally should have materials defined.

The lessons taken from developing this house was that there is a greater informational need earlier when developing a BIM model than when producing CAD or sketchup models. This is because material and junctions need to be more precisely defined at the outset if rework is to be avoided. An example of this is the junction of the first floor with the external wall. Should the floor penetrate the wall, this is a decision that has to be made when constructing the model.

One of the first set of commands that needs to be mastered is how to create and place objects in a dimensionally accurate way. This may sound easy and it is once the technique was mastered. This can partly be achieved by mastering the distance and angle inputs (see figure 9.19).

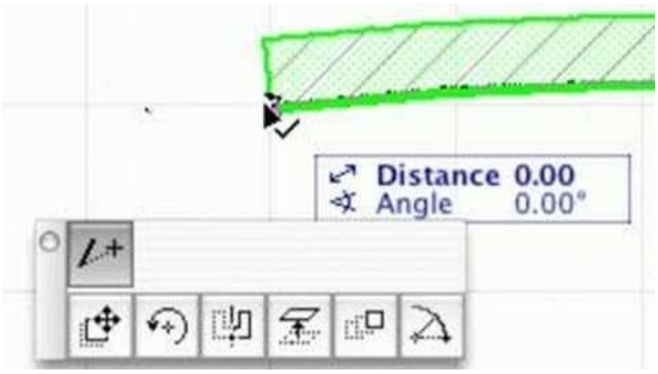


Figure 9.19: An ArchiCAD wall and pointer showing the distance and angle parameters

Using BIM instead of CAD also requires decisions to be made in a different order. An example of this is the need to determine the floor to floor heights as early as possible in a project so 3d walls can be correctly sized when create. The house model took several days to complete. The time taken predominantly was in finding the commands not undertaking the work. The task of creating the house now having learnt how to use the software would be measured in hours not days.

Being able to discuss the issues and problems raised with a mentor knowledgeable in the specific BIM software would have been particularly useful during this early prototype project . Although the software vendor did provide some support over the phone.

9.6 Undertaking Prototype Projects - The Leathers lane Prototype

The Leathers Lane prototype project was the second project undertaken after the selected BIM tool (ArchiCad) had been purchase and installed.

To develop the Leathers Lane BIM models plans, sections and elevations that had already been produced in CAD (Microstation) where provided. These were then converted to dwg files and brought into ArchiCad. As part of this is prototype it was learnt how to uses these as dwg files then places them as underlays onto which to create the model (see figure 9.20). In this way dimensionally accurate models could be rapidly produced by snapping to the original CAD drawings. This was also a useful capability used when training new ArchiCad users.

Figure 9.20: An important lesson learnt while undertaking the Leathers Lane Project was how to use the trace option

Initially the model was developed as separate flats which were referenced into the main model as hotlinks. The junctions of the hotlink files caused unwanted lines when the 2d elevations were generated. In hindsight in this case it may have been easier to create the BIM model as a single model. Although this would have resulted in additional work should amendment to the flat types be required.

The model was created over a period of about two weeks. The importance of setting the setting out line of the walls to the outer face was also realized. This enabled brick dimensioning alterations to be more easily handled. Designing to brick dimensions represents a major cost saving on site.

Issues of brick walls changing to block walls where they were internal proved a particular problem to model. This occurred several times on the gable wall of the development. Horizontal changes of material in walls is relatively easy to create but here the change in material needed to be angled to follow the roof pitch.

Images of the resulting design are shown (see figures 9.21, 9.22, 9.23). The final constructed facility is also shown (see figure 9.24).

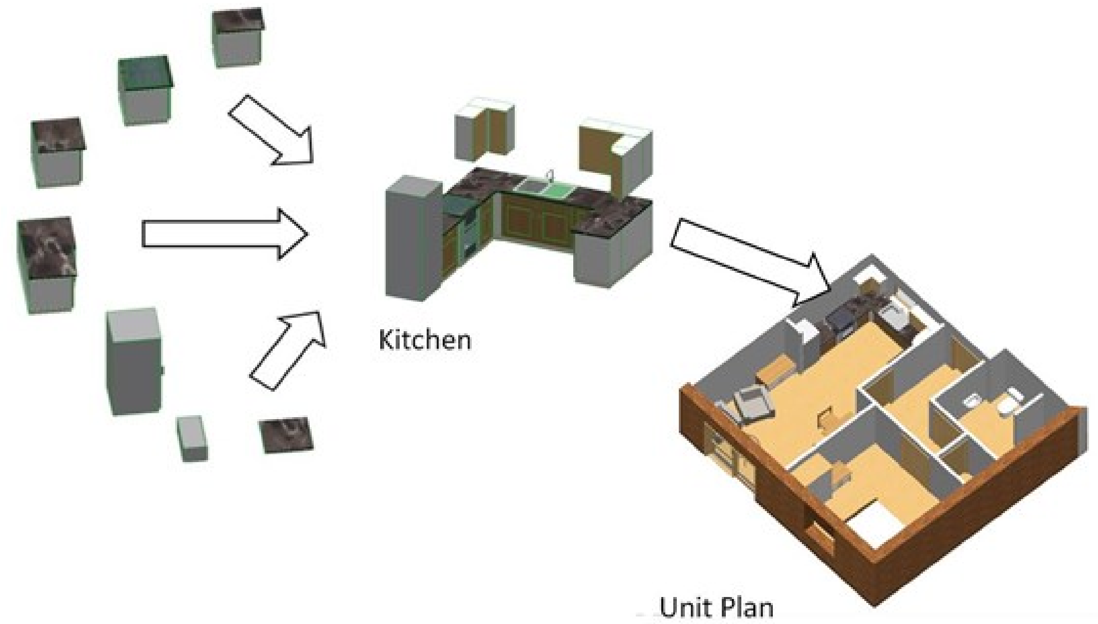


Figure 9.21: Generation of the kitchen designs from individual objects

Figure 9.22: The second prototype a cut away model of Leathers Lane produced using ArchiCad

Figure 9.23: Leathers Lane, work in progress, ground floor plan and axonometric view of model and cross section view

Figure 9.24: Ariel view of the constructed Leathers Lane Facility (source Google Maps)

The Leathers Lane project was a preliminary design so no details were produced at this stage. An outline specification was provided by the design architect which helped create a more intelligent model. What became clear from the Leathers Lane project is how the workload on projects is moved to the earlier stages when using BIM. This fact is also illustrated by a chart by Maccleamy 2004 (see figure 9.25).

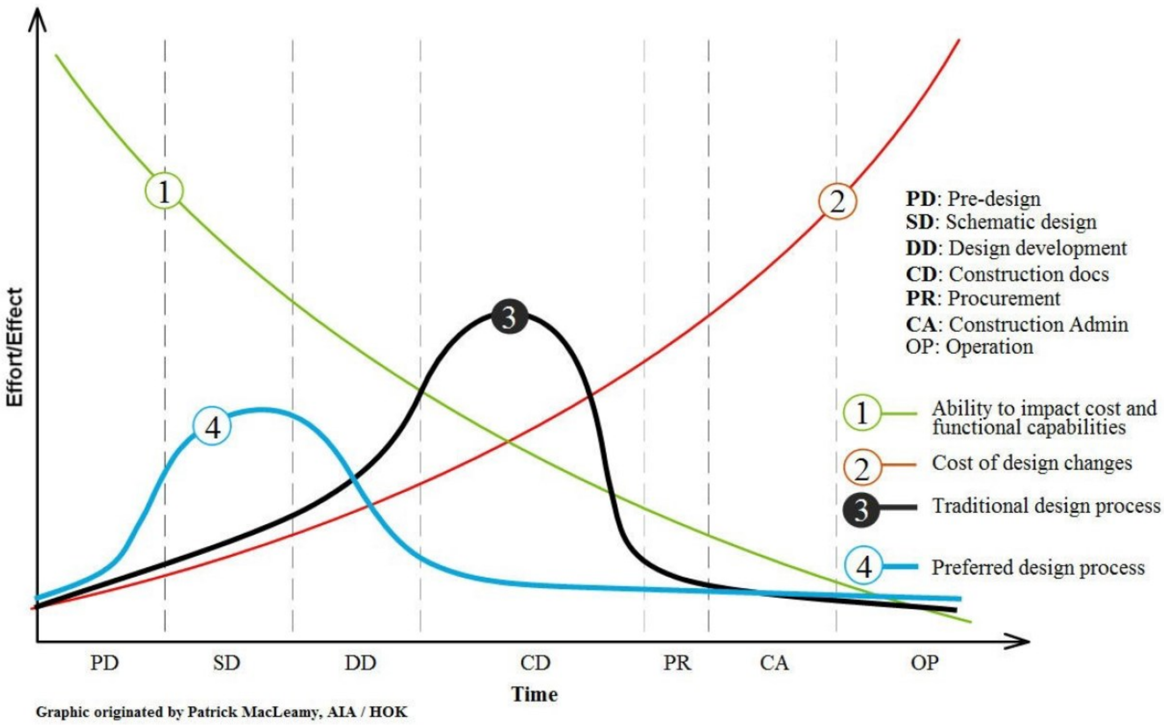


Figure 9.25: Process and Cultural change (Maccleamy 2004)

9.7 Undertaking Prototype Projects - The Salford House 4 Life Competition

The Salford house 4 life competition was a two stage international design competition organised by the RIBA. This competition was entered by the BIM Champion as a vehicle for testing out and understanding the capabilities of ArchiCad software. The required design deliverable was an A1 board illustrated with the design concept. The competition launched in August 2010 was for the design of a new exemplar family housing scheme, on a brown field site in the heart of the Greengate an area of Salford near Manchester city centre. 59 entries were received for the competition. The winner of the competition was to go on to provide the services to build the development.

A lunchtime meeting was arranged at John McCall Architects to brainstorm ideas for this competition. The development of sustainable concepts was an important part of this competition.

The design concept developed was to provide garden space on the roofs of the dwelling this maximising the accommodation on the site. By providing single storey dwelling this avoided the problems of stairs which are often a problem for the elderly.

Using ArchiCad to develop the housing layouts proved useful enabling rapid prototyping. This allowed for the designs to develop and evolve more rapidly. The development of the communal street scape was also an important part of the design. Using the models it was possible for the designer to instantly gain a street level perspective.

The competition submission was developed over the period of a weekend and uses repetitive brick units with a shared rear light well. The master plan was developed using several referenced models. The outputs for the competition are shown (see figures 9.26, 9.27, 9.28, 9.29, 9.30, 9.31, 9.32, 9.33, 9.34, 9.35). Although items such as furniture are not necessary for construction they proved useful when undertaking design to better understand how the spaces can be used.

Figure 9.26:The site allocated for the Salford House4life competition

Figure 9.27: The material palette used for the Salford Home 4 life competition

Figure 9.28: The combined housing models being used to tested out the resultant urban form

Figure 9.29: An example of a low resolution render taken as the design progressed

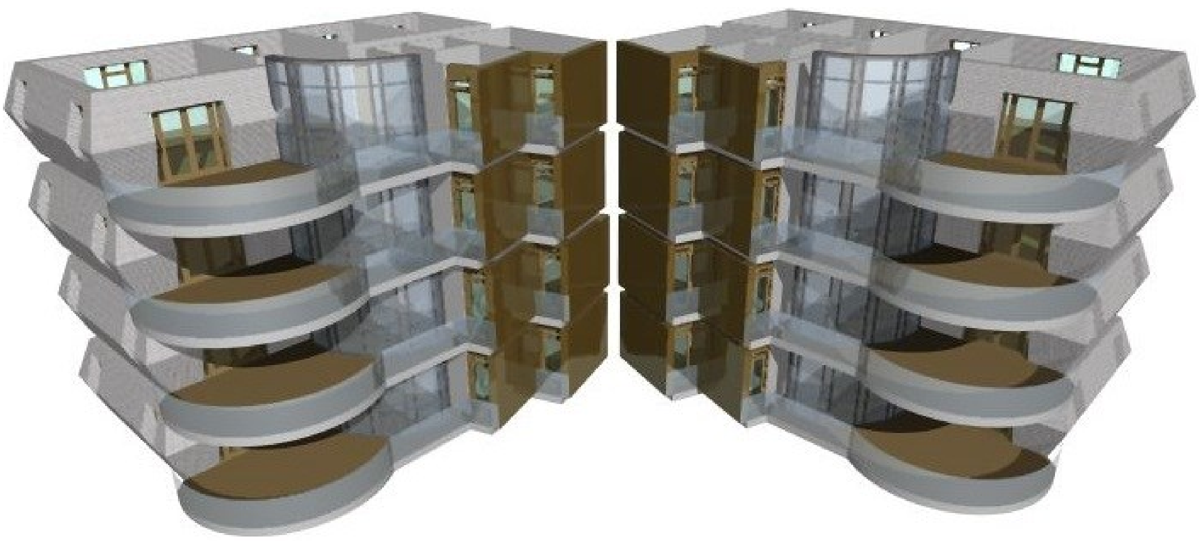


Figure 9.30: The high rise flat units being combined to assess the combined visual form

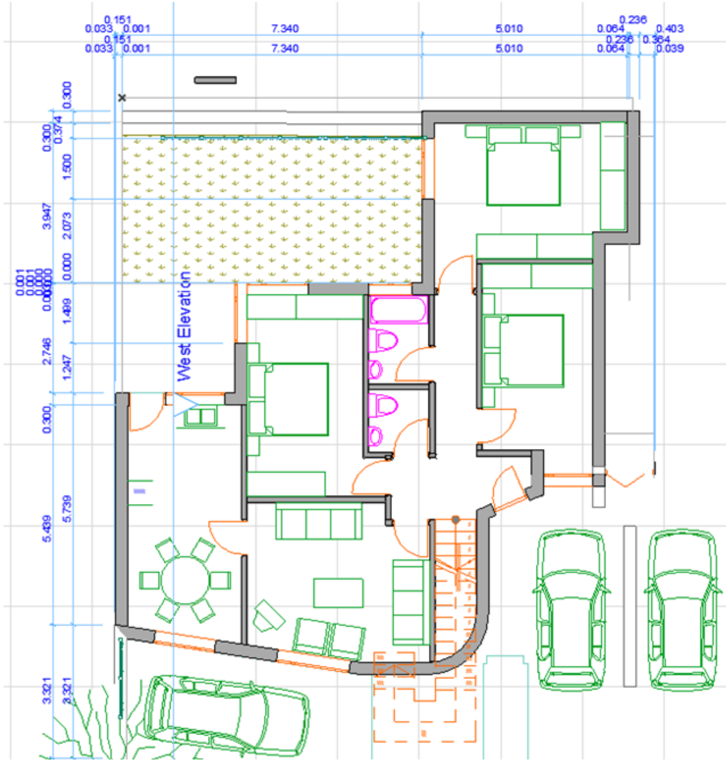


Figure 9.31: Plan developed for the courtyard house used on the Salford House 4 Life competition

Figure 9.32: Salford Homes for Life Competition render using Artlantis software

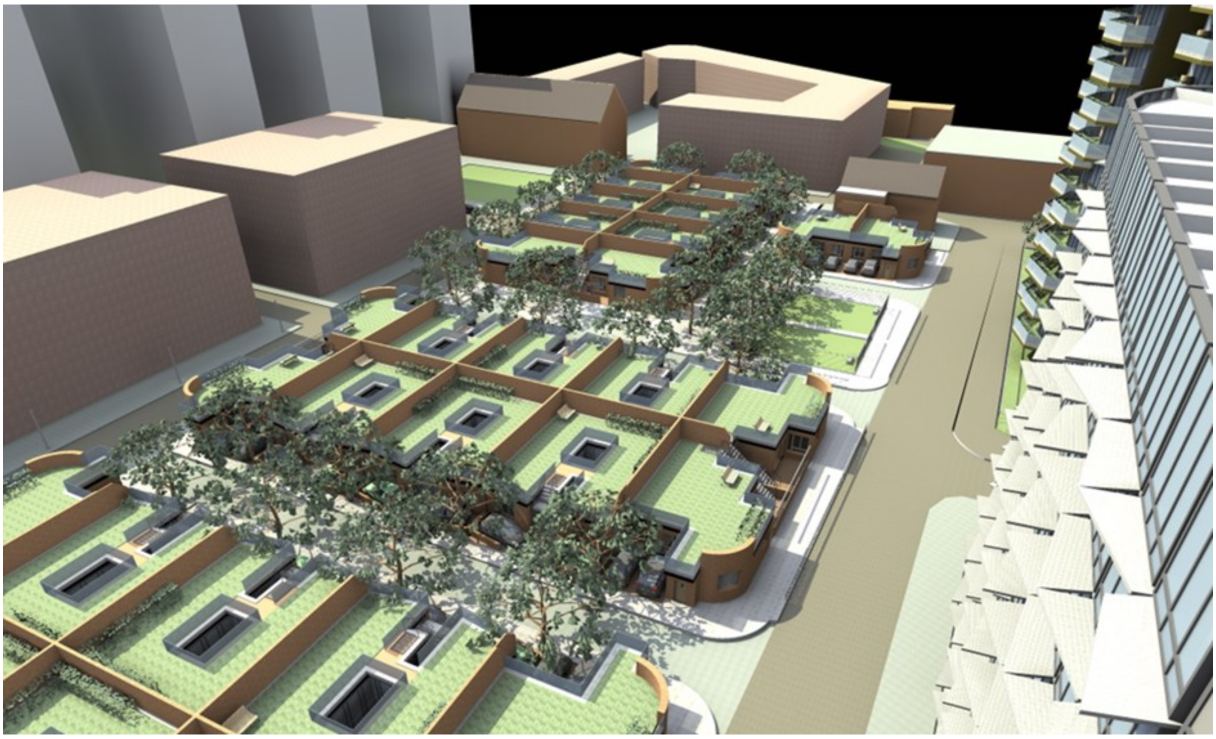


Figure 9.33: Salford Homes for Life Competition render using Artlantis software

Figure 9.34: View showing the single storey dwellings with roof top gardens

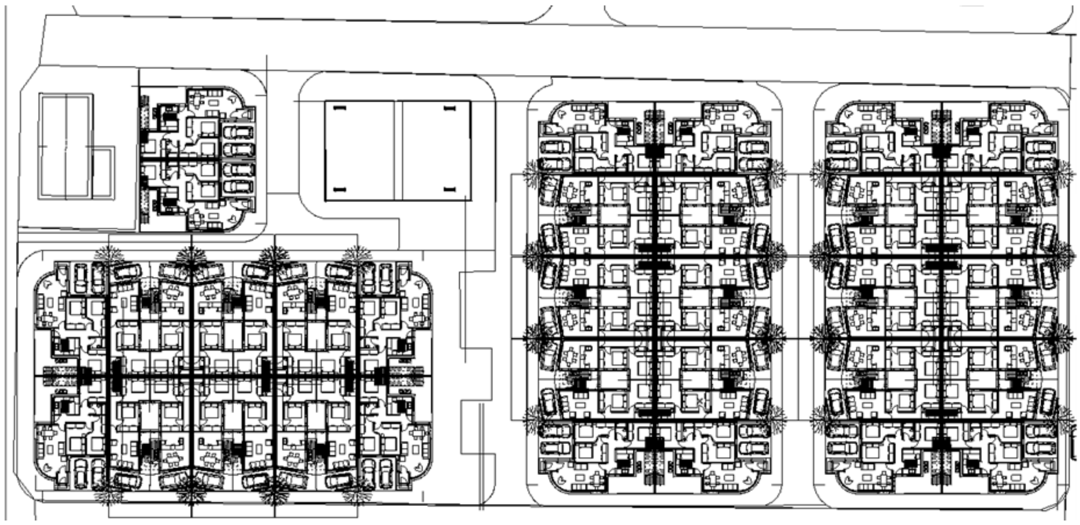


Figure 9.35: Block plan of single storey models used to build up the master model of the Salford 4 Life design model

The lessons learnt by undertaking this competition was the importance of allowing time for the rendering of the images. Alternative rendering software Artlantis was also experimented with to reduce the rendering times. Because the competition only required images there was no need for the objects to be data rich.

Being able to set the design in 3d increased the ability to rapid prototype the design. Even in the short design period many options were explored. Two different design options are shown in figures 9.28 and 9.29. The design also used hotlinked units so all of the 250 units could be amended by simply altering three of four standard designs.

Eco analysis BIM software was not used in the development of the designs but may have facilitated a more validated competition entry.

9.8 Undertaking Prototype Projects - Investigation of thermal models

The two main areas of information needed by John McCall Architects as they develop housing projects is information for Code for sustainable homes and SAP analysis. Currently the information from BIM eco tools needs further amendment before it can be used for these purposes.

Work was also done as part of the prototyping stage experimenting with BIM models and transferring them into eco analysis packages. Such BIM tools can be regarded as complimentary tools augmenting the main BIM authoring tools. The main software that was tested was IES (Integrated Environmental Solutions) (see figure 9.36).

Educational webinars proved useful as a method of understanding this BIM tool. The vendors also demonstrated the software at the practice.

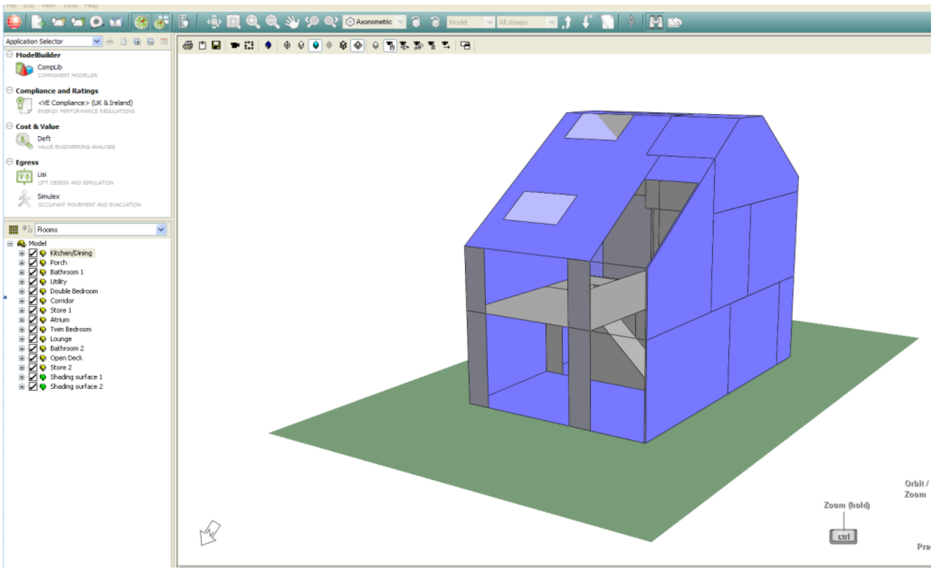


Figure 9.36:Testing of IES software for thermal investigation of BIM models

John McCall Architects was later to purchase a copy of Ecodesigner, another Graphisoft software, Archicad the selected software being owned by Graphisoft.

The limitation of these BIM eco tools is that they deal with individual housing units. Sometimes multi-unit analysis would be helpful. What became clear was the need to simplify the normal BIM models produced. This simplification was required to enable the models to operate correctly in the BIM eco tools. Zone and volumes needed to be simplified and accurately defined (see figure 9.37). Voids and double height spaces also had the potential to cause problems in the BIM eco software tested.

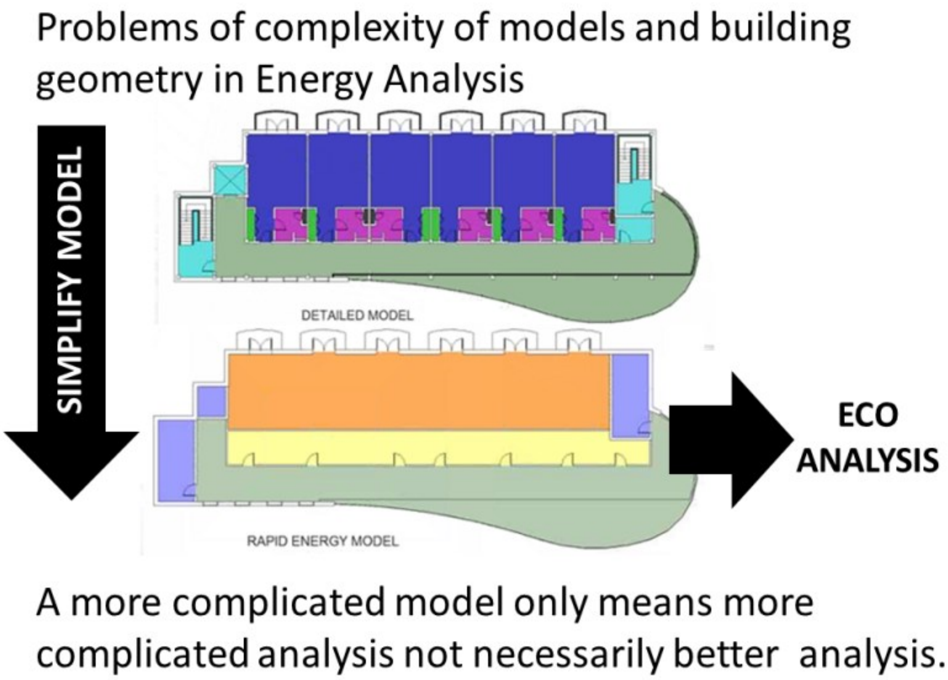


Figure 9.37: Diagrams showing the need to simplify BIM models into simpler volumes so that suitable result could be achieve using eco analysis software

The major issue raised was that a lot of information need to be added to the model once it was transferred to the eco software. It did not prove possible to add this information with the BIM authoring tool. Nor did it prove possible to return this information to the main BIM model.

9.9 Review of Prototype Projects

There were many lessons taken from undertaking the prototype projects. Also many of the lessons learnt by using the legacy CAD software Microstation had to be unlearnt when using the new BIM tool (ArchiCad).

The prototype projects selected proved to be suitable to investigate the BIM tool and the BIM processes necessary. As part of the prototype process no detail production information was created. This would be recommended if the process was undertaken again. Also if external stakeholders using BIM had been available it would have been good to test out the interoperability of the BIM prototype models. Ideally a refurbishment prototype and an interior design prototype should also have been conducted if time and resources had allowed. Testing of batch output and plotting would also have been useful.

Ideally the prototype BIM projects should be used to trigger discussions addressing how BIM should be used on later projects. This was not done at John McCall Architects but in hindsight it would have been beneficial.

The method of saving work in ArchiCad was different from the Microstation software previously used. As a result the autosave was configured on the ArchiCad software to help ensure members of staff did not accidentally lose their work. Configurating the new BIM tool to work in a similar way to the legacy systems helped users transition to the new BIM tool. Such modifications should only be considered were the new productivity remains unaffected.

Revision control has always been a critical issue for architectural design development. This issue remains an important consideration when using BIM. The issue of whether changes to the 3d model should be automatically transferred to the 2d representations was hotly debated at John McCall Architects. In the end it was decided through consensus to adopt a method of manually controlling revisions and amendments. Revision control will remain an issue as long as 2d drawings are used as the primary method of information transfer. Using 3d models change can be indicated automatically by comparing models.

Developing the ability to use the object snaps was an important initial skill to acquire. Without this it is very difficult to create accurate results. This was one of the first areas of training given in the execution of training stage.

Setting the cut plains at the right height to generate appropriate plans was also realized as important. Setting the view depth on sections represents a similar important issue.

Another important lesson learnt was to place the setting out lines for the walls on the outer face of the brick walls. This meant that the external brick coordination dimensions stayed the same when the overall thick of the wall changes. Using full brick sizes means that it is unnecessary to cut bricks on site which is a particularly expensive item of work. On schemes where the net lettable area is critical this strategy may have to be reversed.

A major lesson learnt was the need to use appropriately powerful hardware when producing BIM models. Waiting for models to regenerate is wasted time and is frustrating to the user. This is not such a major problem when learning the BIM tool as actions at this time are likely to be slow. But it becomes a problem when staff have the ability to outperform the hardware they are working with.

The need for pre developed and share object libraries was also recognised. These were later developed as part of the live project mobilization.

The importance of setting up the BIM environment correctly using the template files in ArchiCad also became apparent. Similar files and setups are found in other BIM software tools.

The importance and benefit of sharing learning and experiences across all users particularly at the early learning stage become obvious. Many of the John McCall staff found they were confronted with the same problems when confronted with task to perform using the BIM software. Again this was a task performed before the live projects were undertaken.

The need to modularize models was an important lesson learnt from undertaking the prototype models. Workshops were later held to develop the appropriate method of modularization. This development of a standardized method allows users to easy work on multiple projects and work on the projects previously create by other BIM users.

The time required to render models was realized. The complexity of the tree objects adopted significantly affected the rendering times. In the case of the Salford 4 Life competition it was decided to use Artlantis software as a method of achieving high quality renders in shorter time periods. Where possible a machine dedicated to rending is useful, so the processing does not interrupt the BIM production workflow. Setting up a render farm was also considered. On some of the rendings produced the finial image was enhanced in adobe photoshop software. Also as part of the rendering exercise it was possible to compare the colours on screen to the printed output achieved.

The lessons learnt during the undertaking the prototype projects were later to form the basis of the BIM manual. So ideally notes and findings at this stage should ideally be recorded in a journal which can later be used as the basis of the BIM manual.

One of the unexpected spinoffs at the prototype stage was the development of 3D printing. Thus a new artefact was developed with the potential of earning revenue. A 3D Systems colour printer was used to create the 3D model. The model produced was about 30 cm long (see figure 9.38). This was the maximum size for one element generated by the printer at the time. Using 3D printing has the drawback that it is an external process. Architects and architectural technicians often use the model making process to gain a better insight into the buildings they are designing. This insight does not occur when 3D printing is used.

Figure 9.38: A coloured 3D model printed using the Z-Corp process

Figure 9.39: A selection of 3D printer outputs reviewed at John McCall Architects

A certain amount of cleaning up of the 3d models was necessary before they were sent to the 3d printer as a STL file. The conclusion was that 3d printing was an outsource capability the company might offer to clients. The development of 3d printing from 3d BIM models also flagged up the CNC (Computer numerical control) and design to manufacture capabilities that is possible from BIM models.

9.10 Execution of Staff Training

9.10.1 Training execution – Introduction

Both the development of the training materials and the development of the training plan should have taken place earlier in the project. Here the focus on the execution of the training.

At John McCall Architects the BIM training had to work around existing fee earning commitments. The learning from the earlier steps being undertaken was feed back into the training provided. Members of staff take time to absorb ideas and develop skills. Yet when developing skills it is important that the lessons learnt are quickly put into practice to reinforce the learning with hands on practice.

9.10.2 Training Execution - Actions taken at the case study company

Here we look at the outsourced training, the internal training and the self-study undertaken at John McCall Architects. The research was responsible for coordinating all the different forms of training along with designing, developing and executing all of the internal training.

As the workload at John McCall Architects decreased over the period of the BIM implementation project it became clear to staff that a reduction in staff was likely to take place. This to some extent may have motivated some of the staff to learn BIM skills, a skill that was likely to be needed at the practice in the future.

9.10.2.1 Outsourced BIM Training

The company ‘Applecore’ (an experienced ArchiCad training company) were employed to give four members of staff nine hours educational training (see figure 9.40). The cost of this training was subsidized by educational grants. SkillWorks which provided the funding has been a programme committing 15 million of European Social Funding (ESF) for training.

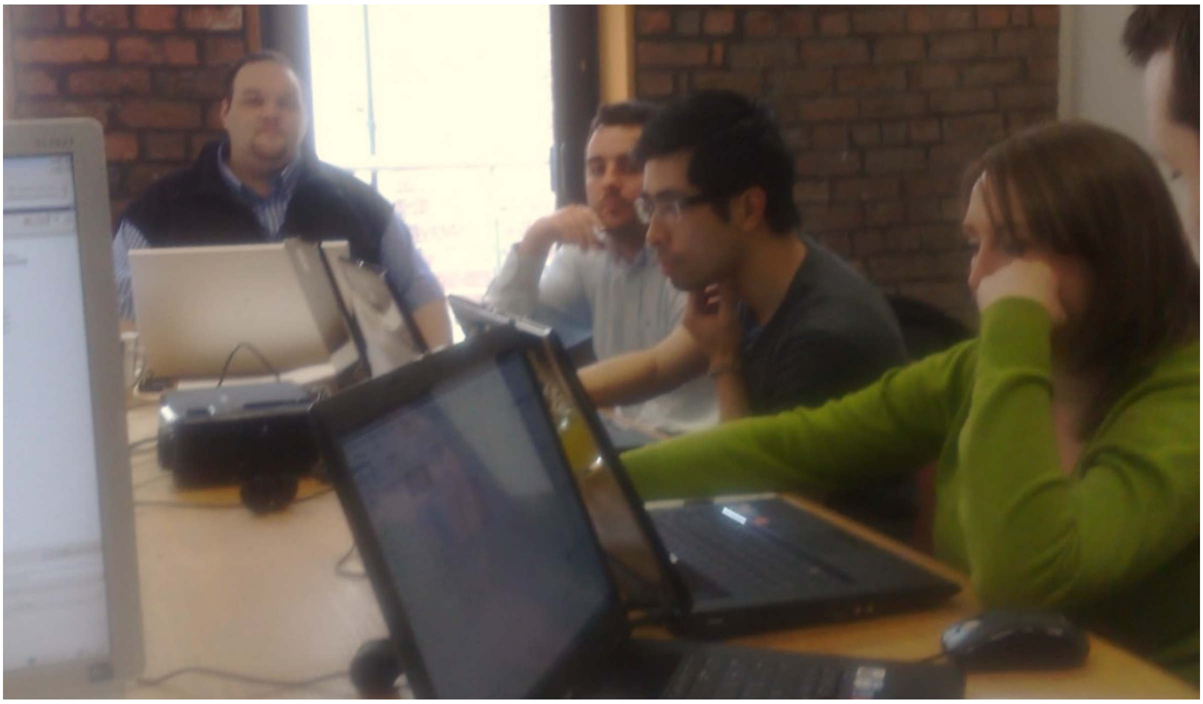


Figure 9.40: Outsourced training being undertaken at John McCall Architects

The training was performed as a group going through predesigned exercises. Paper handouts were also provided of the exercises. These exercises were designed to cover critical issues necessary to understand how to use ArchiCad. Working and being trained in a small group proved to work well. It was possible to develop a dialogue with the trainer (a highly experienced ArchiCad user). The training took place in a room away from the main office so disruptions to the training were reduced. The training was intensive and quite tiring. This was because of the amount of new knowledge and concepts to be digested. Each user had their own notebook computer on which to undertake the exercise. One employee of John McCall Architects took notes which were subsequently useful. Feedback forms were also completed as part of the training.

BRE as part of the BuildingSmart in the UK offers accredited BIM training covering Business management, Project management and Design Management (see figure 9.41)(BRE 2013). This may provide a good method of training senior management about BIM issues.

Course	**Business Management** 1 day training & exam £300 per person	**Project Management** 2 days training & exam £500 per person	**Design Management** 3 days training & exam £650 per person
Main Topics	- Comprehensive overview - Why BIM - Executive leadership - Management of change - Governance - Contract management - Methods of delivery	- Comprehensive overview - Governance - Contract management - Methods of delivery - Data Formats - BIM Process - Data sharing - Collaboration	- Comprehensive overview - Software vendor overview - 3d modeling demonstrations - Data Formats - BIM process - Data Sharing - Collaboration
Designe d for	- Clients - Directors	- Project Managers - QS's - Senior Managers - Architects - Engineers - Senior Technicians - Contractors - Other Designers	- Design Architects - Design Engineers - Technicians - Construction site managers - FM Managers - Other Designers
	Exam only - £100 per person		

Figure 9.41: Information concerning the BRE accredited BIM training courses

9.10.2.2 Internal Training

This was training designed, developed and implemented by the BIM Champion. The development of the training material was developed in parrallel with undertaking the prototype projects. A large element of the developed training material was in the form of powerpoint presentations. A considerable hands on training was also given. Nine hours hands on training was given to each member of the architectural staff. This was broken down into three, three hour sessions. A three hour session being the maximium time staff could sensibliy be taken away from fee earning work at one time. It also proved to be the maximum length staff could actively digested the knowledge they were being given. Also ergonmically it is not a good policy to use laptops for extended periods.

What is important to understand when developing BIM is that different people within the organisations using BIM have different informational requirements and different decisions to make (see figure 8.04). What this suggested is that different lenses and filters and modelling interfaces should be built into BIM to address the specific needs of the user. This can be control through the operating system login and password process. This was not developed at John McCall Architects but represents a further level of customisation and optimisation.

When the internal hands on training took place this was limited to three people at a time. This was partly due to the fact only three laptops were available to undertake the training. Also taking more than three staff away from fee earning work at one time may have been unduly disruptive to the practice. A fourth laptop was used with a projector by the BIM Champion. This enabled processes and commands to be quickly demonstrated to the group. The room where the training was conducted had no phone or email connection so the training was not disrupted.

The laptops were rather slow when running ArchiCad but this was not important at a time when the users were learning the software. The groups were selected so people with the same aptitudes were placed in the same groups. Staff enjoyed the opportunity to develop their skills in a shared non-formal setting. It was hoped that the knowledge sharing between the members of the group in the training session would continue when undertaking work in the practice.

The staff were given a building to produce in ArchiCad that they had already produced in Microstation. This meant they already had an intimate knowledge of the building to be produced. This resulted in a wide range of previously developed schemes being put into BIM. Different schemes raised different questions thus accelerating the development of operational knowledge. Working in a group staff were able to discuss and develop modelling strategies.

The advantage of internal training was that it could be flexible to staff working commitments. The outcome of the internal training was particularly rewarding. After undertaking the internal training staff felt to have enough knowledge to embark on building models without direct supervision. The problem then became that the number of ArchiCad installations purchased by the practice did not meet user demand. Educational copies of ArchiCad can be used for training but they are not suitable to be used for fee earning work.

9.10.2.3 Self-Study

Certain members of staff at John McCall Architects took the initiative to undertake self-study, but the results were unpredicatable. The BIM Champion, where possible directed those who wish to undertake self-study to the most appropriate self-study material available. Several options exist for self-study. Self-study maybe performed using educational versions of the BIM software so the user can experience how the software operates and responds. The ArchiCad initial use by John McCall Architects operated off a dongle. This enabled users to take the dongle home to use the software. Unfortunately the dongle was lost by one of the users.

Many instructional videos concerning BIM are also available online. Online training classes with a live instructor are also available through Learn Virtual and other vendors.

ArchiCad the BIM tool selected provides a series of powerpoint presentations known as the BIM curriculum to help learning about the BIM concept (see figure 9.42).

Chapter Titles:

1. Architectural Representation
2. The BIM Concept
3. Computer Modeling
4. Computer Visualization
5. External Collaboration
6. Internal Collaboration
7. Construction Coordination
8. Calculation
9. Sustainable Design
10. Parametric Object Technology
11. Computer-aided Manufacturing
12. Documentation

Figure 9.42: Powerpoint presentations provided by ArchiCad as part of this BIM Curriculum

Another form of self-study is to access the knowledge and help that is directly available from the BIM software (see figure 9.43).

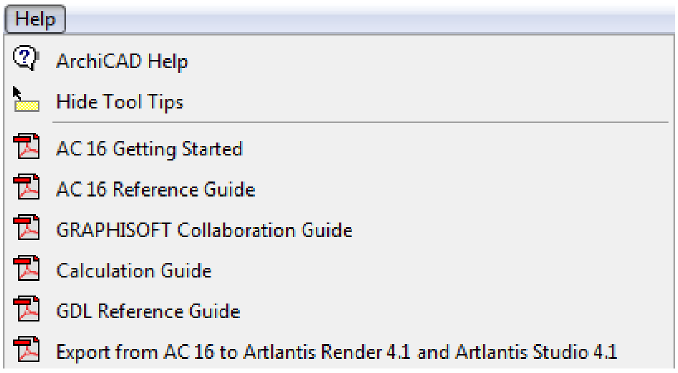


Figure 9.43: Help and training available direct from the ArchiCad 16 software

Also many training videos for ArchiCad are available on “You Tube”. With different staff taking different routes the overall knowledge base in the office was able to rapidly expand. In hindsight the self study information given to staff could have been improved.

Discover smart BIM, an interactive guide to Archicad (Good 2009) was also refered to by staff learning about archicad at John McCall Architects.

9.10.2.4 Recommendation Training Execution

The trainer teaching BIM should have both good BIM skills and good training skills. At John McCall Architects it was considered whether to send the trainer on a “train the trainer” course. But this was not adopted because of cost.

BIM is such a rapidly changing field the BIM champion / BIM trainer should be involved with selective learning opportunities throughout a BIM implementation so they can impart the very latest techniques and methods of using the BIM tool.

Ideally users can be asked to perform skills assessments to determine the team member's mastery of BIM software and design using BIM techniques after the training has taken place.

The need for repetition to embed learning has already been discussed and it is important that staff particularly those not undertaking BIM work directly receive periodic training updates.

The training material developed could also have been put on an intranet available on demand to staff. It is also possible that asking staff who have undertaken self-learning to present to other staff might reinforce the learning and help other staff.

9.11 Project Procedures - Standards for using BIM

The current BIM standards which are in place were documented as part of section 3.4.1 of this thesis. Some of the standards it unnecessary that many of the BIM users will need to understand. But ideally at least one member of staff (the BIM manager) in the company should be aware of the standards that apply and ensures that the practice complies where necessary. Consideration should also be given to whether the demands of the standard are appropriate for the complexity of the deliverable required. A project requiring three hundred drawings needs different systems in place that a project that can be described by three drawings. Many of John McCall Architects projects where successfully delivered using a limited number of drawing contain all the information required. Keep it simple principles should be considered and unnecessary complexity should be avoided.

The standards related to CAD but were not aligned for the use with BIM. At John McCall Architects BIM standards were not an issue because few were in place in the UK at the time of the project. This is no longer the case with new standards regularly being issued.

Using BIM there is likely to be general standards and client (project) specific requirements. In reality when clients asks for certain procedures to be adopted these will be taken on board by the architect but also augmented with the architects knowledge to ensure a quality product is produced (see figure 9.44). Members of staff working to client standards need to be briefed in relation to these over and above understanding the company standards. At John McCall Architects at the time of the research the clients were not BIM aware and had not developed BIM requirements. Efforts were made as part of the stakeholder awareness raising sessions to make the stakeholders more knowledgeable about the standards relating to BIM.

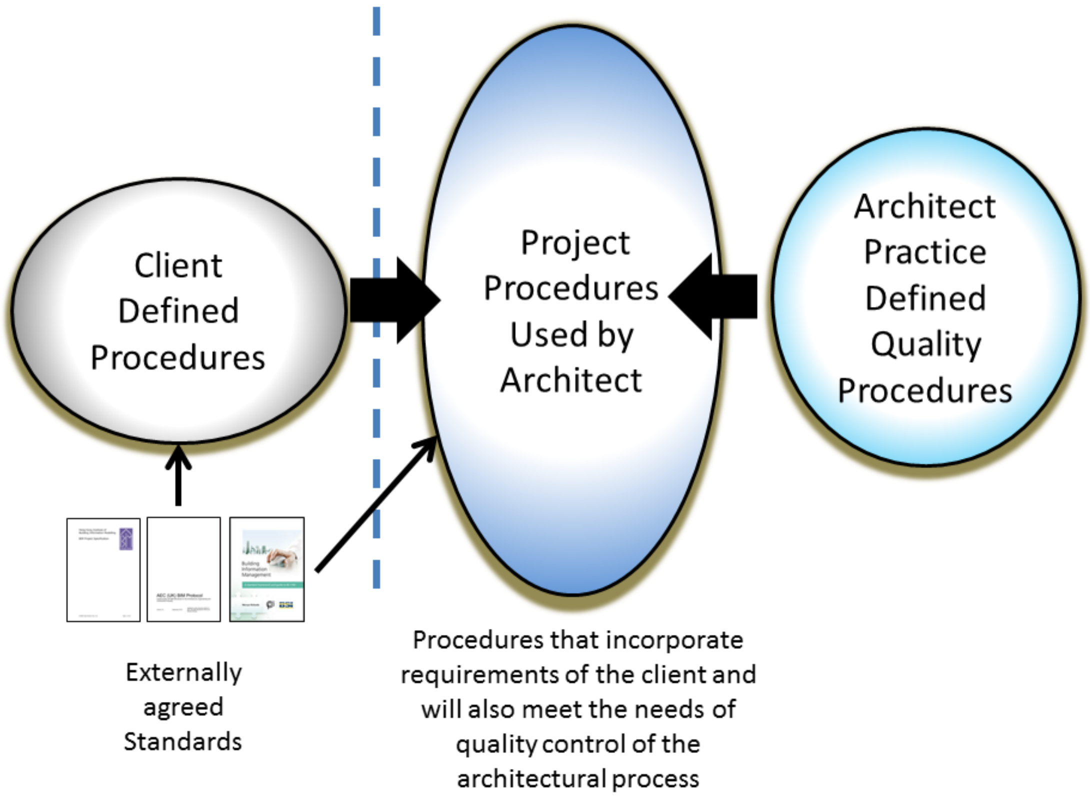


Figure 9.44: How project specific working practices are defined in an architectural practice

Clients may have requirements for geospatial grids, document and file naming, document and database management, building element coding and asset naming. Although it may only be when a project is commenced that the full client BIM requirements are understood it is best to try to understand these as much as possible before the project commences. These client standards may have a time and thus a cost implication affecting the deliverables produced. An architectural practice should have an outline understanding of the procedures required by all its main clients. This may not be easy in this time when client's requirements are being formulated and evolving. The UK government is currently developing BIM employer requirements which may be used in the future.

9.12 The BIM execution plan the BIM manual and the BIM capability Matrix

There are three foundation documents that should be in place to assist in an organisation being BIM competent. These should be created as part of a BIM implementation. These are a BIM project execution plan, a BIM manual and a BIM capability matrix. A BIM competent organization is the one that has consistently delivered a set of high-quality BIM products and services. It not only harbours the necessary BIM-competent individuals but surrounds them with adequate systems, standards and due support (Succar 2010). Of these documents only the BIM manual was developed at John McCall Architects. The relevance of the BIM manual focuses on internal operation while the BIM execution plan and BIM capability matrix are critical for external interaction and interoperability.

9.12.1 The BIM Execution Plan

To undertake BIM projects where collaboration is expected it is recommended that a BIM project execution plan is used and the actions and responsibilities contained agreed by all parties. A good example of a BIM project execution plan is available from Pennsylvania State University (2010). Although this execution plan may need tailoring to UK projects and project specific needs. As part of the BIM project execution plan it would also be expected to provide generic process maps and exchange requirements (see figure 9.45).

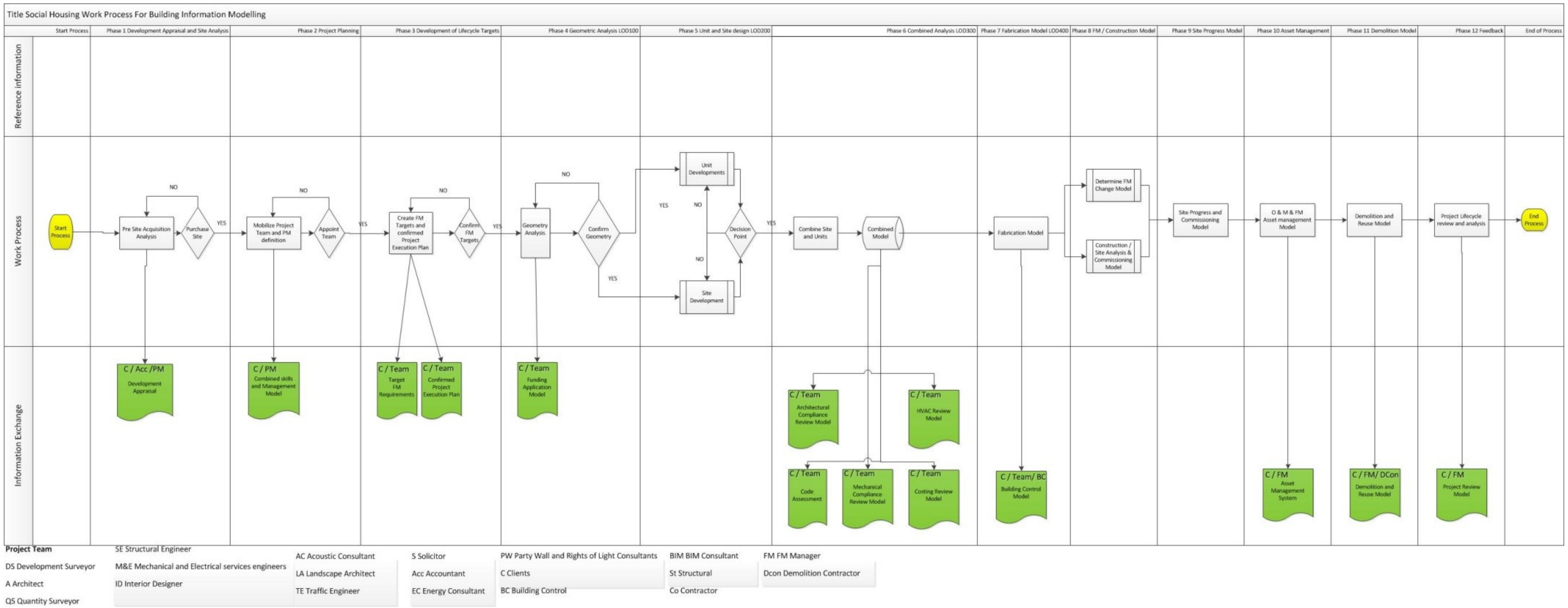


Figure 9.45: Example of a process map developed for a housing project (These were developed after undertaking the case study research)

Each process needs to be defined, with who is responsible for it and the inputs and the outputs. Ideally this should be documented in a formal way using UML (unified modelling language) flow charts. Guidance on how to develop such process maps is available from the “process protocol” (Aouod et al 1998) developed by the University of Salford. Generic process maps are also available as templates from Pennsylvania State University.

Using the process maps each exchange requirement for information needs to be described. An Exchange Requirement (ER) is a non-technical description of the information needed by a process to be executed, as well as the information produced by that process. Generic exchange process maps are available.

A BIM project execution plan was not developed at John McCall Architects because at the time the research their need for collaborative procedures had not been required. In the future as more of John McCall Architects collaborators use BIM this will need to change.

9.12.2 The BIM Capability Matrix

Ideally companies should develop knowledge of the BIM software they use, but also knowledge of the software they might use in certain circumstances. Use of alternative BIM tools maybe driven by clients or driven specific functionalities required by individual projects. A chart was developed by HOK (an international architectural company) for the purpose of recording this information for their architectural organisation (see figures 9.46 and 9.47).

<table>
<tr><td rowspan="2">Proprietary Tools/ Activities</td><td colspan="3">Phase 1</td><td colspan="3">Phase 2</td><td colspan="2">Phase 3</td></tr>
<tr><td>Activity 1</td><td>Activity 2</td><td>Activity 3</td><td>Activity 4</td><td>Activity 5</td><td>Activity 6</td><td>Activity 7</td><td>Activity 8</td></tr>
<tr><td>Product 1</td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Product 2</td><td></td><td>X</td><td>X</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Product 3</td><td>X</td><td>X</td><td>X</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Product 4</td><td></td><td></td><td></td><td>X</td><td>X</td><td></td><td></td><td></td></tr>
<tr><td>Product 5</td><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Product 6</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Product 7</td><td></td><td></td><td></td><td></td><td></td><td></td><td>X</td><td>X</td></tr>
<tr><td></td><td colspan="3">Phase 1</td><td colspan="3">Phase 2</td><td colspan="2">Phase 3</td></tr>
<tr><td>Combination Options</td><td>Activity 1</td><td>Activity 2</td><td>Activity 3</td><td>Activity 4</td><td>Activity 5</td><td>Activity 6</td><td>Activity 7</td><td>Activity 8</td></tr>
<tr><td>Combination1</td><td></td><td colspan="2"></td><td colspan="2">Product 4</td><td></td><td colspan="2"></td></tr>
<tr><td>Combination2</td><td></td><td colspan="2">Product 2</td><td colspan="2">Product 4</td><td></td><td colspan="2">Product 7</td></tr>
<tr><td>Combination3</td><td colspan="3">Product 3</td><td colspan="2"></td><td></td><td colspan="2">Product 7</td></tr>
<tr><td>Combination4</td><td colspan="3">Product 3</td><td></td><td></td><td></td><td colspan="2">Product 7</td></tr>
</table>

Figure 9.46: Tool-activity matrix and BIM Tool compatibility chart (London 2008)

Design Software - Applications
Last updated by Miles Walker 2008-11-11

CATEGORY	STANDARD	APPROVED	RESEARCH	CONSIDER	SPECIAL EXCEPTION
APPLICATIONS	Adobe Creative Suite Standard Autodesk 3ds Max Design Autodesk AutoCAD Architecture * Autodesk Design Review Autodesk NavisWorks Freedom Autodesk Revit Architecture Autodesk Revit MEP Autodesk Revit Structure Autodesk SketchBook Pro ** Google Sketchup Pro	Autodesk Ecotect Autodesk NavisWorks Manage EgoGrafx Land F/X ESRI ArcGIS Google Earth Pro InterSpec E-Specs (for Revit) McNeel Rhino Microsoft Visio PRO Microsoft Visio Standard Mindjet Mind Manager	Autodesk Alias Studio Autodesk AutoCAD Civil 3D Autodesk FM Desktop Autodesk Green Building Studio Autodesk ImageModeler Autodesk Inventor Autodesk Maya Autodesk Quantity Takeoff CityCAD IES Trelligence Affinity	Adept Management - ADePT Autodesk Autocad Autodesk Constructware Autodesk Impression Autodesk mudbox Autodesk NavisWorks Review Autodesk NavisWorks Simulate CityEngine Google Earth Free Edition Google Sketchup Free Edition Innovaya (for Revit)	Bentley Microstation
NOTES	* Not to be used as primary CAD Software on new projects. ** Tablets only				

Design Software - Categories
Last updated by Miles Walker 2008-11-11

CATEGORY	STANDARD	APPROVED	RESEARCH	CONSIDER	SPECIAL EXCEPTION
DESCRIPTION	Approved and installed on all systems	Approved but not installed on all systems	Approved for research on limited systems.	Evaluate if suitable for Research	Approved for special circumstances on limited systems
PURCHASE	Firmwide	Office or Project	Office or Project	N/A	By Office
LICENSING	Central Licensing	Central or Office Licensing	Central, Office or Trial	N/A	By Office
DEPLOYMENT	Firmwide Deployment and Computer Images	Firmwide Deployment or Office	By Office	N/A	By Office
TRAINING	By Office or Firmwide	By Office or Firmwide	By Office	N/A	By Office
SUPPORT	Full Support by ATG	Partial Support from ATG and Experts	Limited or No Support	N/A	Limited or No Support
NOTES			Use on projects with caution. Beta software not to be used on projects. Alpha testing not allowed.		

Figure 9.47: The list of design applications in use at HOK, and an explanation of the different categories in which they belong. (Khemlani 2008)

The ability to be able to use multiple BIM tools may be regarded as a luxury for small architectural practices where the primary need is to become proficient in the use of one architectural BIM tool. This was the view taken at John McCall Architects. Such capability matrices were not developed at John McCall Architects, but this would be a recommendation to undertake on future BIM adoption projects.

9.12.3 Development of the BIM Manual

The BIM manual was written to help and standardize the BIM work performed at John McCall Architects. The BIM manual maybe a physical document, it may reside on an intranet or it may be integrated into the BIM software or the quality system. Multimedia versions of a BIM manual could also be considered. The BIM manual should be a working document that is amended and improved overtime with revisions being documented using revision control.

At John McCall Architects the final form of the BIM manual had not been decided during the period of research. The draft BIM manual was developed in microsoft word. Many of the elements which need to be included in a BIM manual were identified by Heng (2011) (see figure 9.48).

ORGANISATION	TEMPLATE	LIBRARY
ADMIN	**MODELLING ISSUES**	**MODEL FAMILIES**
Folder arrangements	Views	Wall Types
Files saving location	Visibility Graphics	Door Types
Family Folders	View templates	Window types
Consultant files	Call outs	Furniture Families
Archives	Import Title Blocks	Specialty Equipment
File Names	Organize project browser	Title Blocks
Template Location	Set Cameras	Stair Case
	Set the view in sheets	Railings
	Set the default levels	Ceilings
	Keyboard shortcuts	Detail Library
	Default schedules	
	Project parameters	**ANNOTATION FAMILIES**
	Load Families	Room Tags
	Load Patterns	Door Tags
	Load dimension styles	Window Tags
		Keynotes
	OUTPUT ISSUES	Patterns
	Line Weights	Leader arrows
	Line Types	Dimension styles
	Visibility Graphics	Elevation marks
	Color Schemes	Section marks
	Underlying Settings	Details
	Publishing to the Web	Multi view block
	Plotting standards	Fire rating walls
	Archiving	Ceiling Tag
		Furniture Tag
Preliminary Template / Library Issues : Work in progress		

Figure 9.48: BIM File Organisation (Heng 2011)

The features indicated by Heng (2011) are for Revit but the features are similar for ArchiCad and other BIM authoring tools. Revit uses families while ArchiCad uses object libraries. Many elements such as the BIM object libraries, the BIM manual and the BIM authoring tool optimisation are important to make sure this stage is a success. Since the time of writing the manual the AEC (UK) BIM Protocol for Graphisoft Archicad has become available and this would be a good reference for the development of a BIM manual.

The BIM manual as a record and resource for development is a key element of BIM implementation. Appropriate time and resources need to be allocated to develop the BIM manual. Many things are need to be included in the BIM manual (see figure 9.49). Some of the required information may come from existing CAD practices but most will not.

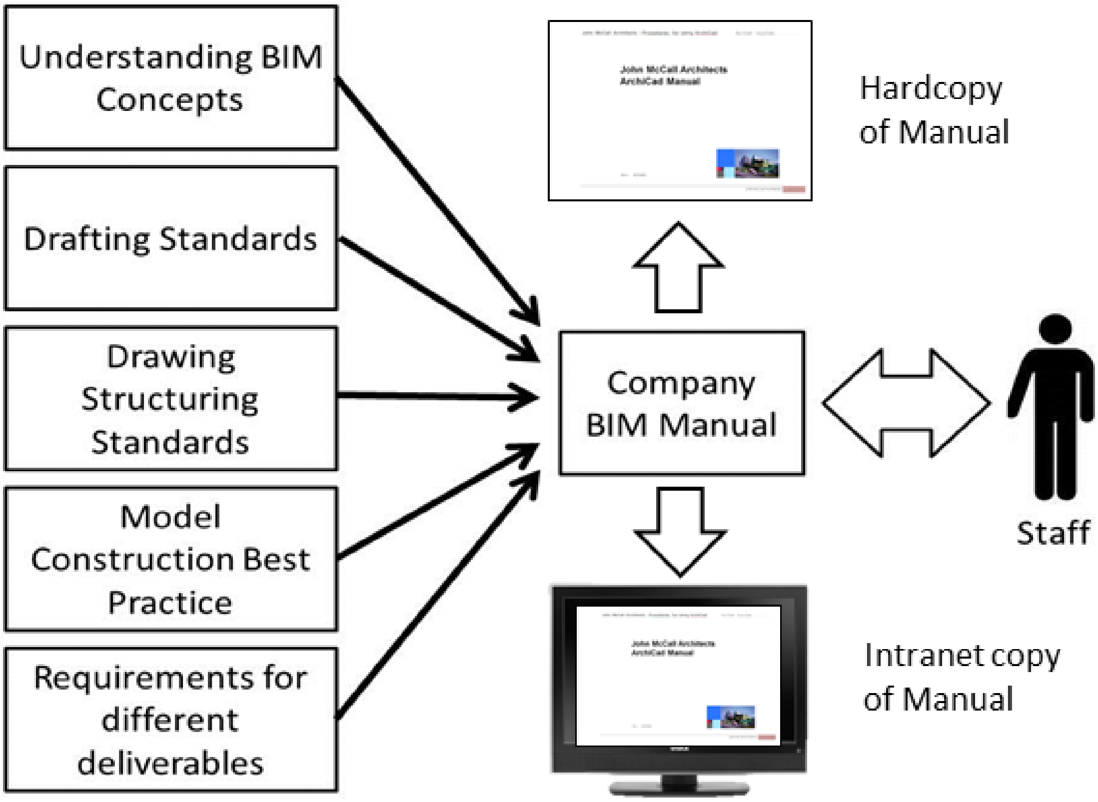


Figure 9.49: An example of the main contents of the BIM manual developed for John McCall Architects

The major exercise at John McCall Architects to document and create standardisation within the office was the development of a BIM manual. This standard method of working is the end goal of the BIM manual. The BIM manual produced at John McCall Architects was a hybrid document. The manual documented the recommended approaches to be taken but it also set out to educate the reader how to use the BIM software and to give some explanation of the building and graphical standards that applied to the objects and model deliverables involved. A good document to refer to, to understand mistakes that are commonly created by BIM modellers is the Norwegian Home Builder's BIM Manual (2011), bolig BIM (see figure 9.50). The VA BIM Guide v1.0 April 2010 is also a good source for reference.

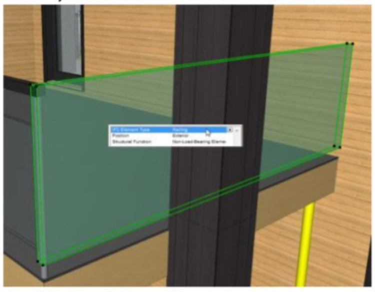
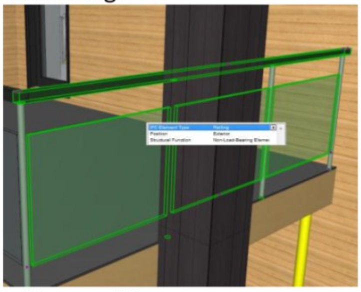
Staircases IfcStair	Staircases should be modelled as a staircase object.
Railings IfcRailing	Railings should be modelled as objects. May also be modelled with wall tools, but must then be classified as IfcRailing.   *Railing with wall tool* *Railing as object*
Ramps IfcRamp	Ramps should be modelled as a ramp object. May also be modelled as a roof, but must then be classified as a ramp (IfcRamp).

Figure 9.50: An image taken from the Norwegian Home Builder's Manual (2011)

Assistance in the task of writing the BIM manual if ArchiCad is the choosen BIM tool maybe be gained from referring to "The Interactive Archicad Practice Manual" (Sullivan 2011). This resource was not available at the time the research was undertaken at John McCall Architects.

The BIM manual as a hardcopy or electronic document or help menu needs to convey the essentials of what staff need to know. Ideally this transfer of knowledge and skills should be done quickly simply as possible. Using a visual format supported with a textual description is a good way to transfer such knowledge.

Much of the material within the BIM manual was developed as part of the training material.

The aims of the BIM manual at John McCall Architects were set out as follows:

1) The manuals should show the best way to do a project at John McCall Architects in ArchiCad from start to finish

2) The manual should comply with John McCall Architects element attributes such as font type, linestyles etc.

3) The manual should cover the differences between different deliverables, building control, planning, construction, code for sustainable homes drawings and as built drawings etc (this is about layers, filters and annotations)

4) The manual should be set at the right level for the users

5) The manuals should mesh with the John McCall Architects Archicad environment and its development

6) Where important information is not contained it should be reference

7) The development of the manuals should feed into the further development of the ArchiCad environment

8) The BIM manual should be a living document being enhanced as more BIM projects are undertaken

As part of the BIM manual it was necessary to define what is necessary to create a standardized graphical product and a standardized informational product. BIM manuals may also provide guidance on constructability and building code compliance.

To create standardized graphical production it is necessary to consider geometry, drawings, attributes and structure. Geometry relates to the actual form and composition of the building. When considering a graphical output / drawings the representation, the annotation, viewpoints, orientation and levels of detail need to be considered.

BIM structure involves defining the inter relation of drawings, layout sheets, schedules and master layouts and title sheets. For attributes of objects, graphical styles, line and fills, libraries, line weights and layer and layer combinations where appropriate need to be considered. Many of these requirements had already been defined as the preferred method of operation used by the legacy Microstation software at John McCall Architects.

There may come a time when a BIM model alone will be viewed as an adequate deliverable on its own but currently 2d drawing sets are usually required.

The BIM manual also answered important questions like how should the storeys be named. Should they be named Ground Floor and First Floor or 0 Level 1, Level 2 Level etc. Recommendations on these matters can be found in BS4157 Construction drawings and Designation systems.

Clients may also have their own requirements not aligned to the standards. Illustrations from the prototype projects were also used where appropriate to make a project focused point in the BIM manual. Images of the manual produced are included (see figure 9.51 and 9.52).

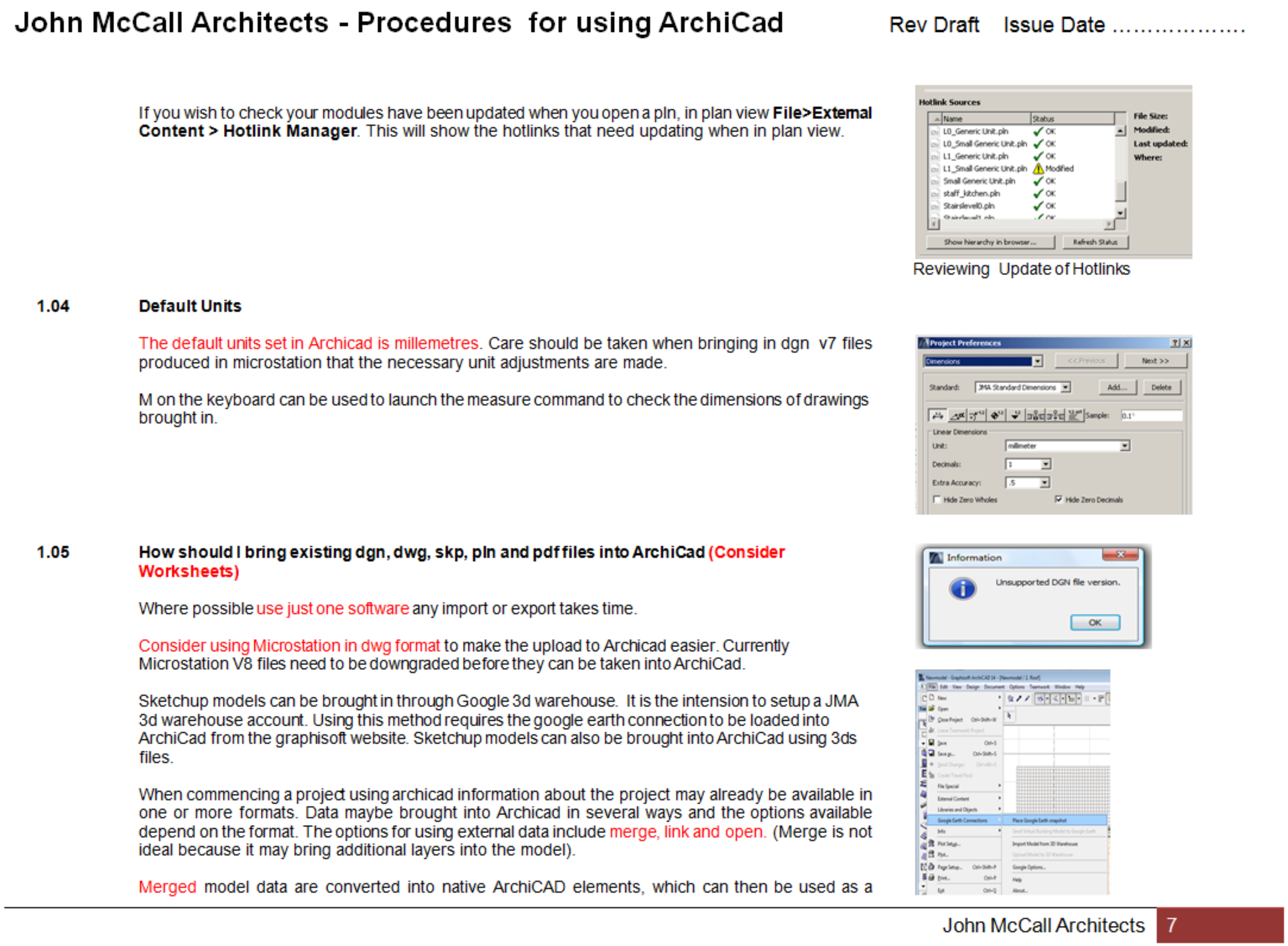
John McCall Architects - Procedures for using ArchiCad Rev Draft Issue Date ....

If you would like someone to run through how to use ArchiCAD please ask

Contents

John McCall Architects 2

Figure 9.51: A screen shot from the contents page of the BIM manual developed for John McCall Architects



John McCall Architects - Procedures for using ArchiCad   Rev Draft   Issue Date ....

If you wish to check your modules have been updated when you open a pln, in plan view **File>External Content > Hotlink Manager**. This will show the hotlinks that need updating when in plan view.

Reviewing Update of Hotlinks

1.04 Default Units

The default units set in Archicad is millemetres. Care should be taken when bringing in dgn v7 files produced in microstation that the necessary unit adjustments are made.

M on the keyboard can be used to launch the measure command to check the dimensions of drawings brought in.

1.05 How should I bring existing dgn, dwg, skp, pln and pdf files into ArchiCad (Consider Worksheets)

Where possible use just one software any import or export takes time.

Consider using Microstation in dwg format to make the upload to Archicad easier. Currently Microstation V8 files need to be downgraded before they can be taken into ArchiCad.

Sketchup models can be brought in through Google 3d warehouse. It is the intension to setup a JMA 3d warehouse account. Using this method requires the google earth connection to be loaded into ArchiCad from the graphisoft website. Sketchup models can also be brought into ArchiCad using 3ds files.

When commencing a project using archicad information about the project may already be available in one or more formats. Data maybe brought into Archicad in several ways and the options available depend on the format. The options for using external data include merge, link and open. (Merge is not ideal because it may bring additional layers into the model).

Merged model data are converted into native ArchiCAD elements, which can then be used as a

John McCall Architects 7

Figure 9.52: A screen shot of an example page from the John McCall Architects BIM manual

It is helpful to show dialogue boxes from the software to explain how to undertake certain tasks. The problem here is that such dialogue boxes may change as the versions of software changes. Mac and PC versions may also appear slightly different.

At John McCall Architects work was started to develop a selection tool. This tool was to help BIM users understand which were the standards to be used for their specific projects (see figure 9.53). New build projects and refurbishment projects were to be undertaken in different ways. Subsequent to the adoption of BIM at John McCall Architects Graphisoft has added specific functionality to the later version of ArchiCad to address refurbishment issues.

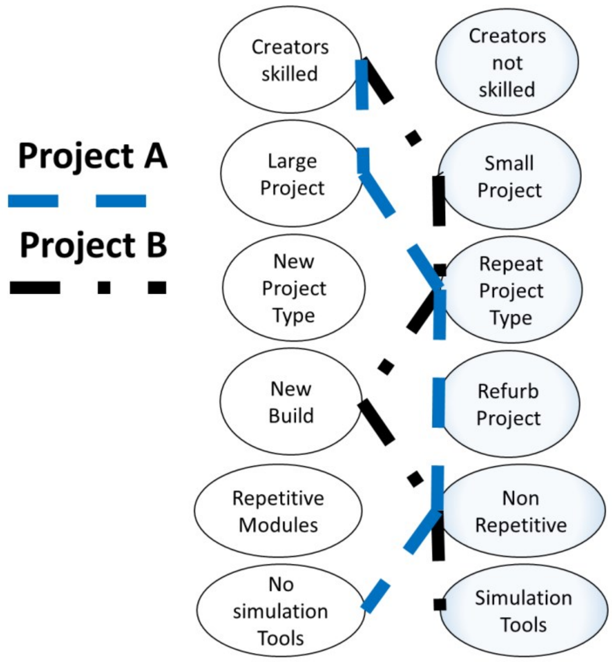


Figure 9.53: An example of how multiple criteria come into play when selecting the appropriate way to construct a BIM model

An important factor in the development of the BIM manuals was the continual peer review which was undertaken at all stages of its development.

9.13 Lean Optimization of the BIM Tool

9.13.1 Lean Optimisation of the BIM Tool - Introduction

BIM tools are usually only 50% efficient “out of the box”. An additional 50% efficiency can usually be achieved by understanding the best way to use the BIM tool and through customisation and requirement alignment. This was also found to be the case during the BIM implementation project at John McCall Architects. Many of these improvements and enhancements can be considered as methods of reducing lean wastes.

The problem is that inexperienced users may not have the skill to optimise BIM tools. As part of organisational BIM implementation strategies a plan should be developed to optimise the BIM tools.

There are a range of optimisations available for individual disciplines and individual tools: (see figure 9.54)

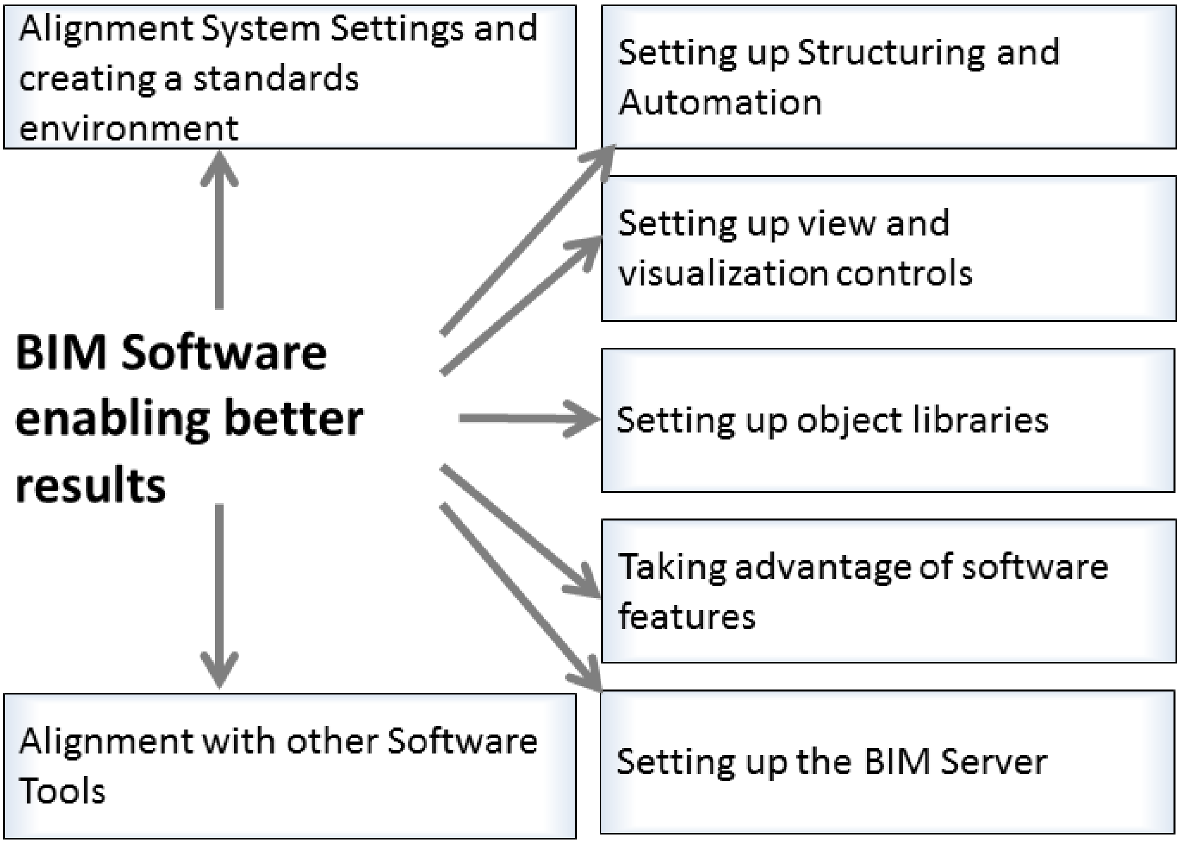


Figure 9.54: Methods of BIM software Optimisation used at John McCall Architects

It is also possible to consider optimisation across multiple disciplines and multiple tools. This was not done at John McCall Architects and is not documented here. Although a brief section on interoperability is recorded.

When setting up an individual discipline BIM setup certain initial considerations must be made (see figure 9.55).

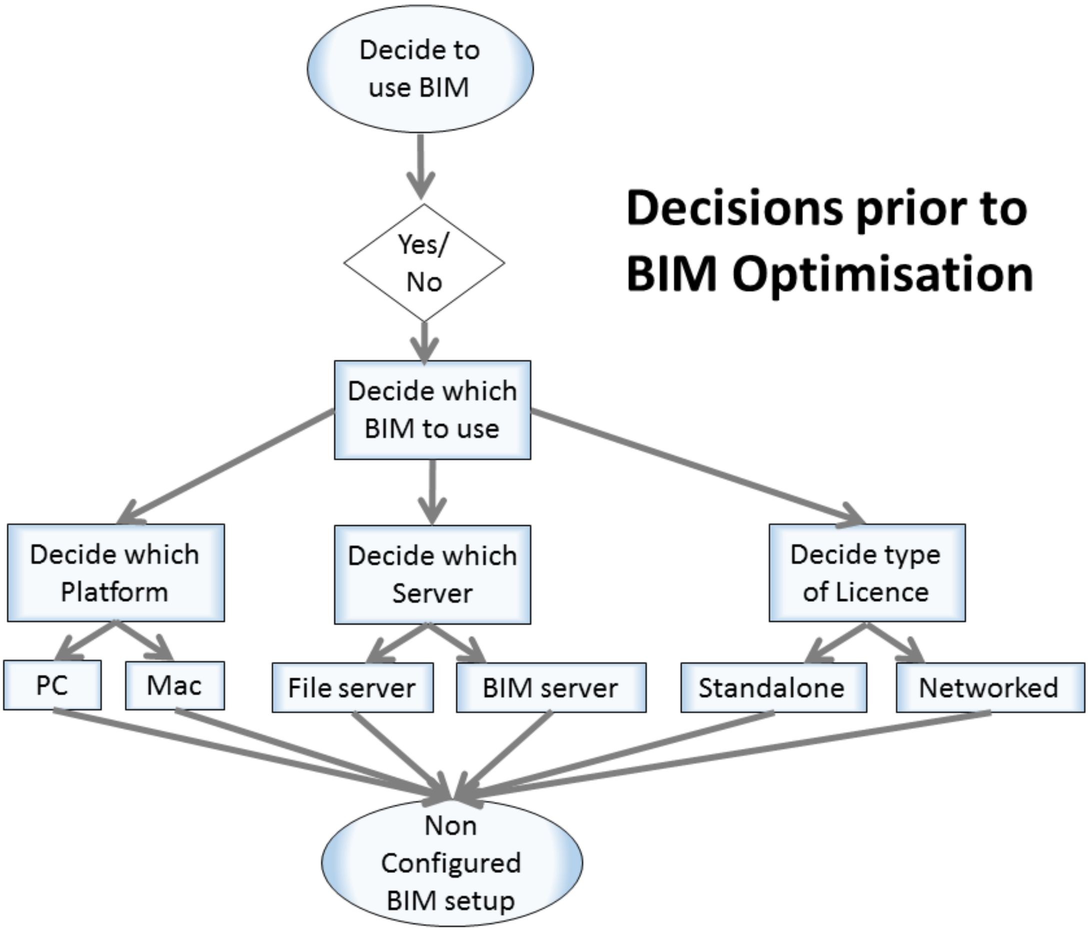


Figure 9.55: Showing initial decisions to be made when setting up a BIM system

9.13.2 Setting up appropriate working environments within the BIM tools

A template file or files and profiles, usually controls the initial setting of many of the functions and constrains within the BIM modelling environment. Configuration of this is perhaps the greatest initial challenge. This is partly because it is a complex task that needs to be undertaken at a point where BIM skills may not have been fully developed.

Customised template files can be developed or purchased and installed. However, both alternatives for the provision of template files can be insufficient to achieve complete templates fully aligning to the needs of the organisation. Therefore it is recommended that the actual development of the template files was undertaken in house with suggestions on how to configure the template files solicited from the software vendor. To make the right decisions in this area in house brainstorming workshops are recommended to decide the configuration of the template files. In the template files, consideration of the settings listed below are particularly important:

- Units - metres or inches or both

- Data Safety – ensuring that work is not lost; a dialogue box needs to be setup and users should understand the significance of this setting. This is not a replacement for an effective backup strategy.

- Mouse Constrains – accurate snap and select objects are important, which is controlled by this setting.

- Tracker Coordinates – different users prefers different ways of doing their tasks, but having the tracker on by default will enable users to rapidly input accurate objects.

- Zones and area calculation – where items such as areas are calculated and sent out to external parties and they must be accurately calculated. To achieve this, research is necessary to determine what should and what should not be calculated in the areas.

There are many more settings that need to be considered.

An example of this issue is indicated in the difference between room areas and unit areas. Unit areas include internal walls while rooms do not. Inclusion of bay windows may also be an issue. A model may need to have several sets of zones to generate areas as gross floor area, net floor area and carpet area, which can be different even though they are all generated from one plan. Layers were used to filter the different area types required by different parties in the development process. Some parties wish for internal walls to be included in the area calculations while others do not (see figure 9.56).

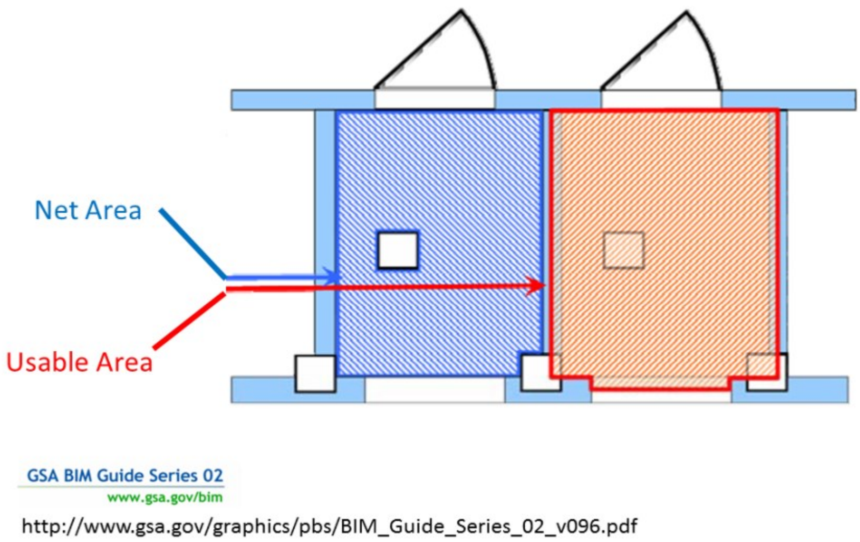


Figure 9.56: Showing the difference between net area and usable area

Also several different template files can be developed to accommodate the needs of the novice user, the standard users and the expert user. Different template files can also be setup for different building types such as new build, refurbishment and interior design and also be project specific.

It was necessary to customise a range of files in ArchiCad to maximise its performance. The directories where these files can be found are shown (see figure 9.57).

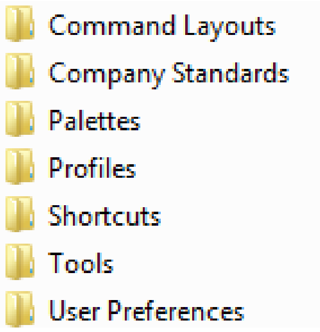


Figure 9.57: Files that it was necessary to customise at John McCall Architects to optimise the use of the ArchiCAD software

9.13.3 Setting up automation within the BIM tools

Using an existing structure of outputs when a new model is created can be a major time saving. The representations from that model can be automatically populate the 2d and 3d output required. It also helps to ensure the quality of the output. For an example showing how standard view sets, sheets and issue sets can automatically be generated from and ArchiCad BIM model (see figure 9.58). Similar strategies can be adopted using software from all the major BIM vendors. This was an approach adopted successfully at John McCall Architects.

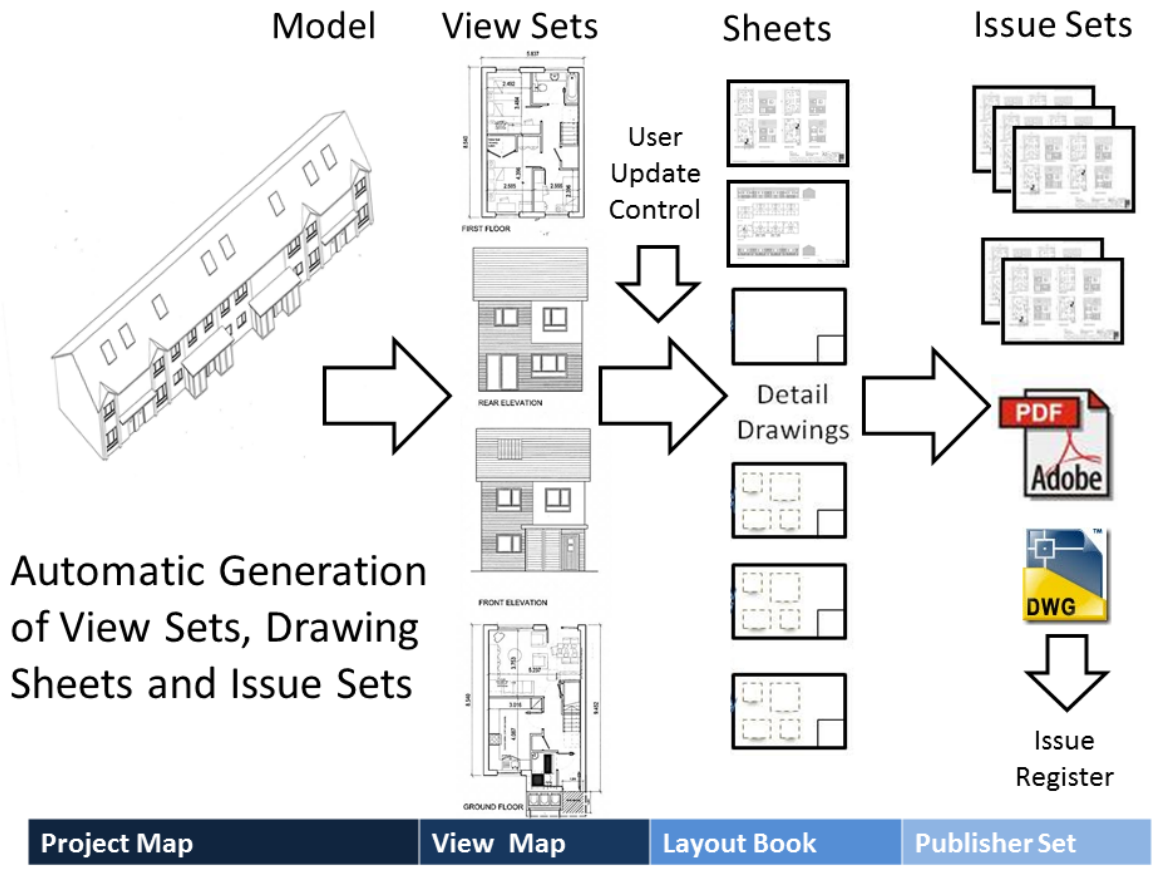


Figure 9.58: Setting up predefined view sets, sheet sets and issue sets to save time when working in Archicad

The problem here is that one project may require a few drawings while some may require many. One strategy is to copy the sheet files between different uses and alter the view control to amend the content shown of the drawing. An example of this would be the differences between a planning submission drawing and a drawing to be submitted to building control. On one the wall construction does not need to be shown while on the other it does.

Sheet generation is not the only form of automation but it is the one that is likely to give the maximum saving in time and effort once setup.

As part of the automation process standard title sheets were developed (see figure 9.59). The caveats included on these title sheets were reviewed before the new sheets were created. The plan was to develop an automated drawing register system linked to the title sheets. This may have taken place after the period of research.

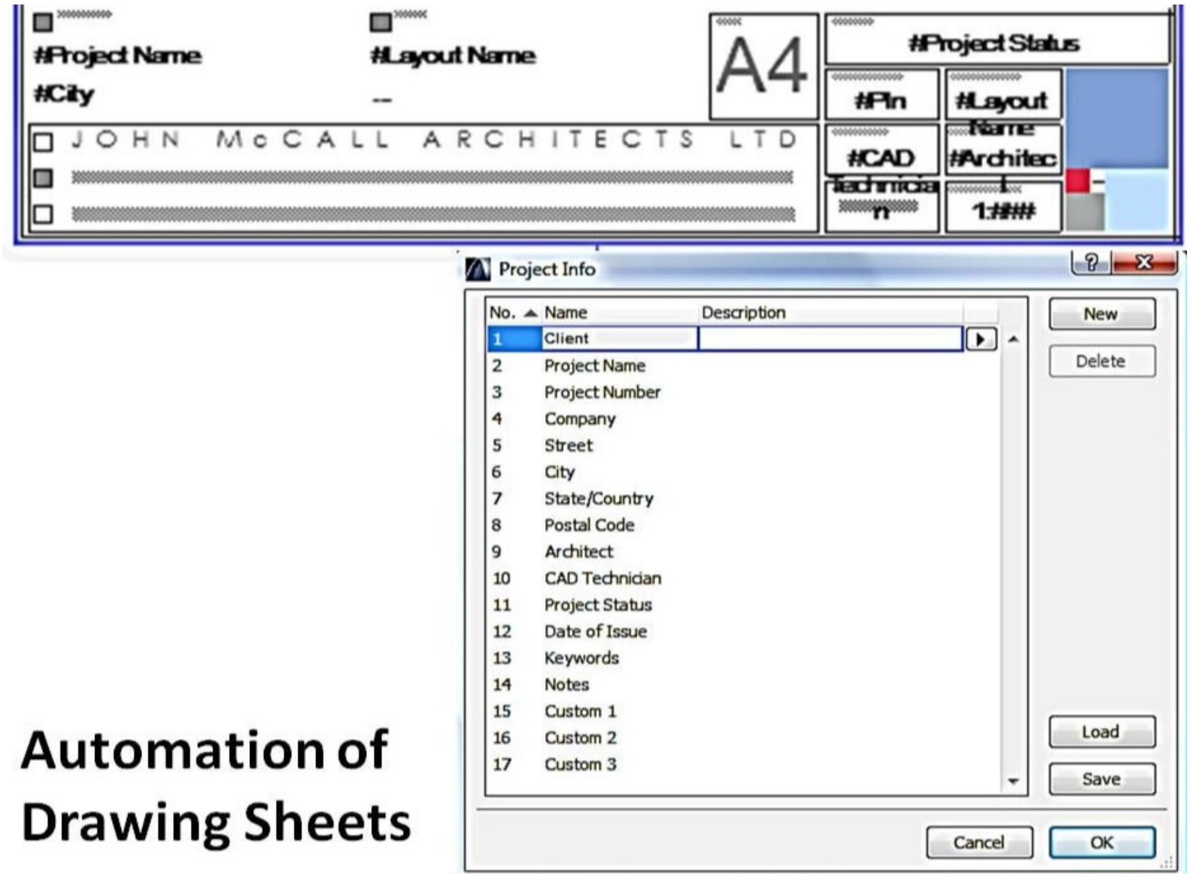


Figure 9.59: Development of an automated title block generated from project information

Developing automation should be an on-going process as a greater understanding of the BIM software and what it is required to achieve is developed.

9.13.4 Setting up view controls and material rendering

Predefined views that are setup at the correct scale, layer combination, pen sets and model view options greatly improves the speed of the BIM output generation process. For instance, if they are not preconfigured in a project, time wasted on this task alone is between 10% and 20% of the time used for modelling. Setting up the view controls was another task undertaken at John McCall Architects (see figure 9.60).

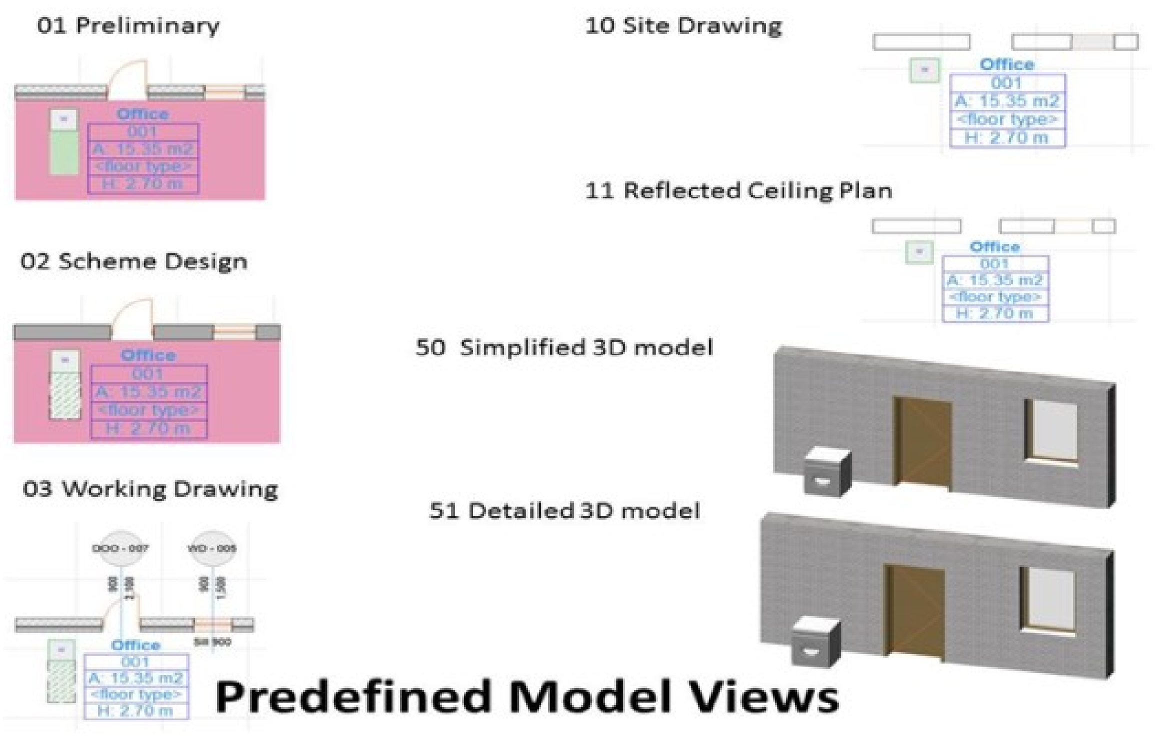


Figure 9.60: Setting up predefined model views to save time when working in Archicad

A meeting of BIM users was arranged at John McCall Architects where the chart (see figure 9.61) was completed. This was used to decide what should be included and not included in each view. The naming strategy for the views also need to be developed. The dialogue box for setting the model view options is shown (see figure 9.62). Setting up of model views can also be useful so 2d representations at different scales can be generated without being cluttered with excessive or superfluous information.

	01 Prelimary Design	02 Scheme Design	03 Working Drawings	10 Site Drawings	11 Reflected Ceiling Plans	11 Reflected Ceiling Plans	51 detailed 3D model
Beams							
Columns							
Curtain Walls							
Door Options							
Window Options							
Cut Fills							
Drafting Fills							
Cover Fills							
Zone Fills							
Zone Stamps							
Minimal Working Areas							
Lamp Types							
Furniture Detail							
Window and Door linetype							

Figure 9.61: A tabled used to decide what should and should not be shown within the predefined model views

Model View Settings

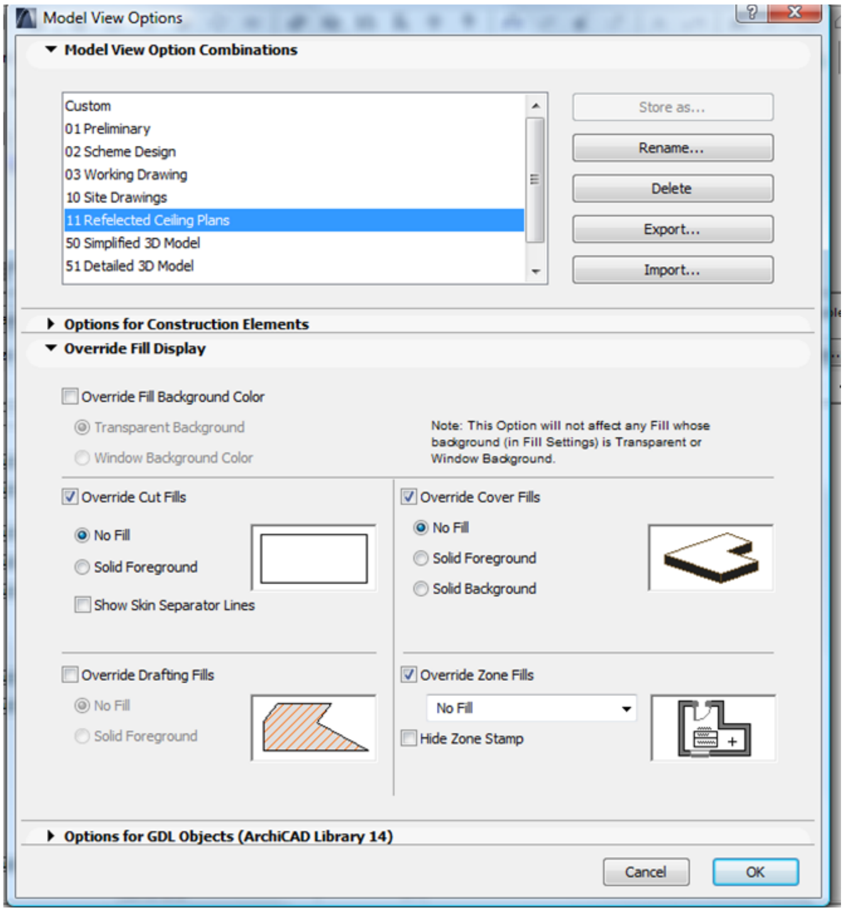


Figure 9.62: Setting the model view definitions for fills in John McCall Architects

BIM models don't always provide the desired rendering results with the materials applied. This is because BIM software may use a range of rendering engines. However, using objects with the correct material properties for rendering, appropriate outputs from rendering can be achieved (see figure 9.63). With the materials developed for rendering and applied to object libraries, a whole stage of visualisation related tasks can effectively be removed from the design process. This was not done at John McCall Architects but it was a task recommended for future action. The decision to do this depends on the rendering engine to be used. At John McCall Architects the Artlantis rendering engine was tested to see if it provided a faster way of achieving high quality rendered outputs.

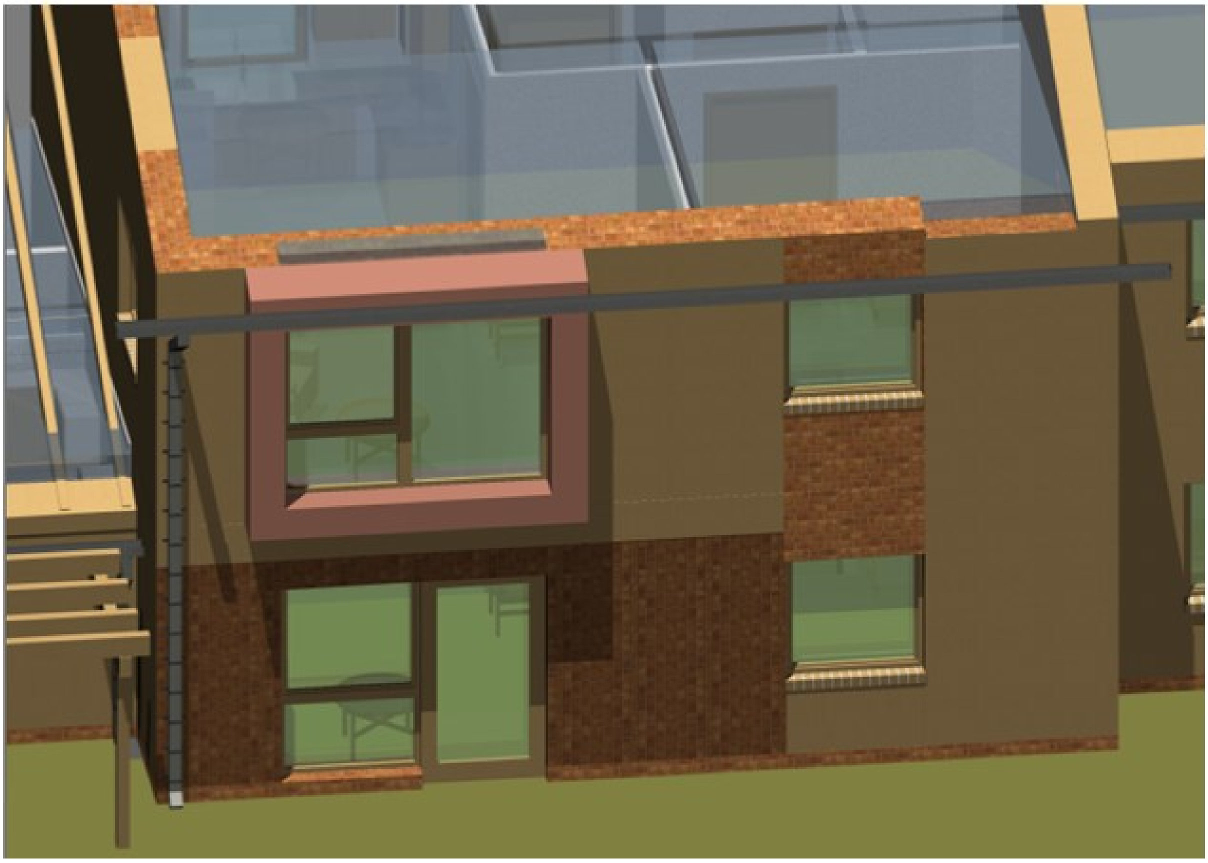


Figure 9.63: Showing brickwork configured and not configured to the Lightworks rendering engine in ArchiCad 13

Due to the complexity of producing high quality rendered output, it is perhaps advisable to train one user to undertake model rending tasks.

9.13.5 Taking advantage of software features

Many BIM tools have add-on features available. ArchiCad was no exception. These may need downloading or acquiring separate from the main BIM tool. If an expert user is in the office they can share their knowledge with other users concerning the add ons available. Some of these add-ons may be free while others are available at a cost. Sometimes they do not operate under warranty. Even so the functionality of the BIM system can often be radically increased by the use of these add-ons. Also these add-ons provide critical functionality that is not available within the base software without programming ability.

Examples of such add ons are the foundation tool add, the roof maker add onand the RAL colour in ArchiCad (see figures 9.64, 9.65, 9.66, 9.67). Additional training was given at John McCall Architects to show staff how to use these tools. Analysis of these add ons should be a specific task undertaken as part of a BIM implementation. Using these add ons can result in major saving in time when producing BIM models.

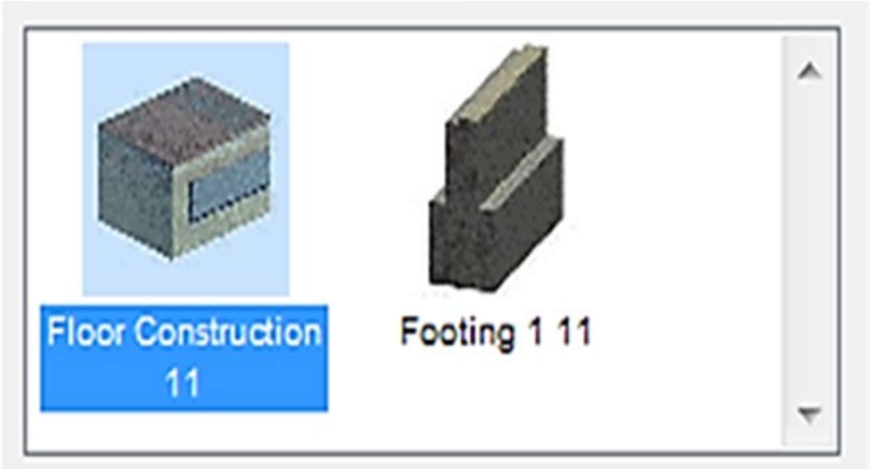


Figure 9.64: The floor construction add on tool for ArchiCad which makes the design of foundation easier

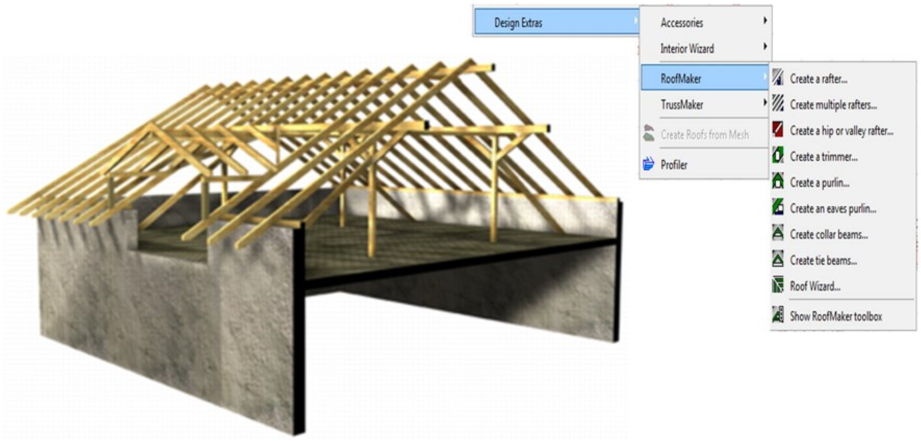


Figure 9.65: Example of roof design develop using the roof maker add on in ArchiCad

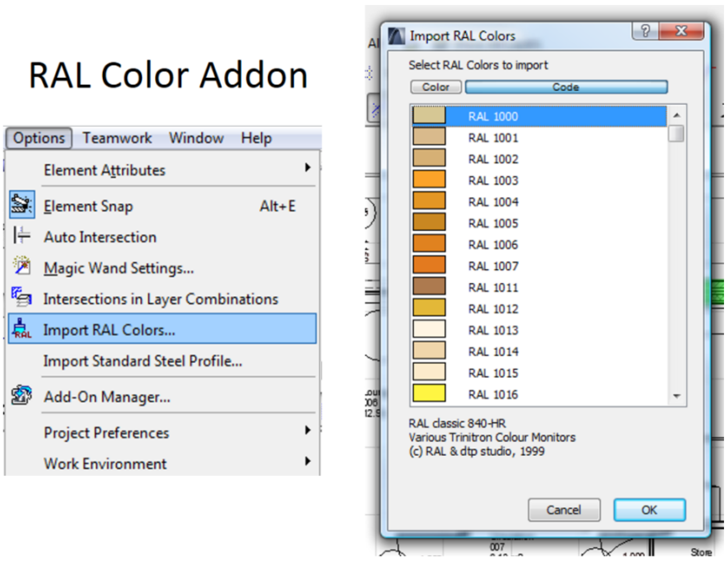


Figure 9.66: The RAL colour add on to be used with ArchiCad

3D Studio In	Read Me	9.76 MB	5.6 MB
Accessories	Read Me	10.6 MB	6.6 MB
Check Duplicates Tool	Read Me	9.6 MB	5.5 MB
Construction Simulation	Read Me	9.77 MB	5.6 MB
Interior Wizard	Read Me	9.97 MB	5.8 MB
Intersection in Combos	Read Me	9.35 MB	5.2 MB
Mesh to Roof Tool	Read Me	9.53 MB	5.4 MB
Polygon Counting Tool	Read Me	9.54 MB	5.4 MB
Profiler	Read Me	9.72 MB	5.6 MB
Ral Colour System	Read Me	9.38 MB	5.2 MB

Last modified : Jun. 14, 2012

Figure 9.67: Addon tools available for download and use in ArchiCad

9.13.6 Using models and multi models

BIM models may be created as a single discipline model but a single discipline model made of sub models. The use of sub models may offer a better solution. Often it makes sense to separate elements into smaller linked models to reduce the processing overhead. This approach was developed at John McCall Architects (see figure 9.68). In this approach the kitchens, the housing units and the gable walls were all referenced into the site model. This approach was similar to the approach used in the Microstation CAD system that the BIM tool was replacing. Using this approach it made it possible to alter multiple kitchens and units from amending a single referenced model. Ideally the way a BIM model is structured should allow for the alterations that are predicted through experience to easily take place. The issue with this approach is to ensure that the correct scheduling is gained from the multiple models. Clash detection also becomes more of an issue.

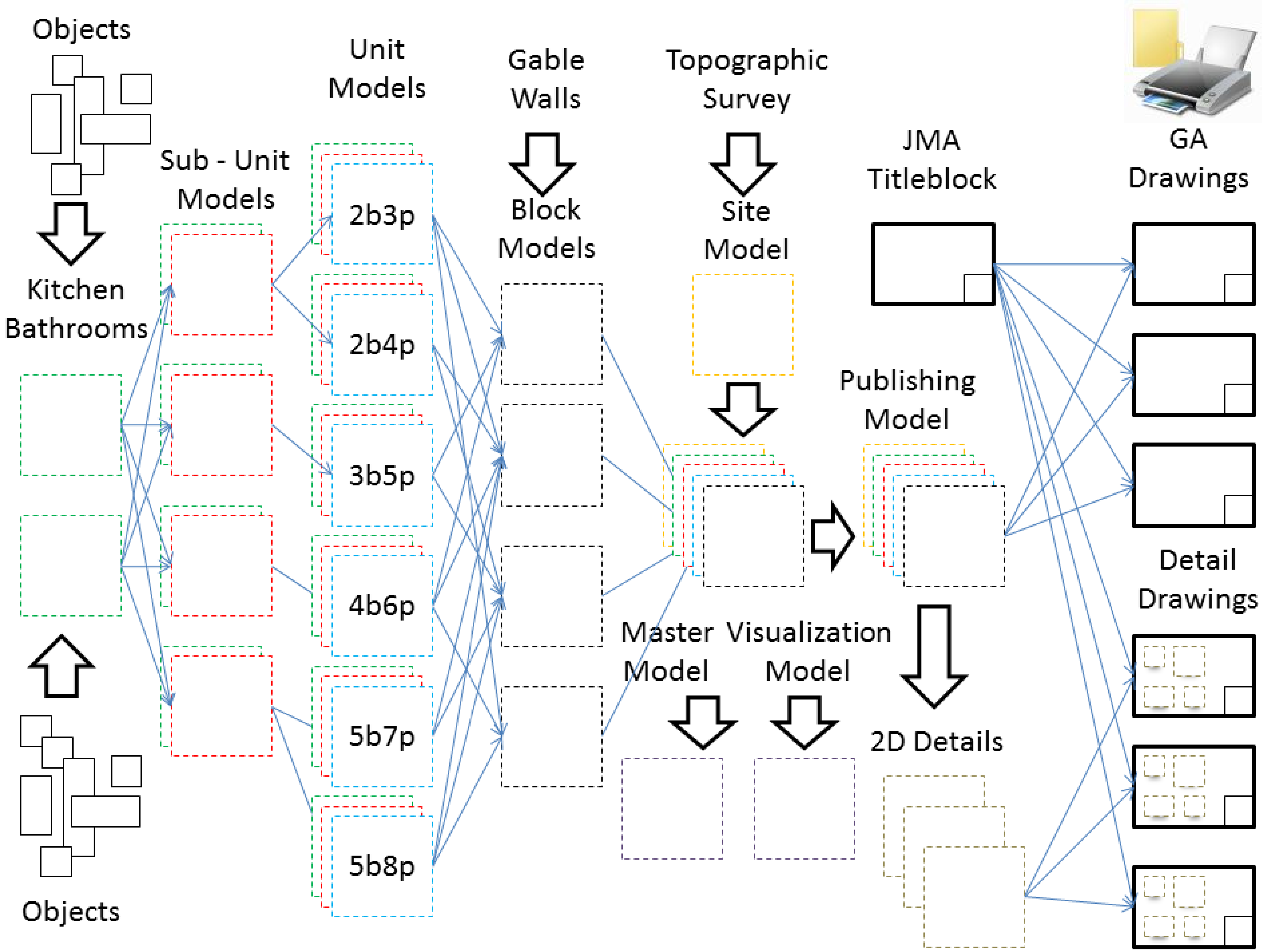


Figure 9.68: Diagram showing the use of Units and sub units to create a BIM master model (Please note this approach maybe suitable in some circumstances and not in others.)

To develop the models for different stages it was decided to utilize the directory structure of the file server (see figure 9.69). This required a system of standardized file naming to be developed.

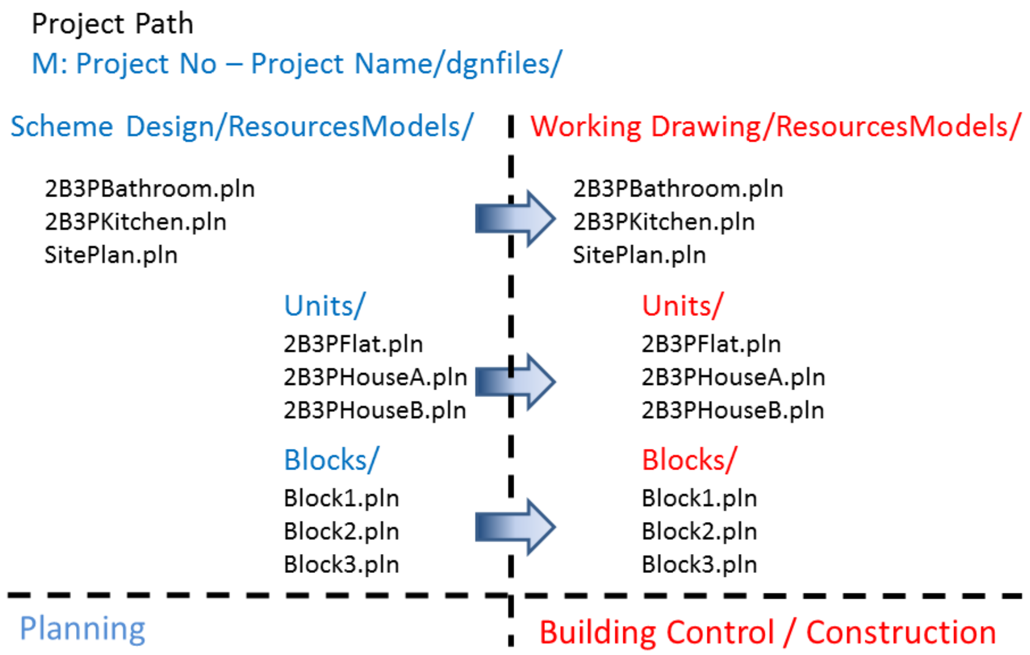


Figure 9.69: Directory Structure of Project BIM Files developed at John McCall Architects

Adopting this approach it was important to decide what was in the unit models and what should be put in the block models (see figure 9.70).

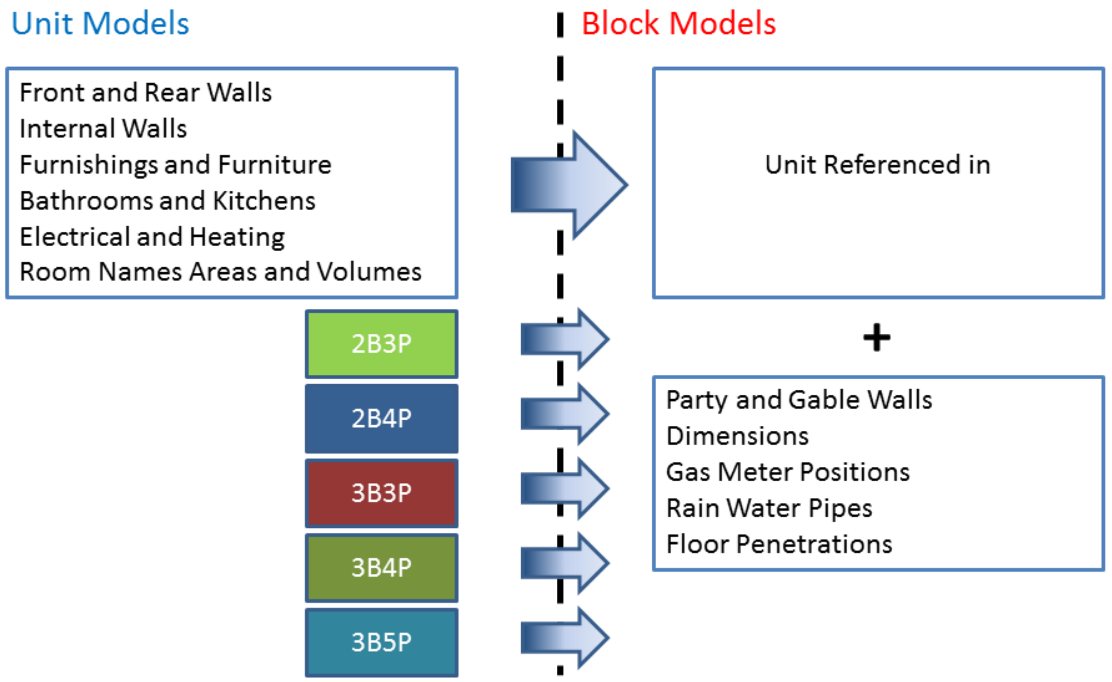


Figure 9.70: Contents of units and block models as used at John McCall Architects

Care has to be taken using these approaches because they are not appropriate in all cases. The way the model is structured for internal use may not be appropriate for when it is issued to external disciplines.

9.13.7 Internal Collaboration

Using one BIM operator on one project does not always give the productivity required. Although using one operator per project may help in consistency. As a result of project demands it was sometimes necessary to have two or more operators working on the same project at the same time. This was the argument put forward to setup a teamworks BIM server which provided addition functionality for collaborative working inside the John McCall Architects organisation. (“Worksharing” offers similar functionality in Revit). The Archicad teamwork server allows the team to manage their combined 3D Model on a shared Host server. At John McCall Architects a standard pc was used as the teamworks server. This proved to be adequate for the task. The Architects ‘check out’ parts of the model to work on. When the Model is ‘checked back in’, the changes are up-dated in the corresponding models. Responding to BIM user demand a teamworks server was set up at John McCall Architects. This was found to be particular useful when novice uses were working on a model. Using the teamswork server it was possible to limit the objects and areas of the model the users had access to (see figure 9.71). A communication system similar to MS messenger is available when using the ArchiCad teamworks server. This enables disparate users working on the same model to communicate with each other using text messages.

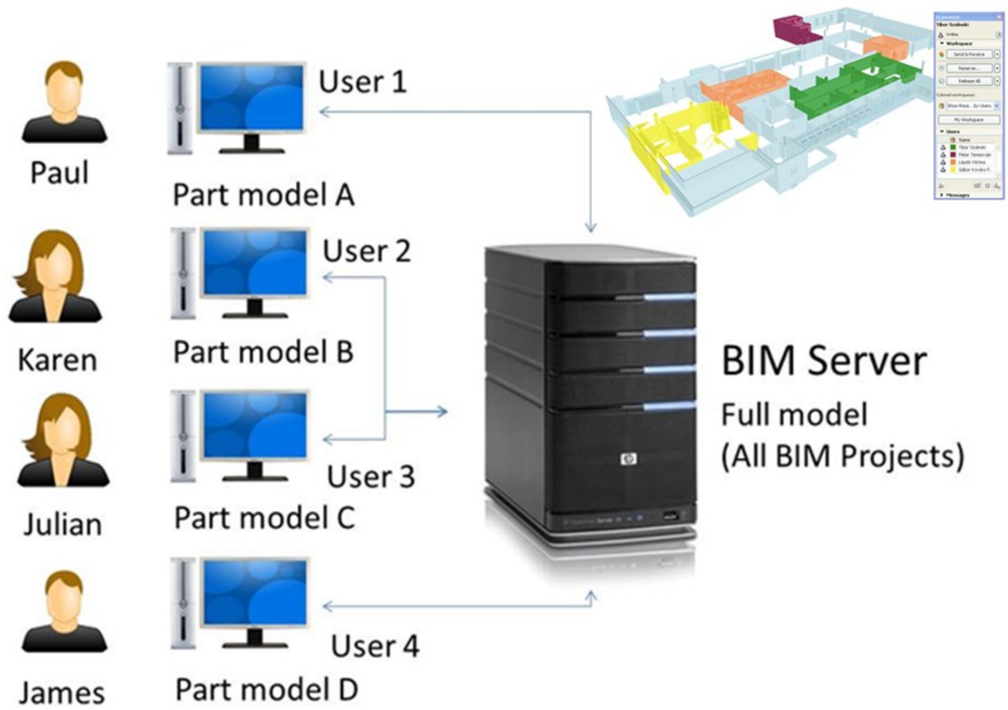


Figure 9.71: Showing model sharing using an ArchiCad teamwork server

The ArchiCad BIM server also can be used to share models with those users working remotely from the office.

9.13.8 Defining the layer structure

Layers are a standard feature using different colours to divide up the contents of many CAD systems. There are British Standards defining layering conventions that are recommended for CAD systems. Layers are a feature of ArchiCad but are not a feature of many other BIM software tools.

Defining the layer structure to be used allowed members of staff to filter the models and generate the range of 2d outputs they required (see figure 9.72 and figure 9.73). It was also decided to make a separate layer for sanitary ware as previously this was on the furniture layer. It was important to be able to filter out all those items not provided by the contractor. An example here was the loose furniture required for funding approval but not provided during construction. Discussion also took place on what naming strategy should be used for the layers. This is important because BIM models may be provide to external disciplines in the form of CAD or dwg files. These disciplines may then use the layers to interrogate and manage the drawings.

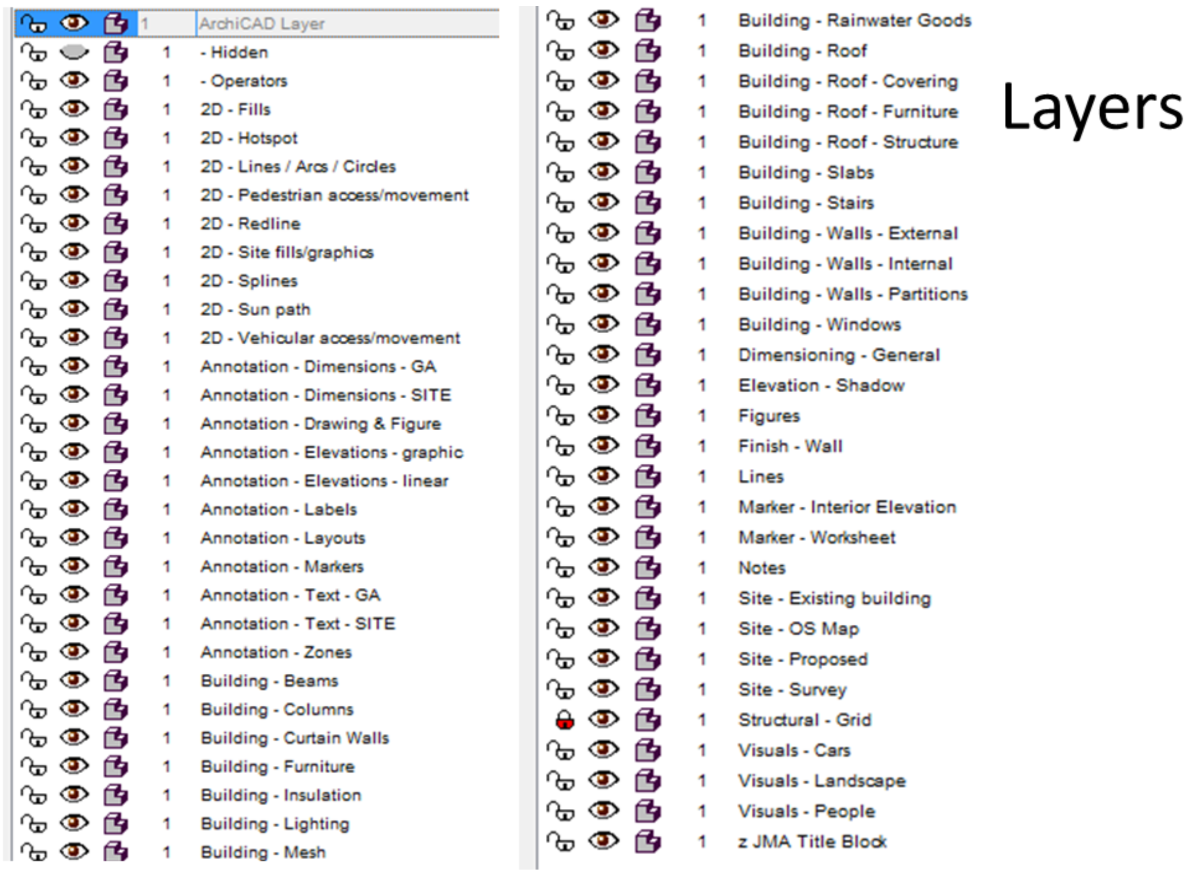


Figure 9.72: Amended ArchiCad 13 layer structure adopted at John McCall Architects

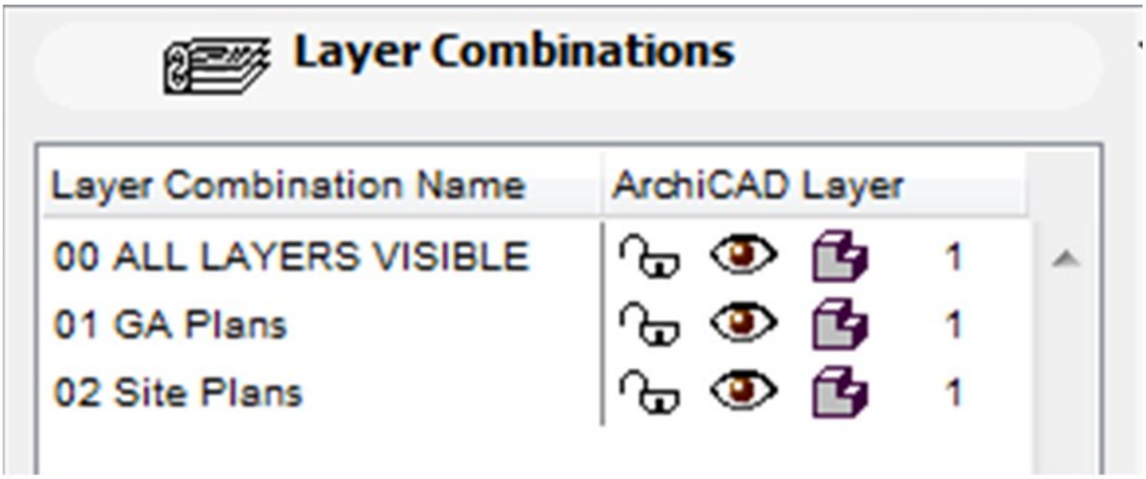


Figure 9.73: Setting up layer combinations specific to certain types of drawings produced in ArchiCad

9.13.9 Object Library Development

The BIM development process can be considered as one of assembling and adding additional data to objects. BIM technologies are "object-based." This means that virtual models must be first created (manually) as geometric objects or imported as pre-designed forms, creating virtual representations of physical spaces and building systems. A major element both making BIM more efficient and providing the results that are required is the development of object libraries.

Documents exist providing advice on the creation of object libraries (Weygant 2011) (Johnson and Fallon 2011). Although these documents do not specifically related to ArchiCad as used at John McCall Architects.

Elements such as walls, roofs and floors are usually designed as composite objects. This means they contain several layers of different materials. This adds to the complexity of these types of objects.

It is possible to consider the tasks of creating data rich objects and the tasks of compiling buildings (BIM models) as two separate tasks. Collection of the information to load into the objects can also be considered as a separate task. The UK government has now provided COBie templates which can be used to assist in the information collection. At John McCall Architects a staff brainstorming session was used to determine the nature of the standard objects to be created. The process of developing objects is explained (see figure 9.74).

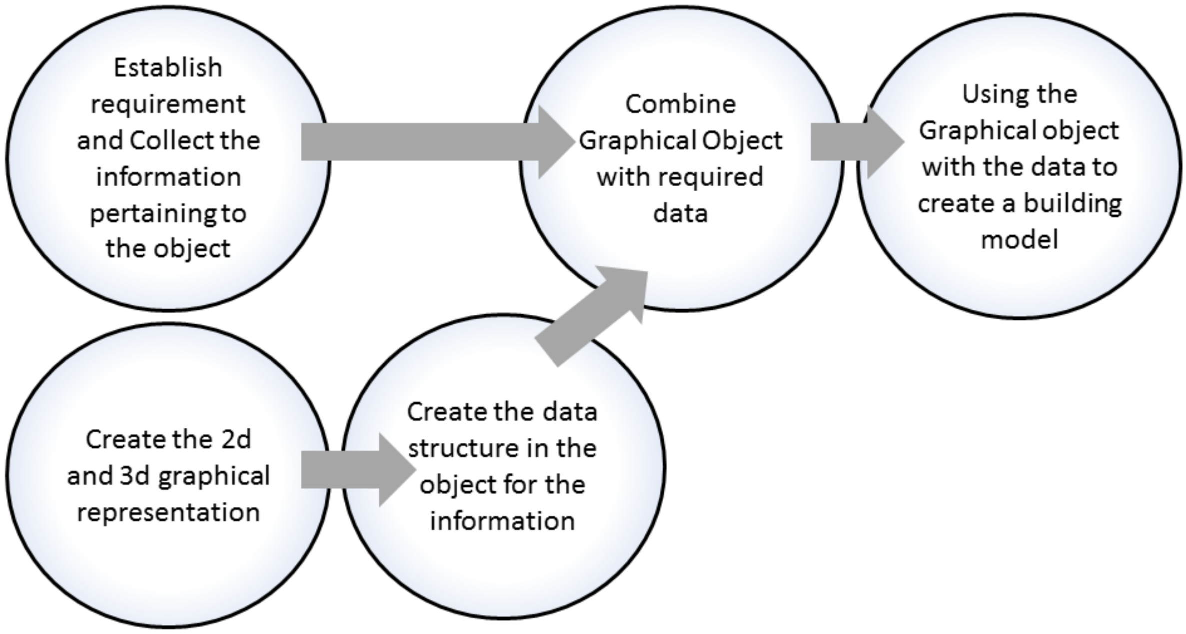
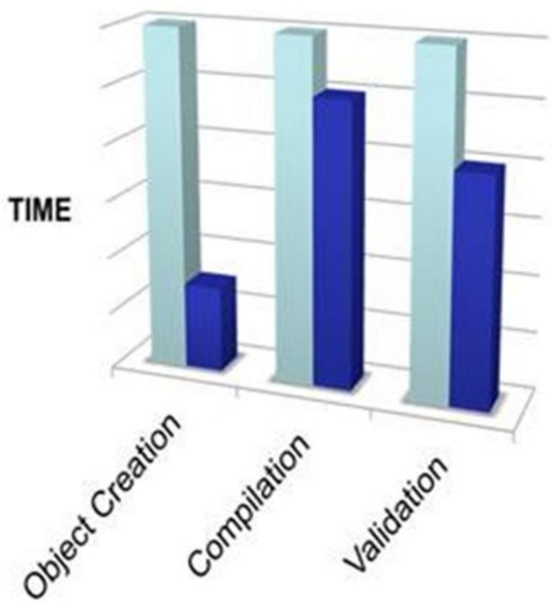


Figure 9.74: Explaining the development of an information rich BIM object

Objects need both 2d and 3d forms generating. The reuse of objects represents a major time saving using BIM technology on future project (see figure 9.75). On a typical project there is likely to be a standard library, a company library and a project library (see figure 9.76). Using existing objects can also provide a method of Quality Control (see figure 9.77). It should be noted that when a version of BIM software changes sometimes the standard object libraries also change. Level of detail is also an issue for BIM objects by this issue was not specifically addressed at John McCall Architects.



1) Pre validated building components

2) Data that is comprehensive and usable in validation tool

3) Ease of amendment of building components

4) Clash detection

5) Data available for interaction with supply chain

Figure 9.75: The potential saving by developing shared object libraries

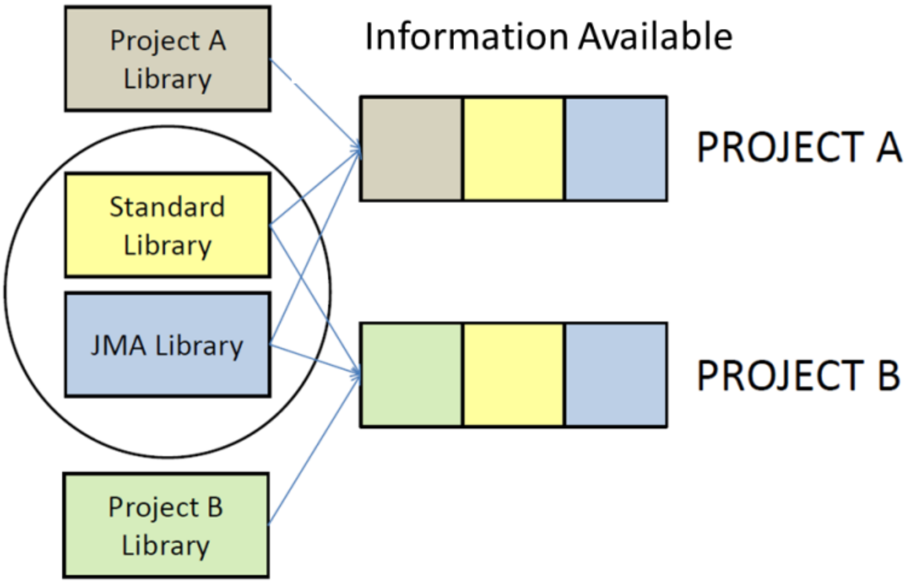


Figure 9.76: Use of the standard library, the company library and a custom project library to provide objects for an individual project, a system used at John McCall Architects

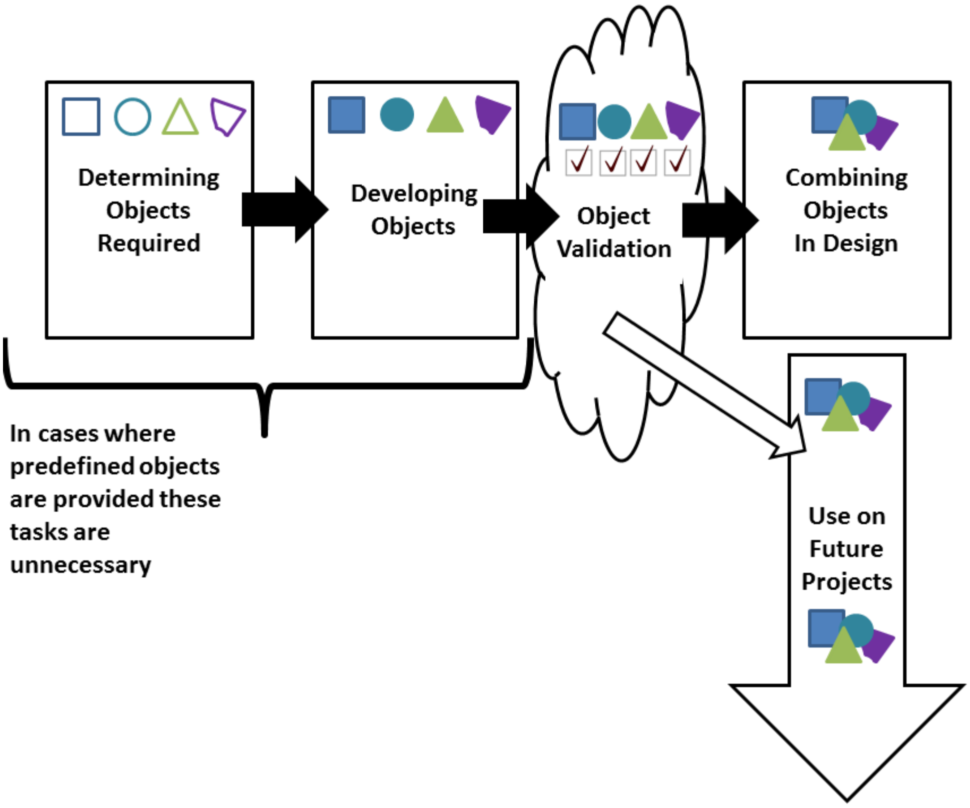


Figure 9.77: The process of developing a BIM model and time savings possible on repeat BIM projects

Although objects can be imported from other BIM authoring tools rigorous test are required to validate imported objects. Therefore currently this is not a recommended method to generate object libraries.

When developing objects it important to consider how the objects are to look at coarse medium and fine detail (see figure 9.78).

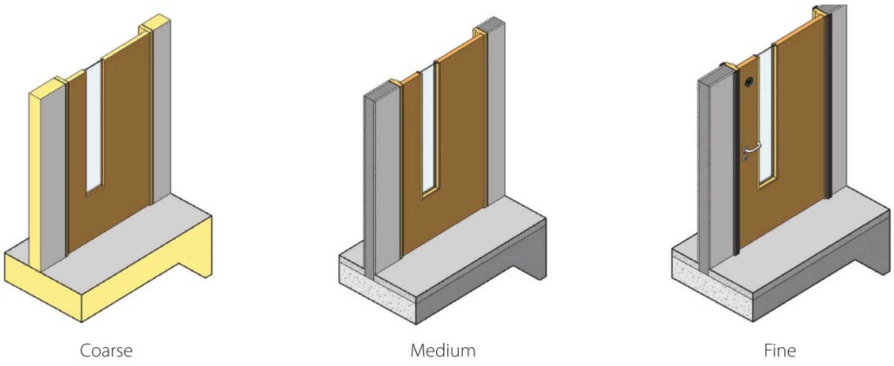


Figure 9.78: Examples of Course, Medium and Fine object views

A specific library was created of Life Time Homes compliant objects (furniture) for John McCall Architects (see figure 9.79).

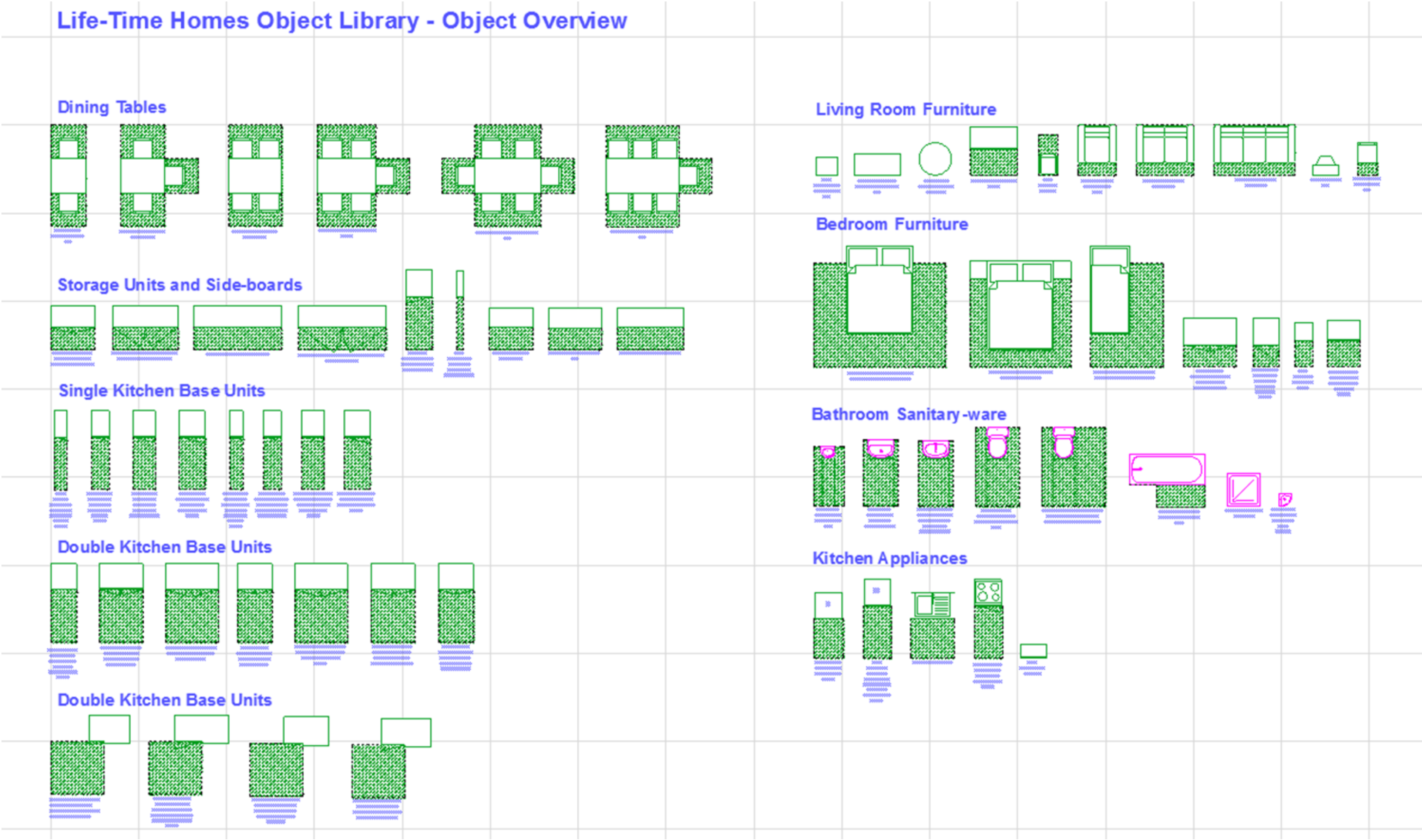


Figure 9.79: An example of a BIM library of furniture developed to comply with lifetime home requirements

One feature of ArchiCad is that it is able to show the object but also the working area around the object. This is a requirement of several housing funding submissions. Although ideally all types of objects should be provided at the outset of design to facilitate the development process. Additional object libraries were in development at the end of the research period.

Where it is necessary to provide data attached to the objects ArchiCad provides recommended IFC fields and PSets (Property sets) where the data maybe added (see figure 9.80).

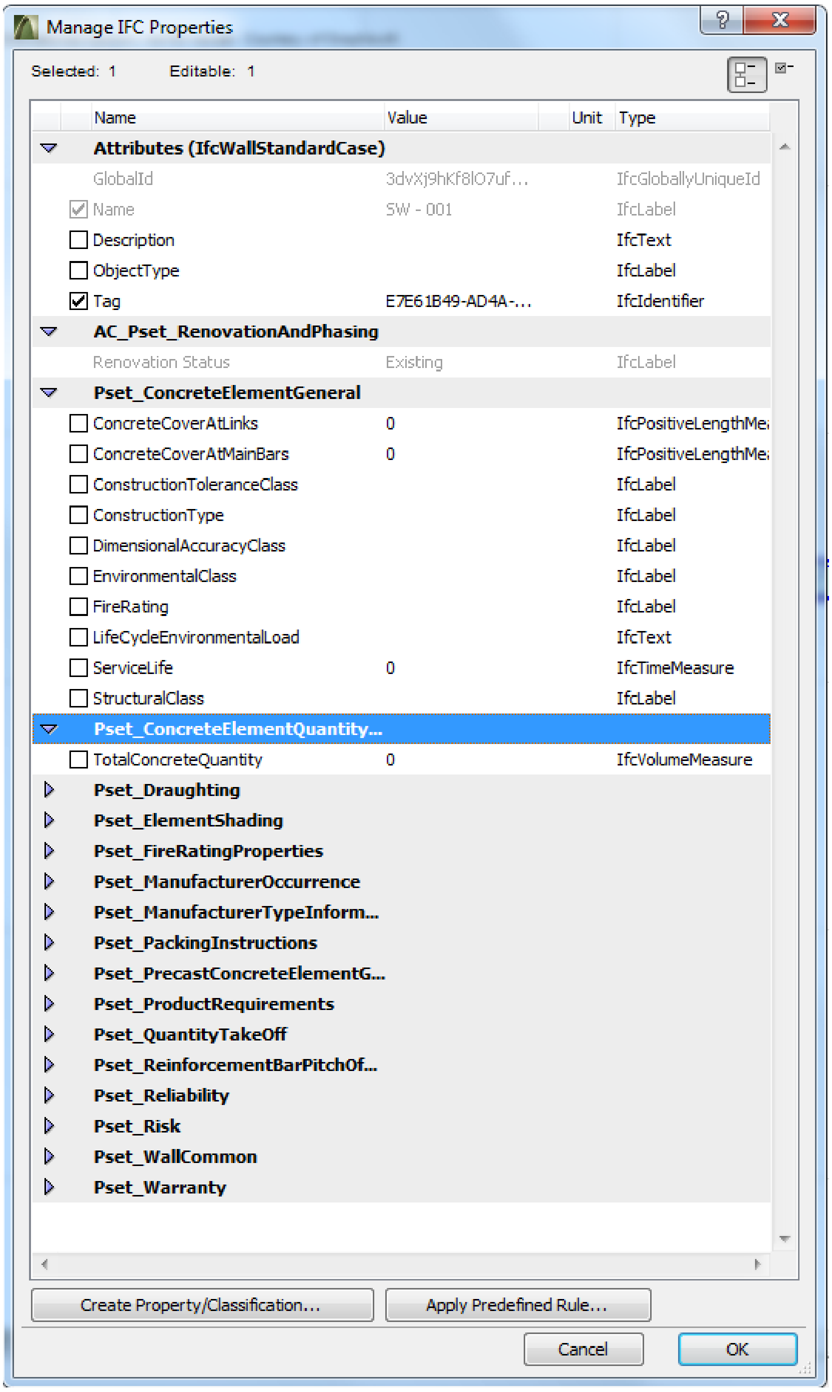


Figure 9.80: The ArchiCad object menu for inputting IFC data into objects

Several options exist as ways of building up an object library. Objects are likely to be provided with the BIM authoring tools also objects maybe downloaded from the internet. There are a number of online catalogues that store a large range of BIM objects in various formats these include:

- SMARTBIM – hosting and design service for BIM objects
- bimobject – hosting and design service for BIM objects
- NBS National BIM Library- hosting and design service for BIM objects (see figure 9.81)
- BIMSTOP - hosting and design service for BIM objects
- Polantis – hosting and design service for BIM and 3CT objects
- BIMstore.co.uk
- ARCAT

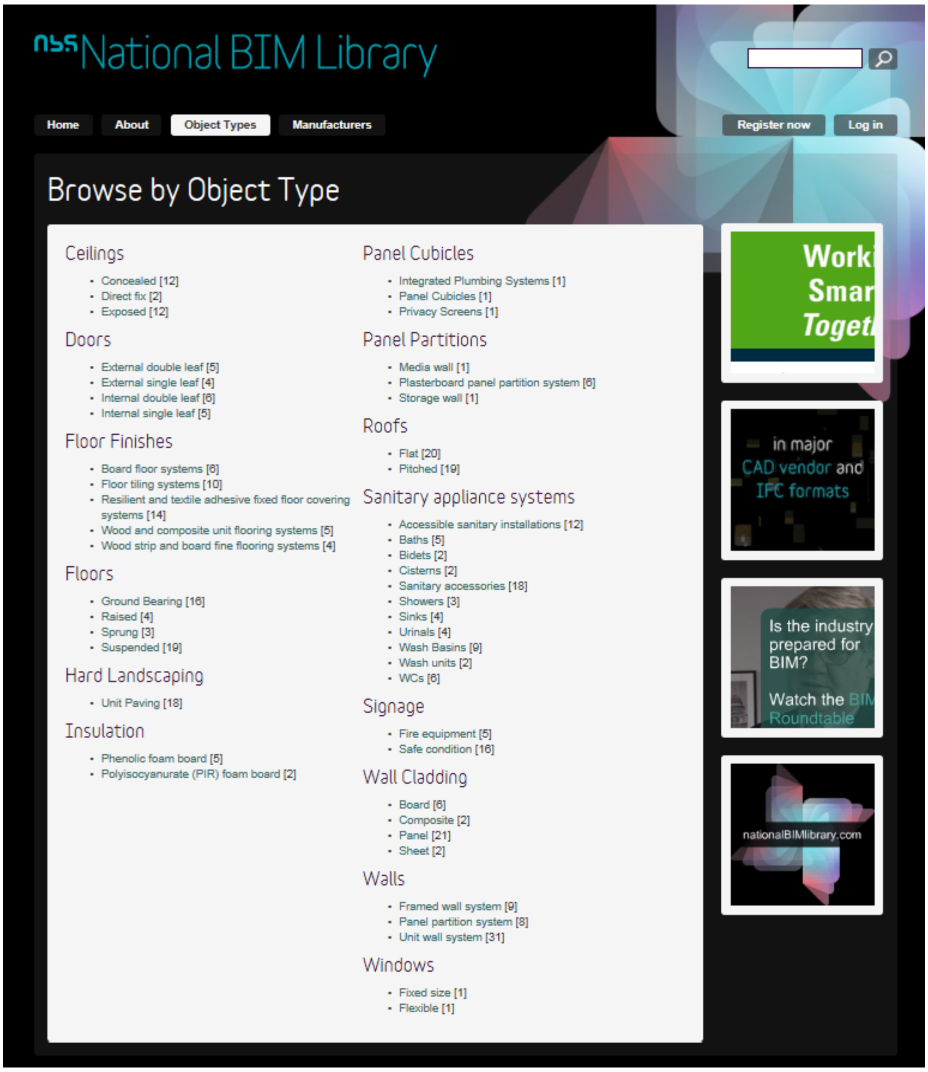


Figure 9.81: A screen shot taken of the NBS National BIM Library which now provides a range of BIM object suitable for use in a range of BIM Tools (NBS 2012)

Most of these object libraries were not available at the time the case study research was undertaken at John McCall Architects. Also no warranty of being fit for purpose is provided with the objects provided. It is also possible to outsource library development. A validation has the take place before it is appropriate for imported objects to be used. A meeting was held at John McCall Architects to decide the libraries that should be developed (see figure 9.82).

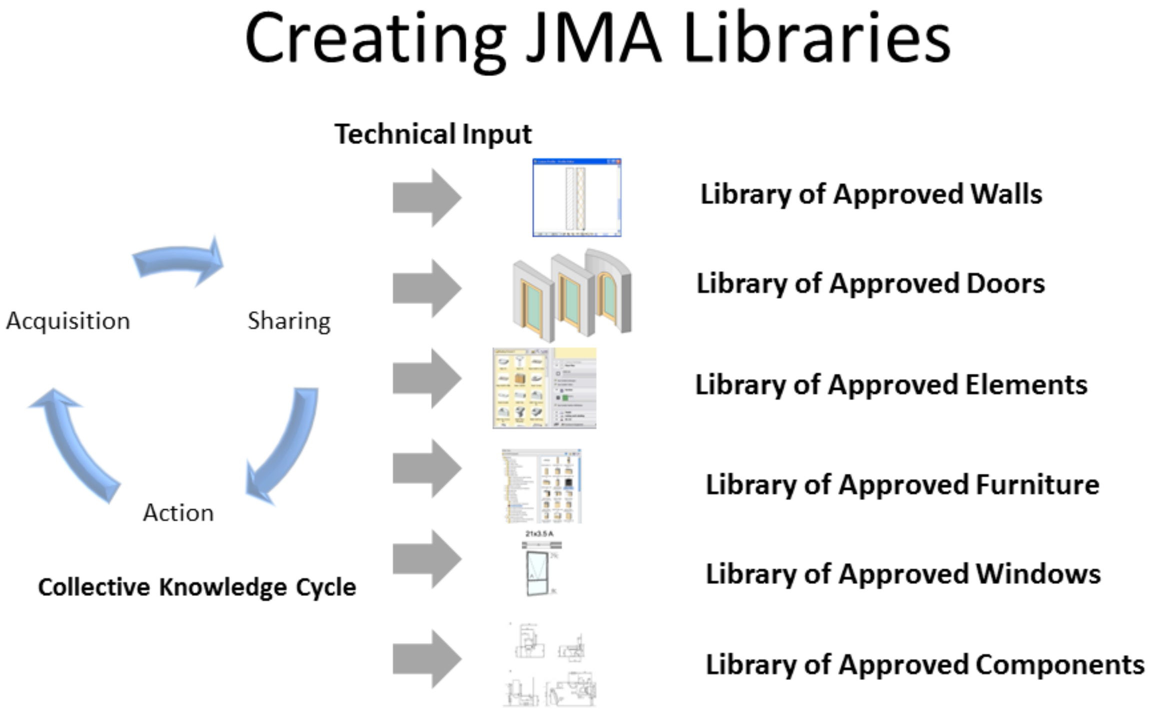


Figure 9.82: Part of a presentation given to discuss the object libraries that should be created at John McCall Architects

None of the external sources identified is likely to provide objects aligned or validated against specific needs. Structuring and creation of an object should be determined by the data output from the object required. The best source of objects is using objects from previous projects that have been through a “fit for purpose” validation processes. At project inception ideally a list of objects that will be necessary for that project should be generated. Once the list of required objects has been completed, the actual model objects must be gathered and organized to form the project object library.

When selecting model objects for the common object library, they must be reviewed to verify that their geometric content (3D model geometry) and non-geometric content (data properties) are a sufficient representation of the real world object.

After the model objects have been selected for the common object library, it is necessary to extend their property sets to include data fields for the required COBie properties.

If possible the first step in developing the common object library is to review the existing models of each building to identify all object types that will be required to recreate each model under a common standard. The exercise was started but not completed at John McCall Architects.

Objects can be produced at different levels of development, but there is argument that the most developed objects available should always be used eliminating the amount of time spent later in object substitution.

There are several issues affecting libraries. These are:

- Compliance with the Building regulations
- Matching the requirements for code for sustainability
- Usability and aesthetics
- Notes and Specification clauses available
- Cost and life cycle costs
- Ease of construction
- COBie compliance

As a result of these changing criteria objects and object libraries need to be continually reviewed and if necessary updated. All of these issues should form the basis of BIM object review when it is undertaken when it is undertaken. An object revision control system should also be put into place. To use objects effectively a library structure must be implemented and maintained. To do this a BIM library manager needs to be appointed.

Here the development of object libraries has been discussed. Development of standard details 2d or 3d should also be considered (see figure 9.83 and 9.84). At John McCall Architects many of the standard details that previously resided in Microstation were brought over into a new Archicad shared standard detail library.

Object Development

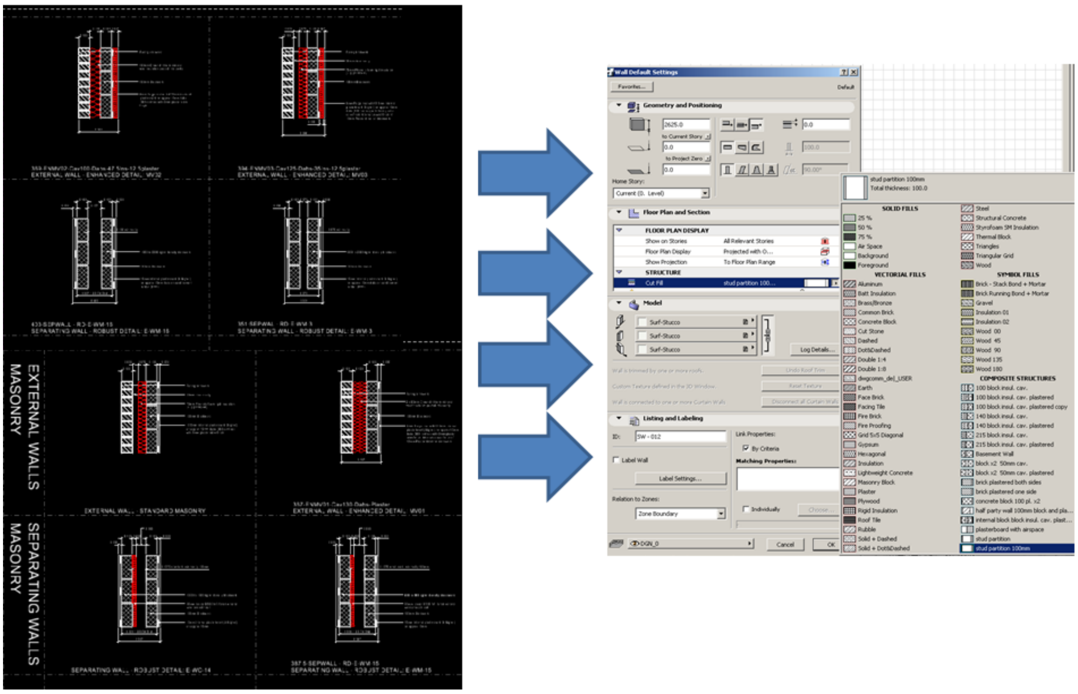
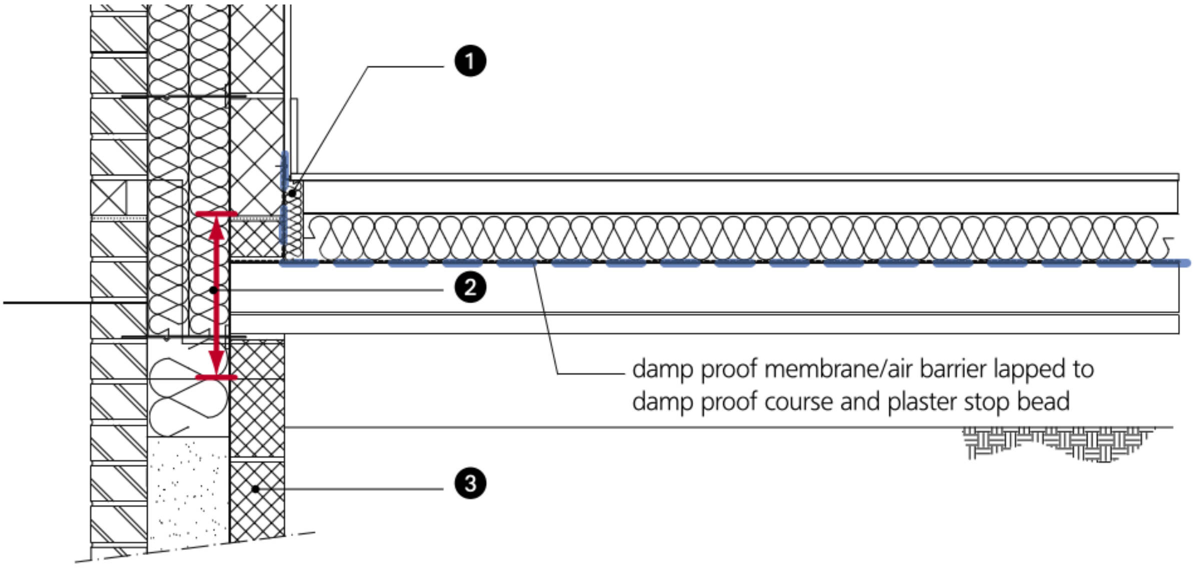


Figure 9.83: Showing how traditional CAD details where developed as object or component types within the BIM authoring tool



1. Minimum thermal resistance of the perimeter insulation upstand to achieve 1.52 m^2K/W.
2. Overlap of insulation to be 300 mm minimum.
3. Blockwork of maximum 0.19 W/mK dry thermal conductivity.

Figure 9.84: Enhanced details from the energy savings trust

9.14 Validation Methods

Validation of BIM models is a developing field. At John McCall Architect design review and technical review procedures were developed checking the model by visual means (see figure 9.85).

Design Review Checklist

Project Number and Name:			
Reviewer	Project Architect	Date of Review	Action Complete Date

1.0 Pre Review
1.1 Project Architect to advise Project Director that a design review is required
1.2 Project Director to fix the review date with the Project Architect and appoint review chair
1.3 Project Architect to make necessary arrangements, and inform participants
1.4 Project Architect to establish content of proposed review and agree content with the review chair

2.0 Contents

Item	Observation			Action
1) Definition of the site and surroundings	Topographical Survey Deed Plan Decant schedule	- - - -		
2) Client requirements check	Requirements Programme Scope	- - -		
3) Functional Relationships and Occupancy				
4) Building Areas and Volumes				
5) Structure Resolved				
6) Principle Building Elements defined				
7) Architectural Design	Urban Design Analysis Relationship to Context Aesthetics Conformity and Contrast Orientation, prospect and aspect			
8) Specification, finishes and colours				
9) Room Layouts				
10) Interfaces	Vehicles - Circulations Services Existing Structures – Party Walls			
11) Buildability site logistics				
12)Other consultants				
13) Project Special Aspects				
14) Statutory and code issues	Fire Vehicular Access Daylighting Overlooking			
15) CDM				
16) Code for Sustainable Homes	Environmental Strategy Energy Assessment Material Selection			

4.00 Post Review
4.01 Chairman to distribute review findings to those present
4.02 Is there a time scale for remedial actions?
4.03 Design review actions to be resolved by project architect and signed off.
4.04 Project Director to review, make necessary comments and sign off design review
4.05 Is further Review required?

M:\0016-KTP Data\PaulC\Design Review Table.doc

Figure 9.85: Design Review Checklist developed at John McCall Architects to visually check designs

Model checking tools such as Solibri Model Checker and Navisworks exist for checking models. Demonstration of these tools were given at John McCall Architects. In time these tools maybe used at John McCall Architects. Additional work needs to be undertaken in this area to develop appropriate procedures.

9.15 Setting up a BIM group

Setting up a group within the organisation to be the focus of BIM ideas and to move the adoption forward is an important element of BIM adoption. At John McCall Architects a group was set up to meet once a month to focus on BIM matters. This proved to be an appropriate vehicle for reviewing and moving BIM matters forward.

9.16 Quality Procedures

John McCall Architects quality procedures reside on the company intranet (see figure 9.86).

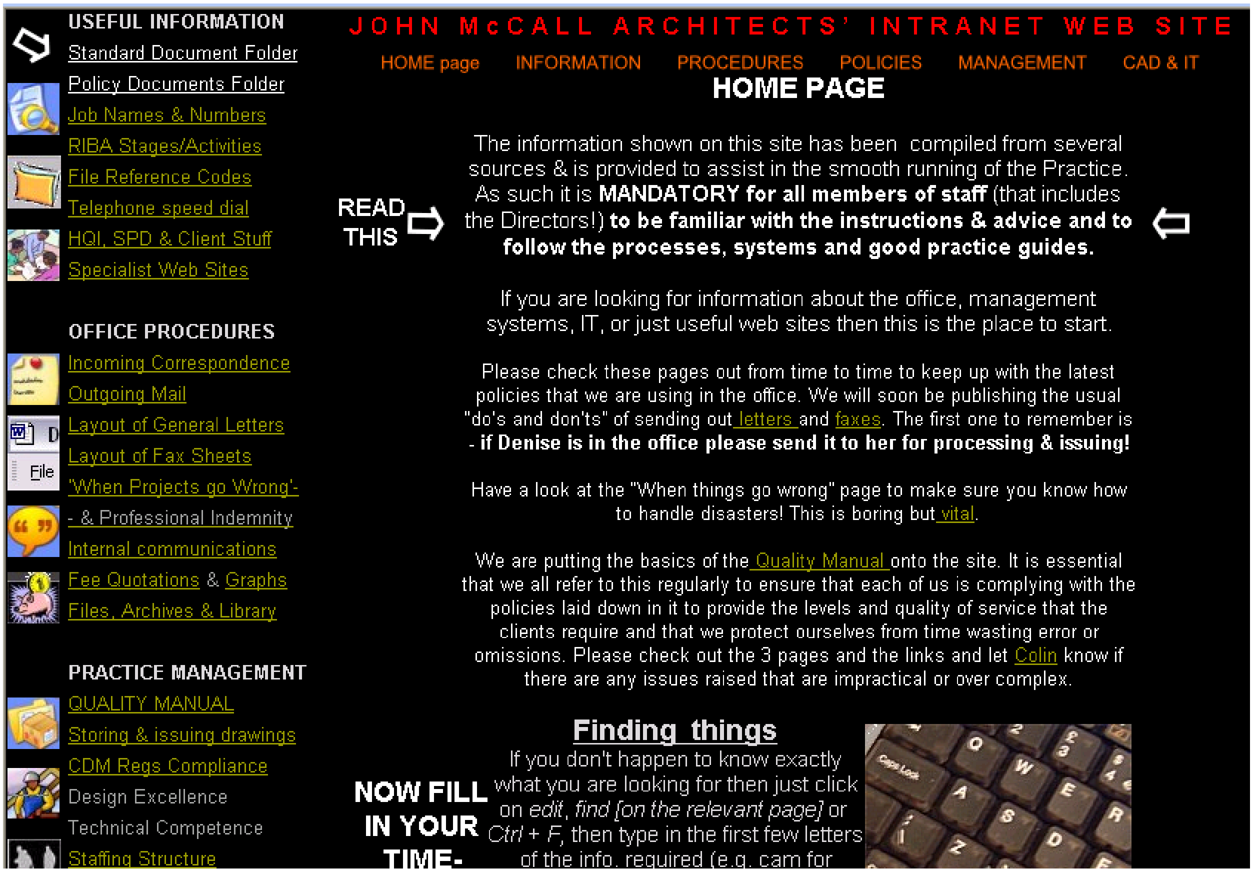


Figure 9.86: Screen shot of the John McCall Architects quality system located on the companies intranet

During the period of the research it was not possible to integrate the BIM procedures with the quality procedure. This is another activity that is recommended to should take place as part of a BIM implementation.

9.17 Definition of BIM roles and responsibilities

To use the technology effectively a new type of BIM management hierarchy and BIM operative is required. The decision processes when constructing a BIM model as opposed to using CAD tend to be more intense. That means that BIM operatives with multiple skills and areas of knowledge are required (see figure 9.87).

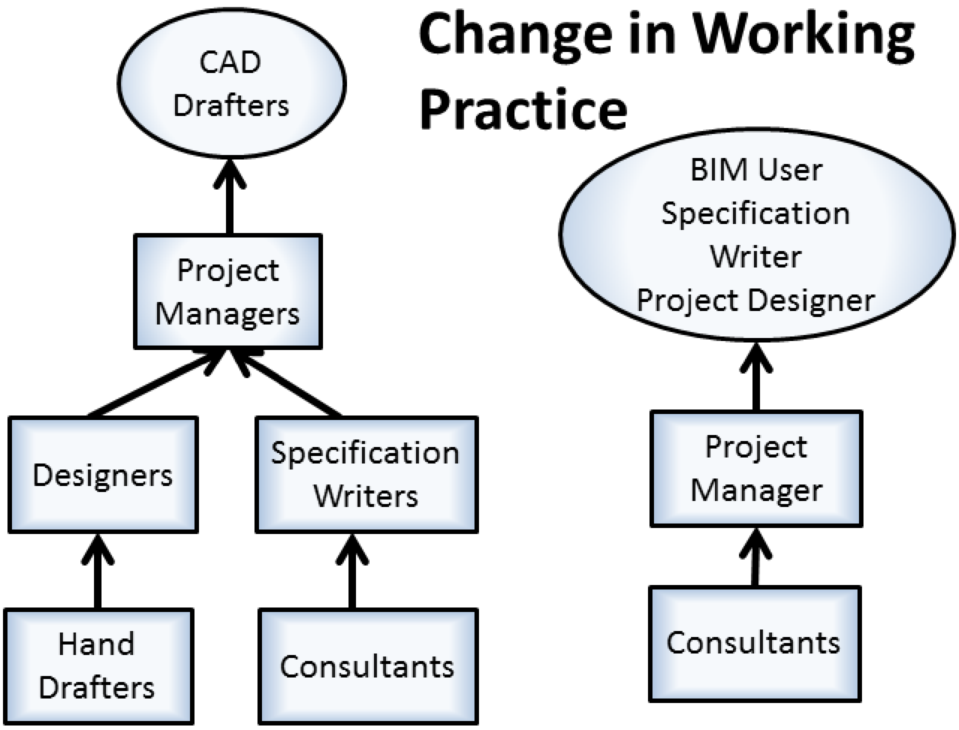


Figure 9.87: Using multi skilled operatives when using BIM

To use BIM new roles and responsibilities need to be clearly defined. Both project and discipline related positions need to be created. Suggested roles are as follows:

A) Design Team BIM Manager

B) Technical Discipline Lead BIM Coordinators (each discipline and trade should have its own BIM coordinator)

C) Construction BIM Manager

D) BIM operators

BIM roles were not defined at John McCall Architects although it is recommended that they are. Reference BIM roles maybe found in “The VA BIM guide”. The CIC (2013) has recently defined a new role the role of the information manager.

9.18 Developing Interoperability

The BIM adoption at John McCall Architects only involved one organisation and predominantly one domain therefore there was little need to develop interoperability (see figure 9.88).

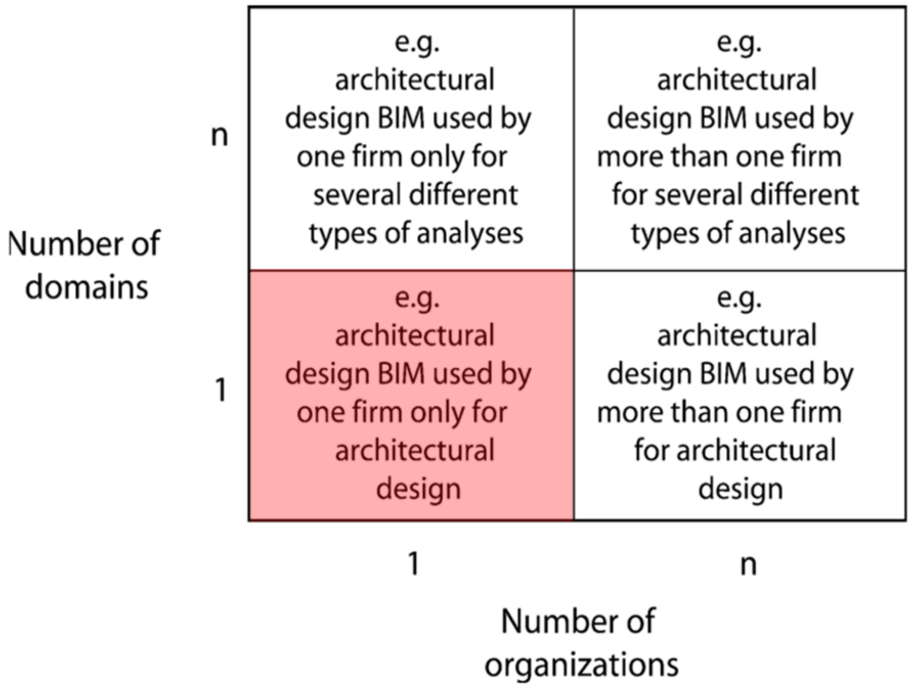


Figure 9.88: The type of BIM adoption at John McCall Architects (adapted from Fox and Hietenen 2005)

“Interoperability, like openness is something we generally think of as a “good thing” in the context of information communication technologies (ICT’s). One of the reasons why we tend to like interoperability is that we believe it leads to innovation, as well as other positive things like customer choice, ease of use, and competition.”

Gasser and Palfrey 2007

When implementing BIM it may take place to develop a stand-alone system (lonely BIM) or it may be developed as part of an integrated interoperable system. Where interoperability is required or mandated by government requirement additional elements are need to be in place as part of the BIM implementation. Here we highlight the additional elements to assist others to achieve the interoperability they require.

The UK government requirement currently is to provide five COBie data drops. COBie data is interoperable with the Maximo computerised maintenance management system (Nesbit 2008). Although many current CAFM (computerised aided facilities management) systems fail currently to be interoperable with COBie. Many parts of COBie are discretionary in nature and consideration and agreement is needed on what needs to be provided. The interoperability requirement for the other disciplines in the development process needs to be worked out. To achieve this goal analysis, process mapping and documentation of informational exchange are all required. These should all then be formalized into a BIM execution plan. Once the data exchanges have been agreed it must be decided on what methodology is to be adopted to achieve the exchange. There are many file formats and methods where by interoperability can be achieved.

Once the method of transfer has been agreed, the data needs to be collected and input into the primary software. The process is different depending on the BIM software used. Once the data is input into the primary source the interoperability needs to be validated. Several tools are available to assist with this validation. An example of the data mapping necessary is shown (see figure 9.89).

Understanding and Mapping Input Data

	Thermal Properties Opaque Materials						Thermal Properties Window Materials				Surface Properties			Sound Absorption	
Elements	U-values	Specific admittance	Thermal lag	Thermal decrement	Solar absorption	Colour reflection	Shading coefficients	Alternating solar gains	Refractive indexes	Transparency	Emissivity	Specularity	Roughness	sound absorption coefficients	Noise ratings (NR).
	(W/m2K)	(Y:W/m2K)	(Lag: hrs)	(Decr: 0-1)	(abs:0-1)		(SC: 0-1)	(SG: 0-1)	(RI)	(Trans: 0-1)					
Voids	x	x	x	x	x					x	x	x	x	x	
Roofs	x	x	x	x	x	x				x	x	x	x	x	
Floors	x	x	x	x	x	x				x	x	x	x	x	
Ceilings	x	x	x	x	x	x				x	x	x	x	x	
Walls	x	x	x	x	x	x				x	x	x	x	x	
Partitions	x	x	x	x	x	x				x	x	x	x	x	
Windows	x	x				(x)	x	x	x	x	(x)	x	x	x	
Panels	x	x	x	x	x	x					x	x			
Points										x					
Solar coll.						x			x	x	x				

X Nessesary values for

X Values there is not needed for normal simulations

Necessary values for thermal simulation

Useful values for solar and reflections simulation

Needed for normal simulations expect simple shadow visualazations

Figure 9.89: An example of data mapping (Levring 2011)

The CIC (2013) has issued the Building Information model (BIM) protocol which provides recommendations concerning interoperability.

Modelling Collaborative Systems (MCS) are developing with capabilities for model content management, model content creation, model content viewing and reporting and system administration (Shafig 2013) (see figure 9.90). Such system offer an alternative to direct interoperable exchange between discipline related applications. When developing methods of collaboratively using BIM such systems should be considered.

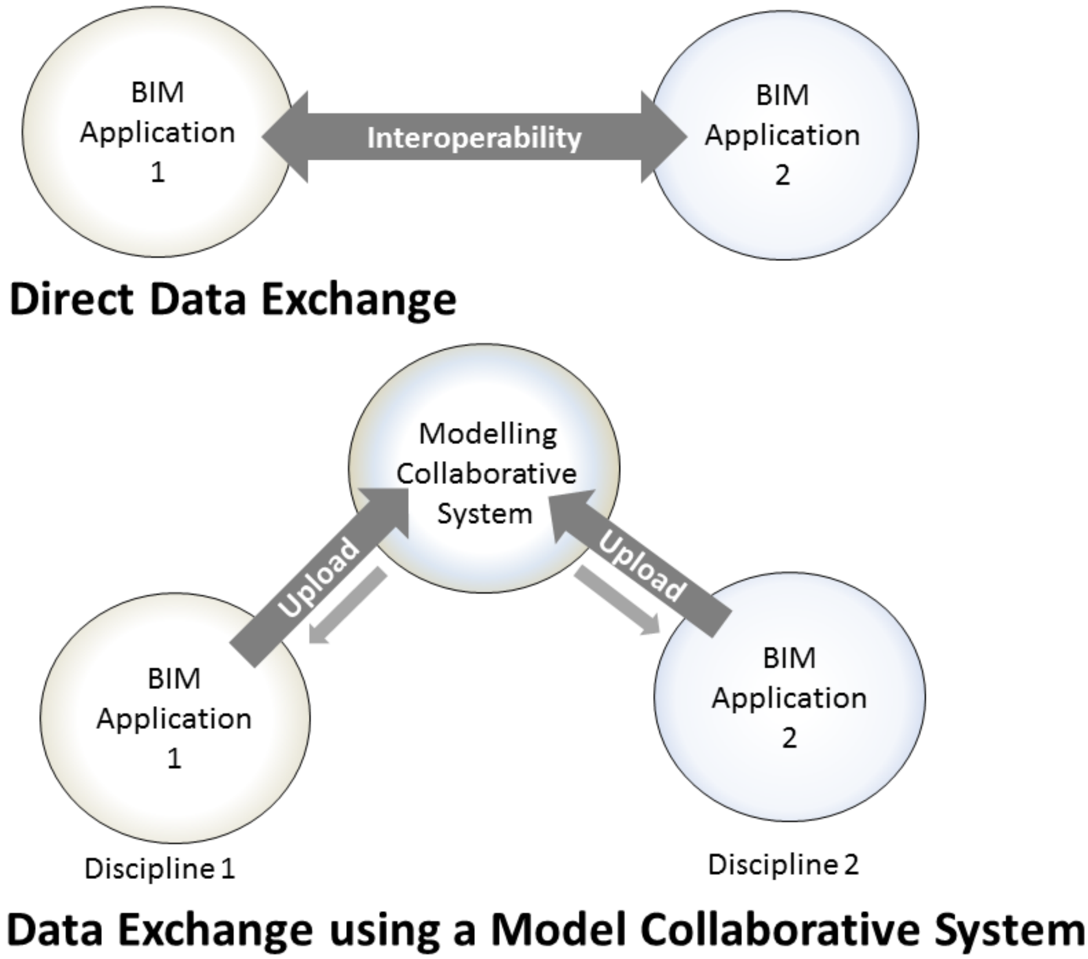


Figure 9.90: Show direct data exchange and data upload to a modelling collaborative system

9.19 Ensuring the necessary insurances and indemnity is in place

Taking insurance and legal advice is advised at this stage if not before is recommended. Where advice is given it may be necessary to amend the companies BIM strategy as requested.

The taxonomy of legal limitations in BIM is provided here (see figure 9.91). But this in no way is meant to substitute for the need to seek out appropriate legal advice. Architects need to become more vigilant in obtaining and filtering information this is a result of the increasingly litigious nature of the building industry (Race 2012). At John McCall Architects a letter was sent to the insurance company indicating the changes taking place and asking for these to be included within the PI (Professional Indemnity) insurance.

Legal Issues with BIM		
	Obligations	- New set of skills required – how comparative are gains made on skilling to benefit of project goals - Integration services – New order? - Services Framework – Hardware software, who pays, who benefits?
	Duty of Care	- Model Ownership (integrated system v fragmented system) - Exposure of Trade Information) - Copyright issues - Authorization of E-documents
	Considerations	- Standard remuneration is not defined yet for BIM projects - New sets of responsibilities
	Tools	- Interoperability - Standardization - Value integration / intrinsic conflicts - Commitment to IT innovation and deployment of same in multidisciplinary context
	Cyber Security	- Snooping - Theft - Virus and Worms - Hacking
	Jurisdiction	- Indefatigability of e-doc as evidence - E-contracts , jurisdiction, virtual enterprise, recognition, taxation laws, government policies - Disclaimer clauses - Error emanating from other contributors

Figure 9.91: A taxonomy of legal limitations in BIM (Turk Ž 2011)

Recently the “Best Practice guide for professional indemnity insurance when using BIM models” has been published by CIC / BIM INS (2013). This provides advice on insurance issues.

9.20 Undertaking live projects - Introduction

The requirement here is to manage the process and the use of BIM to ensure the deliverables are produced on time, using the allocated resources and to the prescribed standard. This involves controlling work assignments, dealing with problems and issues and managing product delivery.

Before commencing the live BIM projects a meeting was arranged to determine the following factors:

1) What are we intending to do?
2) What functionality do we intend to demonstrate?
3) What do we intend to issue to other disciplines?
4) To confirm the software and hardware provision?

5) To confirm if software training by external parties is to take place at this time?
6) To discuss the level of detail to be provided
7) To discuss if a group presentation to the project team is necessary and how it should take place?

9.20.1 MillaChip Phase 3

The first “live” project to be created using BIM tools was Millachip Phase 3. This was a series of bungalows for elderly residents. The project way located beside an earlier sheltered housing development.

The user selected to undertake this project was already an experience BIM users having previously used Allplan (another BIM tool). Undertaking the Millachip Phase 3 project using BIM was assisted by the fact that the plans for the project had already been drafted in Microstation. Again the project was developed in reduced time scales when compared with CAD production.

An important decision was would elements to be placed in the model and what information was to be provided as part of 2d details. Many of these details had already been created and were imported from Microstation into the ArchiCad information set.

Also alterations where necessary were produced in reduced time scales. Undertaking this project standard drawing notes were developed. At John McCall Architects many of the lessons learnt from this project were also input into the BIM manual and the BIM training.

The roof making tools was also used for the first time on this project. Standard 2d sheets were also set up generated from the 3d model (see figure 9.92 and 9.93). What should be pointed out here that the plans in both these drawings illustrated come from the same 3d model.

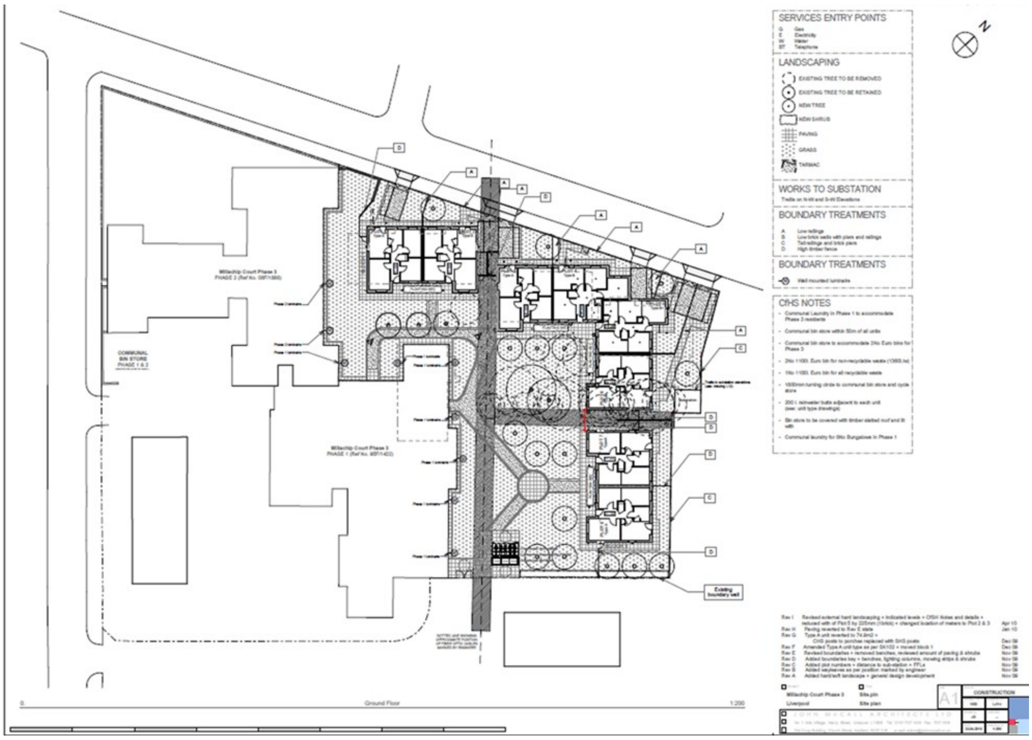


Figure 9.92: The site plan of Millachip Phase 3 generated from a BIM model

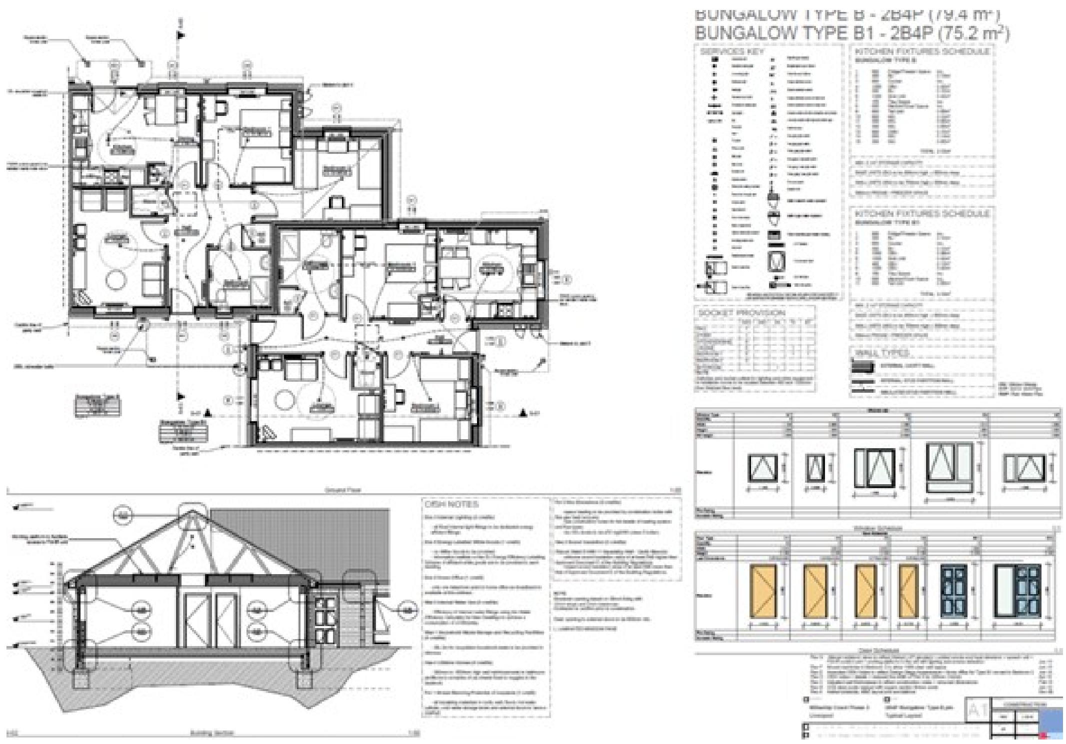


Figure 9.93: Drawings produced on the Millachip Phase 3 project

The standard reference keys were developed as part of this project (see figure 9.94). These were subsequently reused on later projects. Automated title blocks were also developed.

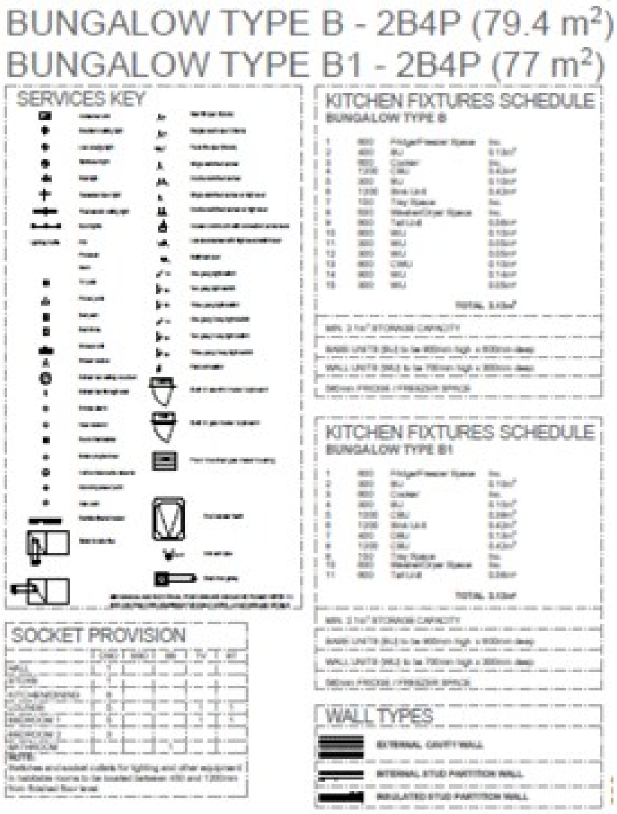


Figure 9.94:The standard object key developed as part of the Millechip Phase 3 project

A particularly useful capability using BIM on Millachip phase 3 project was the instantaneous ability to check the area of the designs as the design developed (see figure 9.95).

Rooms by stories							20/11/2009
Story		**Room**		**R. Height**	**Perimeter**	**Wall surf.**	**Measured Area**
Ground Floor							
	001	Bungalow Type A		2.40 m	36.36 m	26.38 m²	74.77 m²
	004	Kitchen/Dining		2.40 m	17.86 m	19.41 m²	16.87 m²
	005	Bedroom 1		2.40 m	14.93 m	18.00 m²	12.83 m²
	006	Bathroom		2.40 m	9.87 m	13.16 m²	5.54 m²
	009	Bedroom 2		2.40 m	14.03 m	13.26 m²	11.62 m²
	010	Hall		2.40 m	15.56 m	22.23 m²	8.45 m²
	011	Lounge		2.40 m	14.84 m	15.26 m²	13.64 m²
	012	A/C		2.40 m	2.83 m	4.21 m²	0.39 m²
	013	Store		2.40 m	4.87 m	7.25 m²	1.45 m²
	014	Boiler		2.40 m	2.81 m	3.79 m²	0.48 m²
Ground Floor		**total**			**133.96 m**	**142.94 m²**	**146.05 m²**
For all stories		**total**			**133.96 m**	**142.94 m²**	**146.05 m²**

Figure 9.95: Areas for the Millachip phase 3 project automatically generated from the model

Using the 3d BIM model proved particularly useful as a method to resolve 3d details (see figure 9.96 and 9.97).

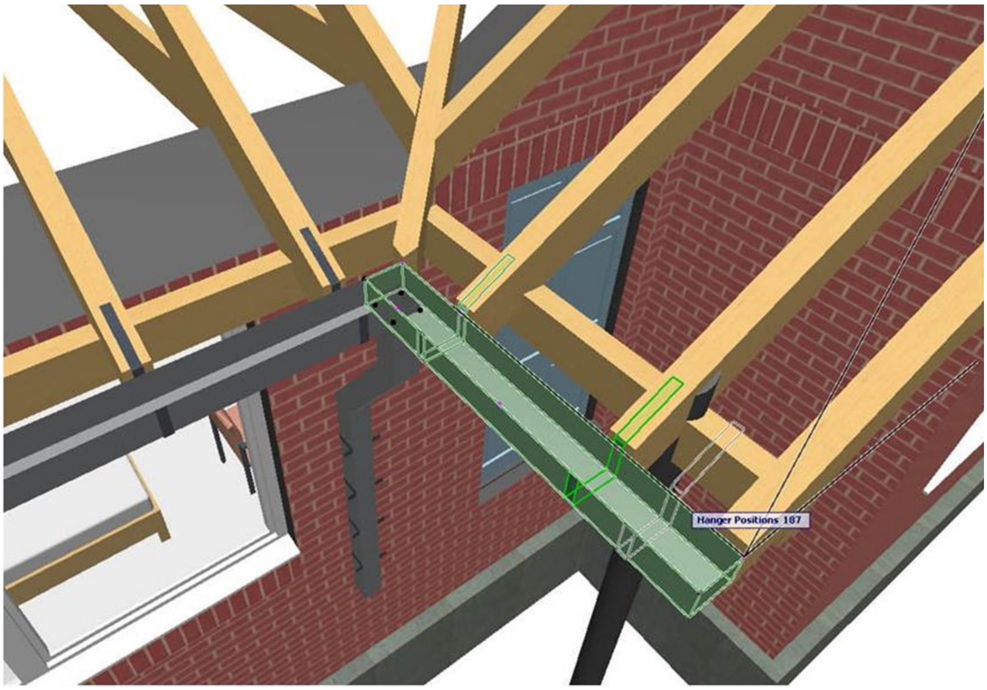


Figure 9.96: The 3d BIM model being used to help resolve detailing issues on the Millachip Phase 3 project

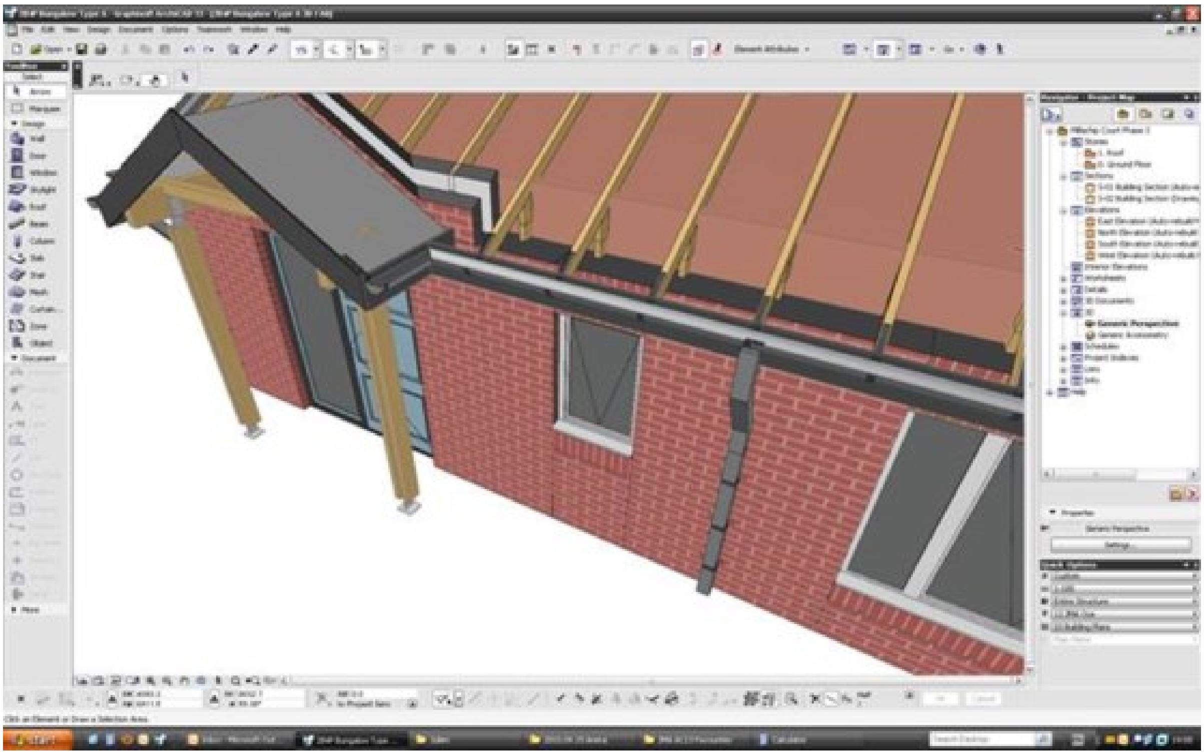


Figure 9.97: One of the bungalows produced for the Millachip project showing investigation of the roof wall interface

3d images generated from the BIM model were also used as part of emails when attempting to resolve details with remote members of the construction teams (see figure 9.98).

From: Julien Denis
Sent: 28 April 2010 16:07
To: 'Dylan Woodham'
Cc: Jonathan Smith; 'peterwood@bardsley.co.uk'; 'Malcolm Sothern'
Subject: Millachip Court Phase 3 (1052/Ka) Roof Trusses

Dylan,

I have checked with the client and the 35mm trusses are acceptable, however the plans for the trusses in their current state are not.

I have annotated Type A & B, Type C can just be derived from the Type A drawing, could you forward these to Andy at Howarth Timber if appropriate.

With regard to the front canopy, we will need a separate tie (not a truss tie) as below, essentially a couple of rafters supported on a beam arrangement.

I trust this is satisfactory but do not hesitate to contact me should you require more information.

Best regards,

Julien

Figure 9.98: An email on Millachip Phase 3 including a 3d image from a BIM model being used to resolve detailing issues with other disciplines.

The 3d models were also used to assess the visual aspects of the design as it developed (see figure 9.99).

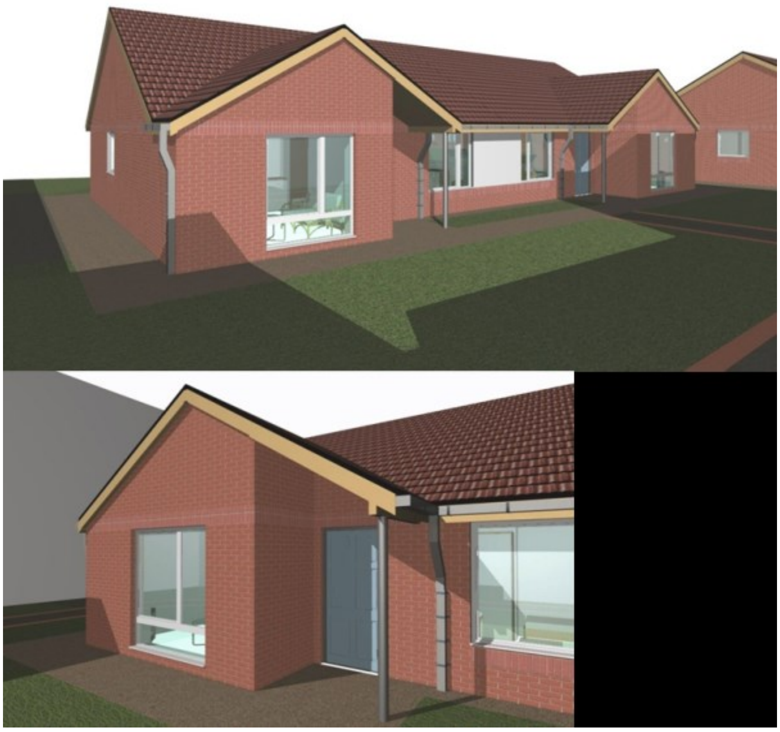


Figure 9.99: The first commercial project Millachip Court Phase 3 produced using ArchiCad

Internal aspects of the design were also investigated visually (see figure 9.100).

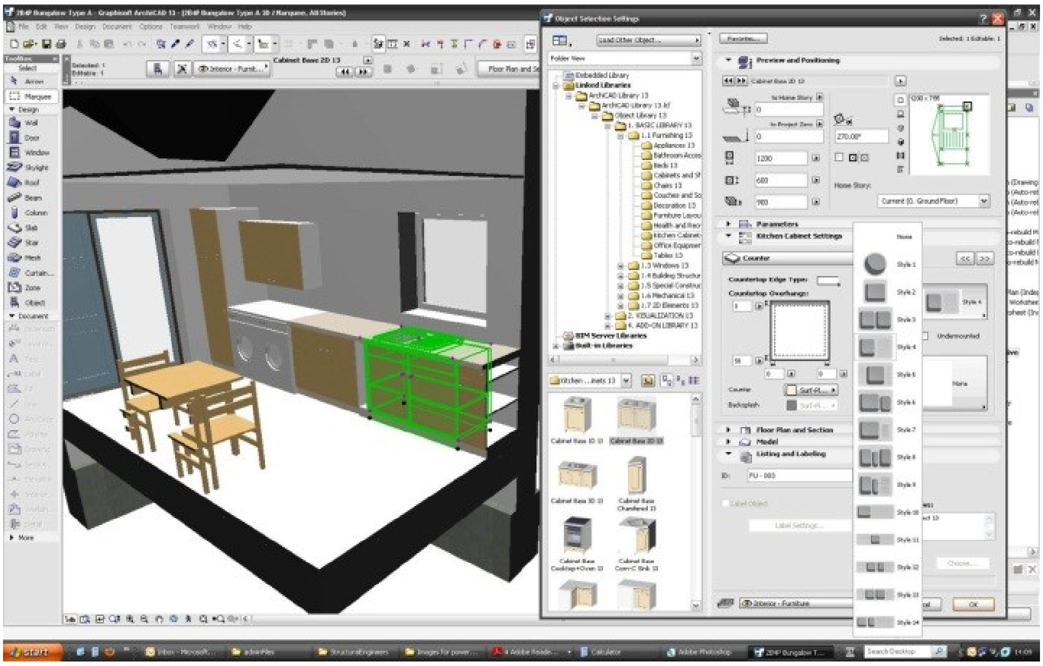


Figure 9.100: Being able to visualize the kitchen design while testing out alternative kitchen arrangements

Animated solar studies were also generated from the Archicad (see figure 9.101)

Figure 9.101: Investigation of solar studies generated from archicad models

The details for the Millachip phase 3 project were drawn in 2d. But the details from the model where used as underlays for the development of these details which allowed for an element of coordination (see figure 9.102).

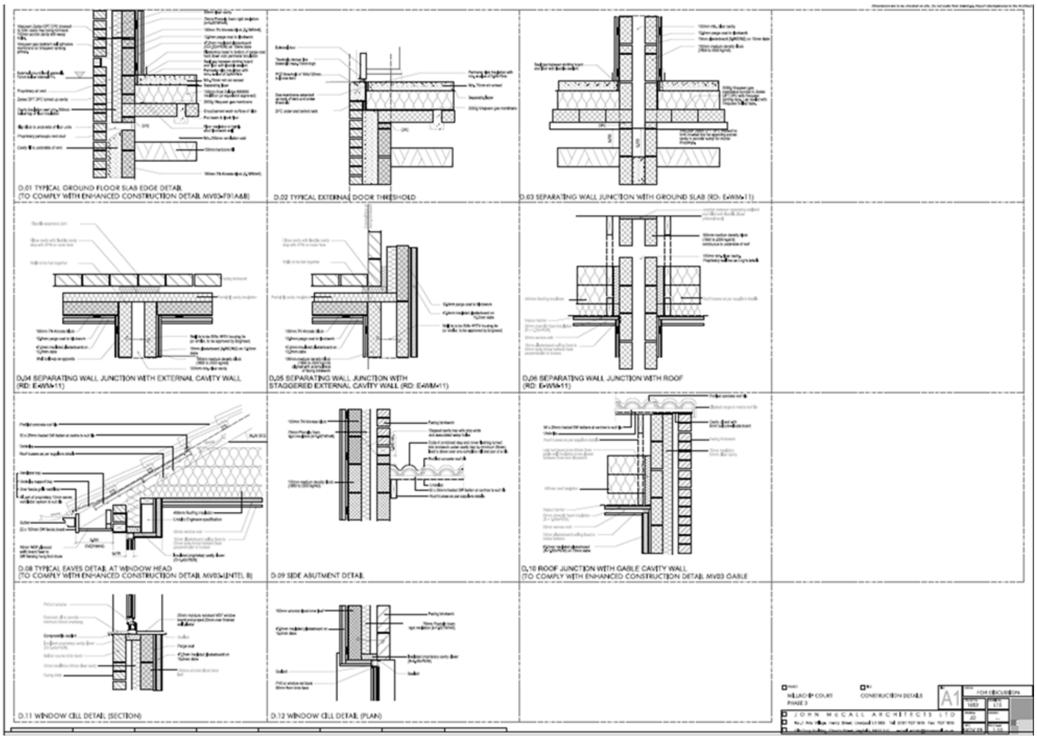


Figure 9.102: A standard set of 2d details drawn for the Millachip phase 3 project

As part of the Millachip Phase 3 project filtering the information to be sent to the structural engineers was experimented with (see figure 9.103). The engineers used on this project already had been introduced to BIM through a presentation given by the BIM Champion.

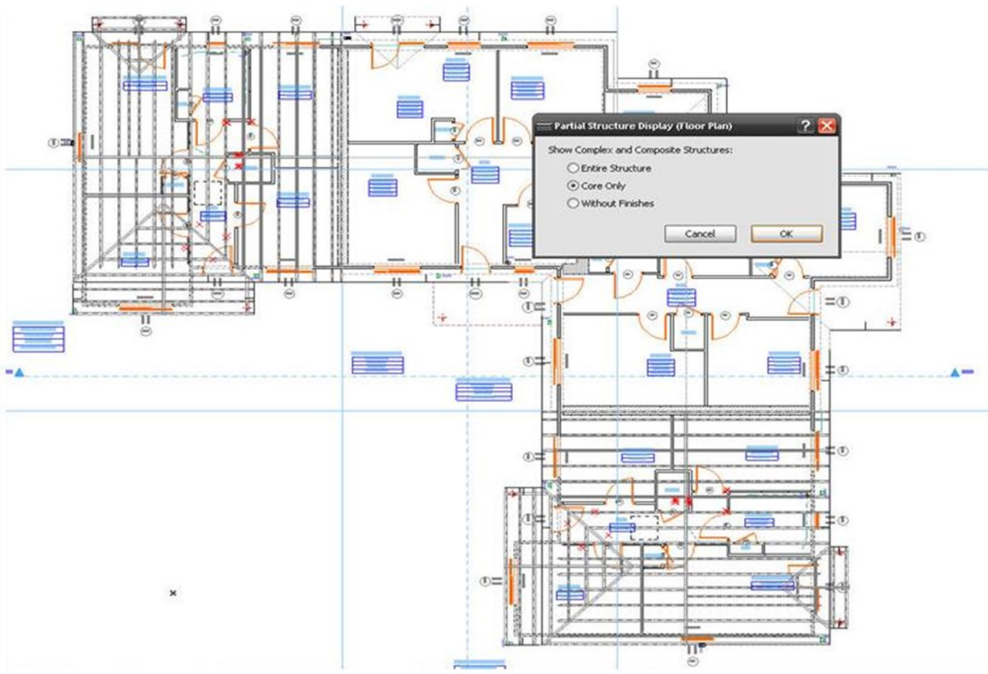


Figure 9.103: Filtering the model on the Millachip Phase 3 project to just send the structural elements to the structural engineer

Material scheduling was also generated from the model (see figure 8.104).

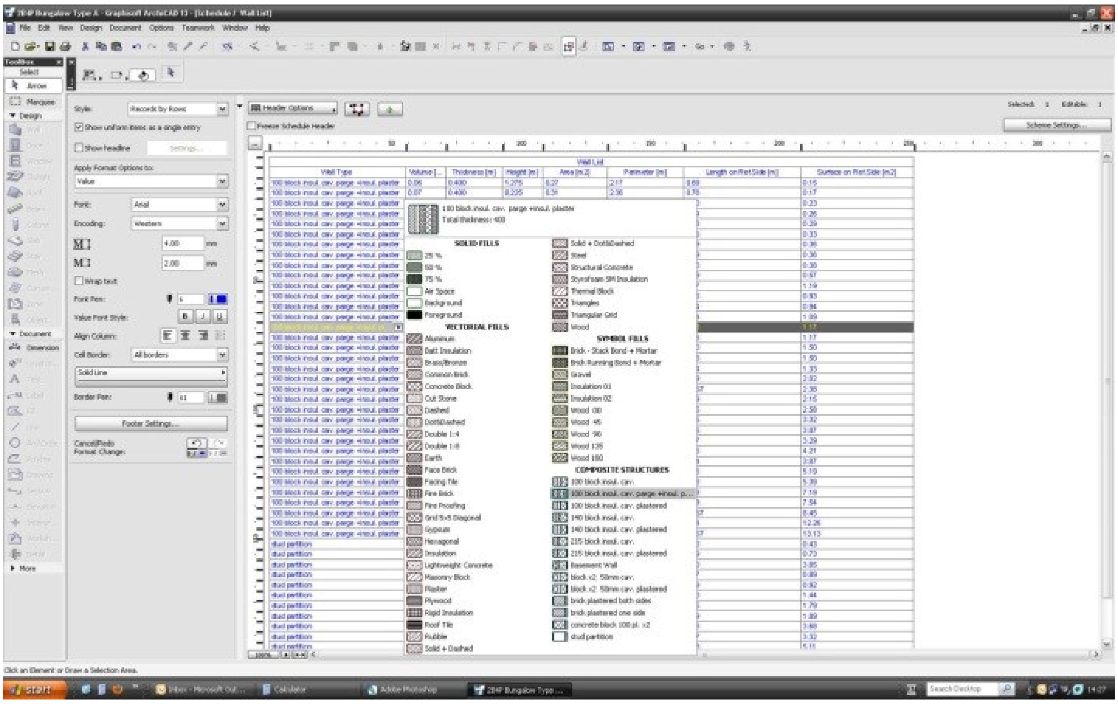


Figure 9.104: Automatically generating wall schedules from the BIM model

As part of the Millachip phase 3 project the 2d output representations were perfected for different purposes (see figure 9.105). This involved setting the line weights the colours and the shading requirements.

Figure 9.105: An elevation from the Millachip project using the John McCall Architects predefined line weights and styles

An interesting factor on the Millachip Phase 3 project was how closely the initial BIM rendering resembled the final built project (see figure 9.106).

Figure 9.106: The final result of the Millachip Phase 3 design

Later as part of the BIM implementation virtual working was experimented with. This involved members of staff working from home and collaborating with staff in the office using the ArchiCad Teamworks capabilities. The Teamworks facility has a built in messaging system.This was particularly useful when weather conditions made it difficult for the staff to access the office or when staff were suffering from colds they did not wish to share with the rest of the office.

The Millachip phase 3 project was regarded as a success by the architects, contractors and the client. The 3D images that were produced using BIM were able to illustrate potential issues allowing them to be address before they became an issue on site. John McCall Architects currently show some of their models from this project on the company website. This is an indication of the achievement of this project in moving the company from a 2d CAD based process to a 3d BIM based process.

9.20.2 Broomlane for Great Places

After the pilot projects had been undertaken, one of the live projects chosen was the Broom Lane project in Manchester for the Great Places Housing Group and the City Care partnership. The estimated build value was £1.6 million. The scheme was designed with four distinct areas for residents with autistic spectrum conditions. Such residents often suffer from panic attacks and secluded corners were provided in the design were the residents could feel safe.

The speed with which this project was undertaken was considerably quicker than the previous projects. Again the 3d visualization helped in the development of the design. In this project different rendering techniques and tools were experimented with (see figure 9.107 and figure 9.108). Again the likeness of the model to the reality is striking (see figure 9.109).

Figure 9.107: Broomlane (Archicad models rendered using Artlantis)

Figure 9.108: The Broomlane development under construction

Figure 9.109: An example of an experiment to make the BIM model of Broomlane look like a watercolour sketch

On this project again 2d details were used to supplement the information contained in the model.

An important element of the BIM role out is a coordinated set of meetings to monitor what is happening on the projects. An interesting development on the Broomlane project was the use of the 3d model by the procurement manager to communicate with subcontractors (see figure 9.110).

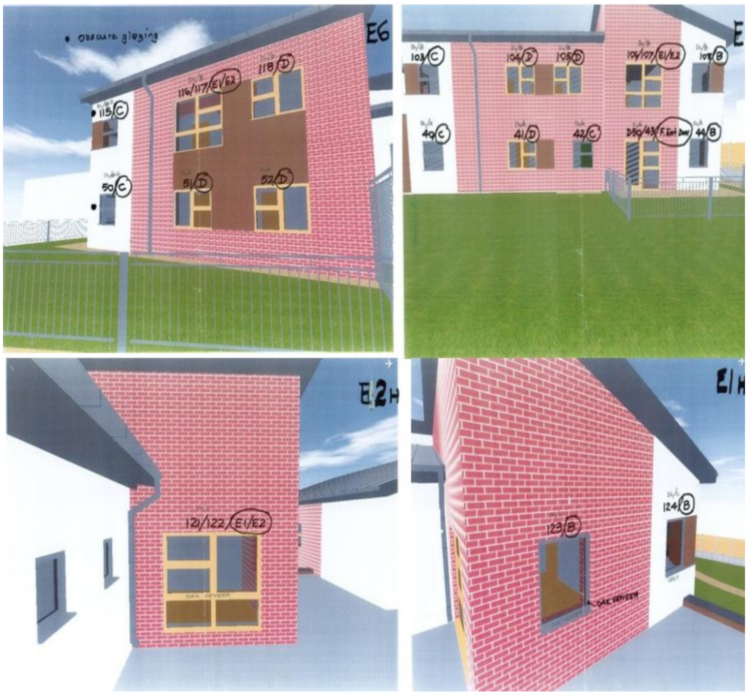


Figure 9.110: Use of the Broomlane model to communicate with subcontractors

Virtual building explorer models were also develop for this design (see figure 8.111). Virtual building explorer is now known as BIMx. It is an innovative, interactive, BIM communication tool for architects. It allows architects to create photorealistic walk-through models direct from their ArchiCad models. The file produced becomes a navigable 3D model which is small enough to be sent by email.

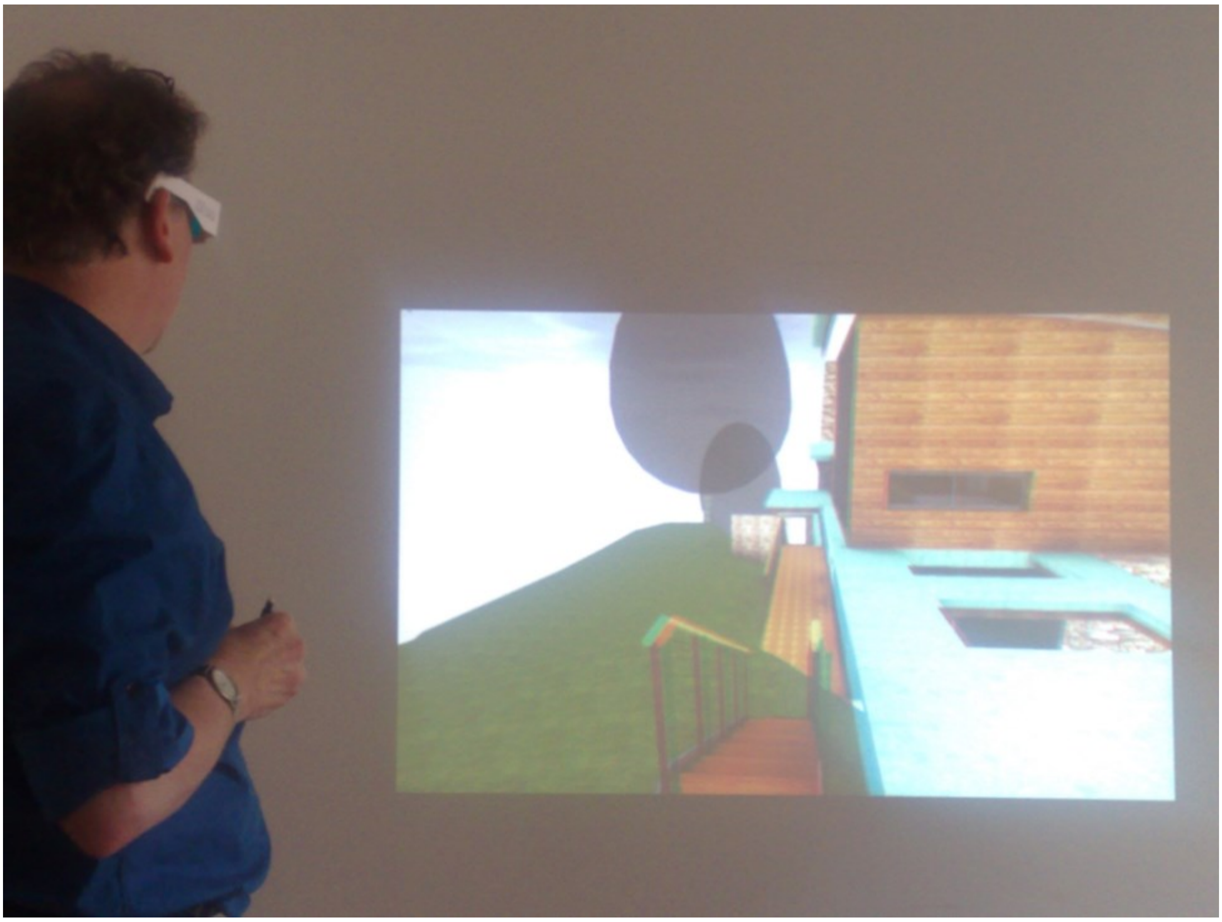


Figure 9.111: Use of Virtual Building Explorer in 3d mode at John McCall Architects

9.21 Summary of Chapter 9

The purpose of this chapter was to describe the action research undertaken at John McCall Architects. The action undertaken as part of the prototype project, the mobilization for live project and the live project undertaken have been recorded. The action undertaken have then be reviewed and considered. Where appropriate, better methods have been suggested.

Many lessons were learnt from undertaking both the critical path project at John McCall Architects. At the time so much learning was being generated from the projects undertaken the problem became one of capturing and disseminating the learning. The setting up of the BIM committee and the on-going development of the BIM manual were important in this regard.

Chapter 10

Chapter 10: After undertaking live projects using BIM this chapter records, explains and considers the BIM implementation project undertaken at John McCall Architects. The activities necessary for the continued development of BIM within an architectural practice are also documented.

CHAPTER 10 Explanation of the evaluation stage

10.1 Introduction

The review of the actions undertaken at John McCall Architects was documented preceding each stage and each step. The review of how this understanding can be used to develop an improved BIM implementation framework is documented in this chapter. Here it is the BIM implementation at John McCall Architects that is specifically reviewed. Appraisal is important because it puts events that have occurred into perspective.

New uses and capabilities emanating from the BIM adoption should also be revisited at this time. Process and methods to stabilize and standardize the successes achieved should also be considered. The principles adopted at the outset of the BIM implemented should also be considered and verified. Final a consideration and strategy to dissemination the lessons learnt should be developed.

10.2 Post Project Review

Here the work that has been undertaken on the live BIM projects and the BIM implementation in general is reviewed. Post project review (PPR) involves data collection, data analysis, consolidation, forming recommendations and dissemination. A project review should achieve the following:

- A review of the events that occurred
- An evaluation of not only what happened in terms of people, process and technology, but also why those events happened.
- To determining the correct actions to improve the results of the next event or project

Elements for consideration as part of a project review are listed below:

- Project Planning (how effective was this)

- Project Management (did it occur in an appropriate way)

- Project Status reporting (where all the necessary reports produced)

- Project costs (was the project completed with agreed budgets)

- Risk Management (where risks identified and mitigated)

- Quality Management (were the deliverables from the BIM implementation achieved to the necessary standards)

- Stakeholder Management (where internal and external stakeholders informed and included as necessary)

- Resourcing (where adequate resources made available and managed effectively throughout the BIM adoption)

- System users (where the BIM users adequately trained and provided with the knowledge necessary to perform the task necessary)

- Development Approach (was the development approach in hindsight correct)

- Standards and Guidelines (where they developed)

The previous chapters of this thesis represent one form of a project review undertaken on the case study BIM implementation.

At John McCall Architects shortly after the completion of the two year BIM implementation project period a project review meeting with all parties took place. At this meeting how successfully the project was completed and what was achieved was discussed. There was a general satisfaction on both counts from a company perspective. By that time BIM was embedded in the company and its potential was demonstrated.

There are issues when BIM is rolled out as to whether individual skills are developed or the company wide skill is developed. Both are required. But whatever method of architectural production is used whether traditional or BIM the company has to meet and preferably surpass client expectations. Meet the client expectations proved possible during the initial live projects. In fact there was a reticence by the directors to let the client be aware of the productivity gains that were being achieved. Clients also were interested in what was possible from the BIM approach, which was new to them at that time.

At the BIM adoption at John McCall Architects a tangible benefits log was produced and monitored through the progress of the projects. The tangible benefits were both in the development of the BIM Champion and the architectural practice.

The impact of the BIM adoption has already been realized several benefits. During the project at John McCall Architect's the practice had achieved the following:

- eliminated the risk of duplication
- reduced the misinterpretation of design
- improved communication
- streamlined the processes
- provided the basis for collaborative practice
- ensured control and sharing of documentation and data

In future it is believed BIM and an understanding of Lean principles at John McCall Architects will provide a clear vision and roadmap for further continuous improvements. Based on the current findings and the optimistic behaviour and culture evolved during the project, it is shown that BIM can re-engineer the operational and IT processes and broadens the knowledge of existing staff and stakeholders up and down the supply chain.

What became clear is that BIM adoption and implementation is actually as much about people and processes as it is about technology. As part of a BIM adoption the following is important:

- to engage people in the adoption
- to ensure that people's skills and understanding increases and companies building up their capacities
- to ensure successful change management strategies are adopted
- to diminish any potential resistance to change using vision building within the process

10.3 Identifying new uses for the capabilities developed

When undertaking a BIM adoption it is useful to keep an open mind. Better ways of doing things and potential new markets may become apparent as part of the adoption process.

According to the UK government BIM task group, the overarching strategy is to use consolidation of BIM exploitation in the domestic market as a spring board to exploit the collective expertise and to maintain leadership in the global markets.

At John McCall Architects the collaborative element of BIM with other disciplines had been investigated but not put into action. Subsequent to the period of research improved methods of quality take off and working with quantity surveyors was developed. This development used the quantity information available in the BIM model.

10.4 Stabilise success / standardise process and implement method

In order to stabilise success, standard methods need to be put in place and rolled out across the company. Standards may be incorporated as part of the quality system, also a BIM manual whether as a hard copy or electronic document may be developed. Finally the BIM authoring software with associated templates and libraries can be customised so the required standards and processes are adopted by default.

In the case of John McCall Architects, considerable effort was made to customise the software templates and develop object libraries. Incorporation into the quality system had not occurred at the time of completion of the research at John McCall Architects. But it was a process that was taking place. Although many of these activities had to some extent taken place as part of the mobilization for the live projects, there was a need for a continued effort to stabilise and standardize success.

An area that perhaps was not given adequate consideration at John McCall Architects was the consideration of legacy data, drawings and documents. Maintaining legacy systems after a time can become a difficult matter for companies adopting new technologies. It is recommended that this area also needs to be considered and resolved so the BIM system adopted be used as the common interface to create, access and interrogate information.

10.5 Setting up Continuous Improvements

The adoption of BIM can be seen as a radical change “Kaikaku” in lean terminology. Once this change has been made the way BIM is undertaken need to be reviewed and monitored and efforts made to achieve a continual improvement in the BIM process. Continual improvement is known as “Kaizen” in lean terminology. Kaizen Groups or Quality Circles are groups specifically brought together to identify potential improvements. This is effectively what was set up at John McCall Architects.

In earlier sections we have discussed BIM training. It is important the use of BIM is continually improved using lessons learnt from the projects previously undertaken. Knowledge development should take place as showing (see figure 10.01 and not 10.02). Knowledge gained from the projects performed should be transferred to the project undertaken. This has the potential to reduce time spent on problem solving and increase the quality of work (Dave 2009). To achieve this, an active effort must take place to distil the lessons learnt from the projects undertaken.

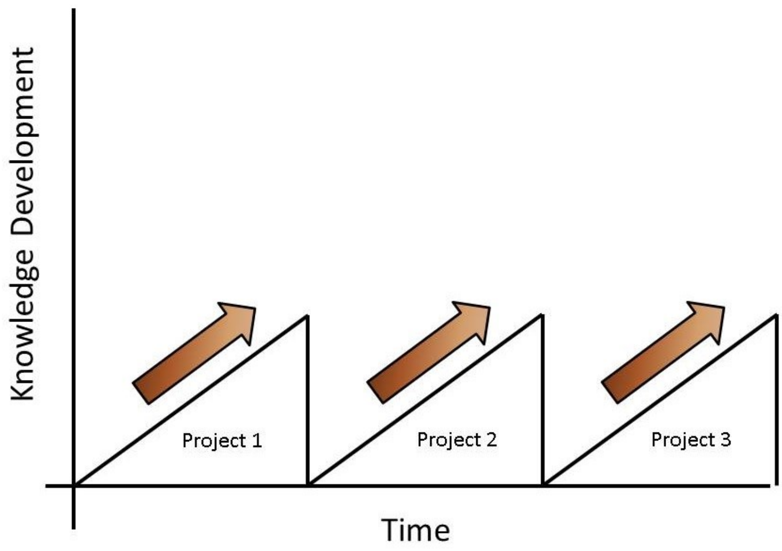


Figure 10.01: Projects were knowledge acquired through doing is not effectively transferred

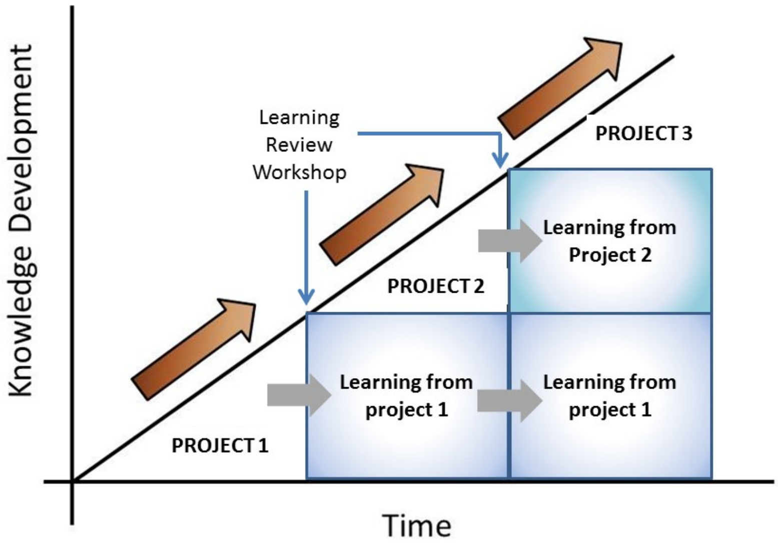


Figure 10.02: Projects were knowledge acquired through doing is effectively transferred

The main activity undertaken at John McCall Architects to initiate continuous improvement was the setting up of the BIM focuses group. This was a group of staff using the BIM authoring software who agreed to meet up once a month. The focus of the group was to discuss problem and potential improvement. Once these potential improvements where established they could be rolled out to the company. The principle of time task reduction is illustrated (see figure 10.03).

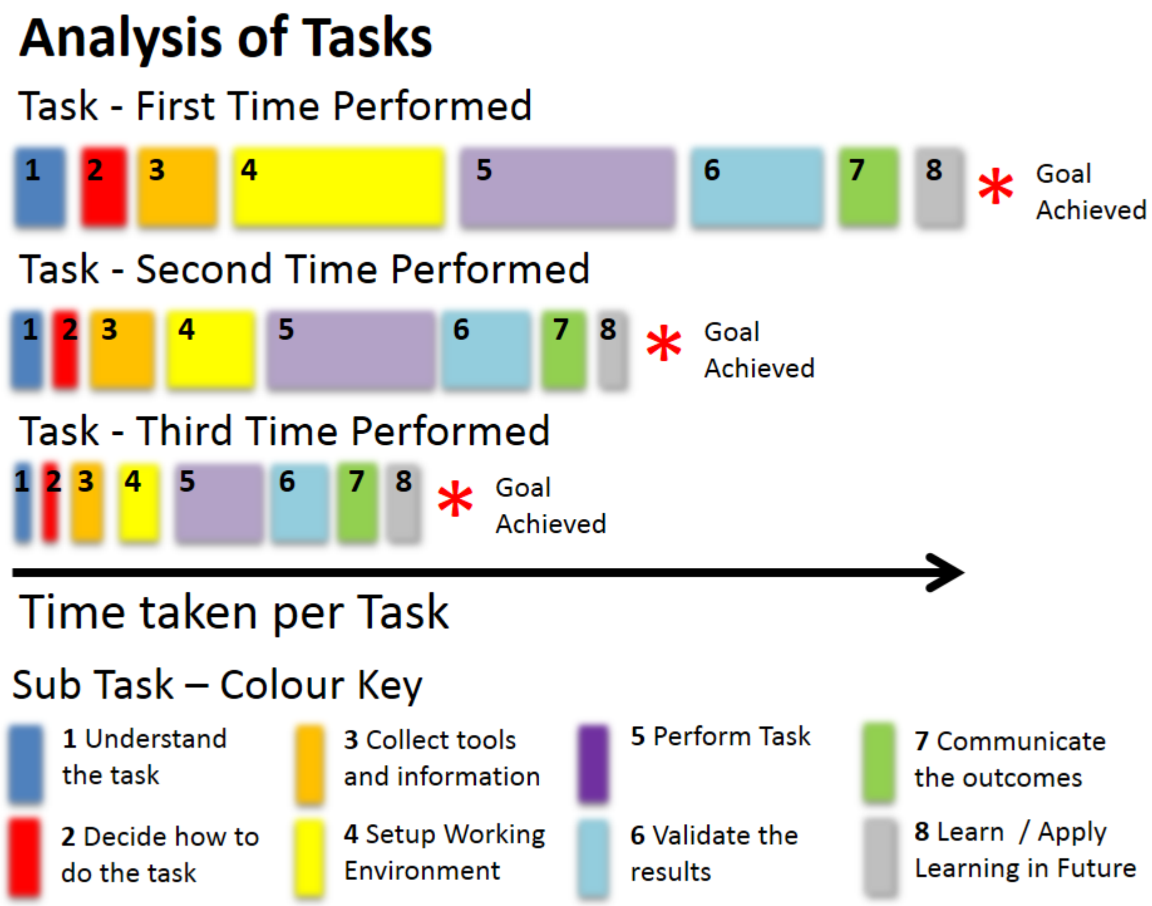


Figure 10.03: How the time taken to undertake tasks can be reduced though a process of action reflection and application of improved methods

10.6 Verify if improvement principles are correct

There are several factors when verifying whether BIM improvement principles are correct. The factors are listed below:

- Has the product improved in terms of cost, time or quality
- Does the client or other parties recognize and or utilize these improvements
- Has the adoption of these approaches proved to be cost effective?

To monitor the success of a BIM implementation project it is necessary to establish key performance indicators for the project. At John McCall Architects these were established in stage three of the BIM implementation. The findings are documented (Table 10.01).

Key Performance Indicator	Observation at John McCall Architects
a) Man hours spent per project - efficiency with cost per project: It is possible to compare the man-hours spent on one project that utilizes BIM software with the man-hours spent on the same project using a traditional CAD system.	The projects generated were considerably quicker when BIM tools are used.
b) Speed of Development: Turnaround time is important and if handled correctly, it can reduce outstanding work and costs, and improve cash flow. In addition, speed of turnaround also engenders client satisfaction.	As above
c) Revenue per head: Higher revenue per head is achieved when fees increase. Clients will only pay more if they perceive greater value. The potential value of BIM for many clients remains unproven in areas such as facilities management.	The fees pre project did not increase through the use of BIM. But the revenue per head did increase as a result of a greater volume of work being produced.
d) IT investment per unit of revenue: The use of IT has become a prerequisite of architectural practice and many IT solutions exist. It is important to measure the success of one IT innovation against other potential innovations.	Not Known
e) Cash Flow: On a daily basis, cash flow is not profitable every day, but setting and achieving a daily margin of profitability is critical to success. Successfully monitoring cash flow allows meeting obligations and protecting the future. By increasing the rate at which product is turned around enables invoices to be raised earlier and liquidity can be maintained.	BIM enabled work to be turned around quicker. Therefore there may be a potential to claim fees at shorter intervals.
f) Better Architecture: Whether	The architecture did not change as a

architecture is better or not is dependent on the individuals' perspective. How to achieve better architecture is critical by making better informed decisions. The use of BIM claims for greater investigation and understanding which has the potential to lead to better decisions and better architecture.	result of using BIM tools.
g) A better product: Many facets attributes to BIM have the potential to produce a better product through the reduction of mistakes, clash detection, automated model checking, reduction in build ability issues, reduction in professional insurance costs, etc.	Consistency across all of the 2d representations was achieved. This made a saving in the time required and allocated to checking.
h) Reduced costs, travel, printing, document shipping: Travel expenditure in time and money may be reduced to fewer issues. Printing costs may be saved because less check sets of drawings will be necessary. Document shipping should be reduced when a single multidisciplinary federated model is used.	Not Known
i) Bids won or win percentage; BIM is supposedly a marketable commodity and helps attaining competitive advantage to win bids, which is based on many different factors. Most of the work gained by John McCall Architects is through framework bids through long term partnerships.	BIM was not seen as a major factor in winning new work. Winning new work seems to be determined on the lowest bid.
j) Client satisfaction and retention: capturing client requirements and needs and establishing a shared understanding with them on the design and developing a partnering approach are critical and involving them throughout the process to inform and receive feedback from them can be achieved through BIM adoption in	The 3d views and the animated models were appreciated by some of the clients.

order for client satisfaction and retention.	
k) Employee skills and knowledge development: staff reaction and acceptance, their cultural attitudes, their skill and knowledge level and related BIM training should be also measured and managed accordingly.	Skills and knowledge was developed across all the architectural staff at John McCall Architects

Table 10.01: Review of Key performance indicators

10.7 Recommendations for the case study company

A great deal was achieved at John McCall Architects over the two year period of research. It is important that the momentum for BIM and process improvement in maintained. Recommendations for John McCall Architects include:

To develop BIM to better address sustainable requirements

To develop greater interoperability with other stakeholders

To further develop the systems process and standards adopted for the practices operation

10.8 Summary of Chapter 10

The purpose of this chapter was to describe the action research during the final stage of the BIM implementation project undertaken at John McCall Architects. The stabilization of the BIM adoption or “refreezing” is a critical element of successful adoption. The findings of the action research have been reviewed and where appropriate better or enhanced methods have been suggested.

The BIM adoption at John McCall Architects achieved what it set out to achieve. Although considerably more effort was required than was shown in original plans. In reality the BIM implementation at John McCall Architects continues and it is recommended that its progress is reviewed and shared on a regular basis.

Chapter 11

Chapter 11: This chapter documents the refinements to the BIM implementation framework that were suggested through evaluation both during and after the period of action research at John McCall Architects. The aim here is to provide information and a usable framework for small architectural embarking on the adoption of BIM.

CHAPTER 11 Review of the BIM implementation Framework

11.1 Introduction

In the previous chapters every effort has been made to include all the salient details critical to a successful BIM adoption in a small architectural practice. These salient details were then considered and evaluated. In this chapter how the initial framework that was adopted at John McCall Architects was improved is documented.

First the overall structure of the framework was reviewed. Going back to first principles and using theories of project and change management the stages, steps and activities required by the framework were considered. These were then mapped to the competency and maturity level required to be achieved through the BIM adoption. This was undertaken using the knowledge and experience gained from the BIM implementation at the case study company. Then the revised overall framework was defined (see figure 11.01).

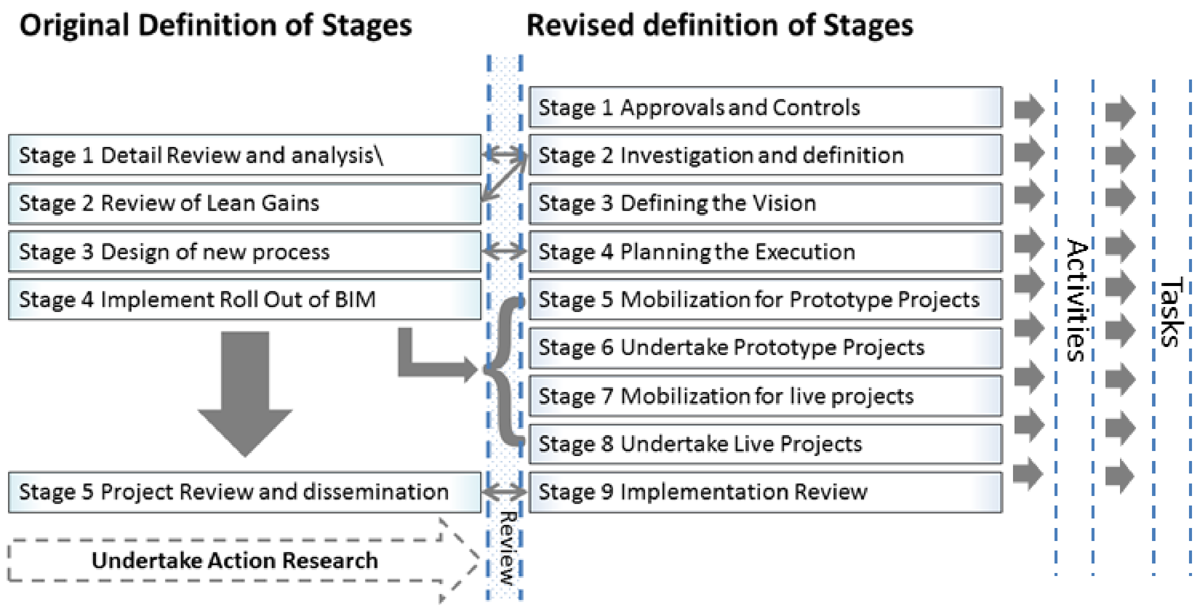


Figure 11.01: Original and revised stages for BIM implementation

Having established the new overall framework an overview is given to each stage of the revised strategic framework. Then the requirements of the new stage are stated and shown in a flowchart. This is then followed by observations and recommendations made in hindsight following the completion of the case study BIM implementation process. Using the lessons learnt it should be and has been possible to develop approaches to avoid, reduce or transfer the risk involved in the BIM implementation process.

Again it is emphasised that the stages suggested here will need to be reconsidered if the approach to be adopted in specific architectural practices. Also as technology and regulations advance other considerations may come into play. If the knowledge required by certain stages is already available or the activities outsourced then the stage may be reduced or ignored.

The risks that became apparent concerning BIM adoption are documented in this chapter. Appropriate methods of responding to these risks are documented in the recommendations at the end of each session. As with all projects effective project management is key to a successful BIM implementation.

11.2 Development of an improved framework

When starting out on the journey of BIM adopting the prospect and the many tasks to be achieved may be somewhat daunting. For this reason it is necessary to set intermediate goals and objectives. These allow for a more agile methodology (Beck et al 2001) to be adopted where learning taking place can be feedback enhancing the BIM adoption project. The setting of intermediate goals allows for more effective project monitoring and management. Intermediate goals also reduce the likelihood of disillusion taking place as the project progresses.

In developing an improved BIM implementation strategy framework we need to consider different levels. These levels are the stages to be taken, the activities these stage involve and the tasks that go to makeup the activities (see figure 11.02). This approach is in line with the standard method of developing work breakdown structures. A work breakdown structure (WBS) divides the entire project into its component elements in order to establish a framework for effective management control of the the project scope, schedule and budget.

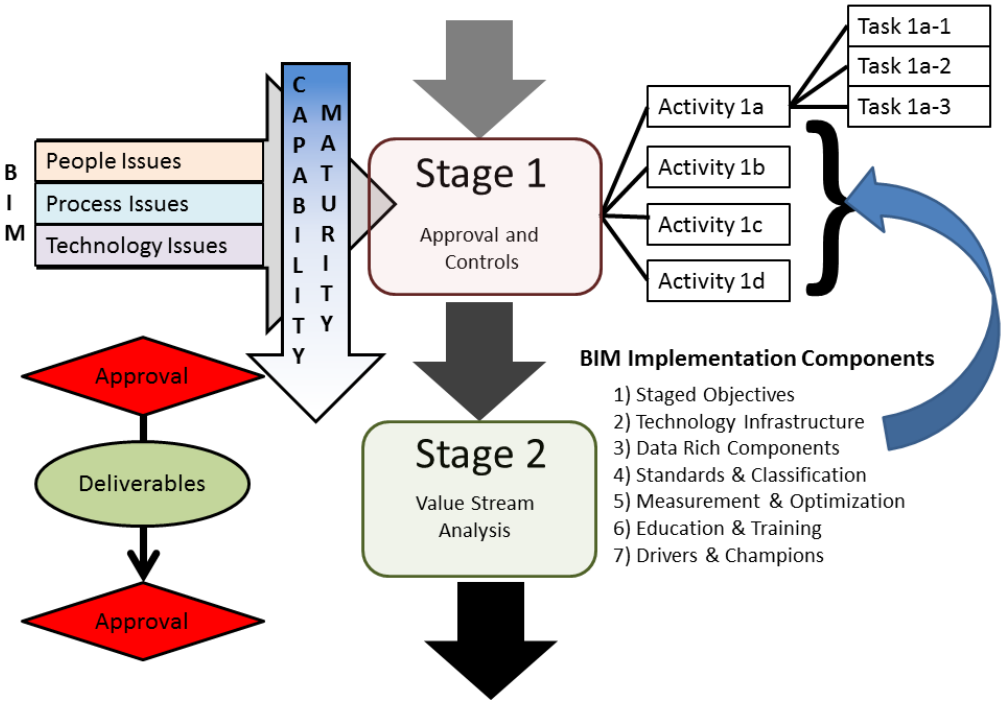


Figure 11.02: The relationship of stage, activities and tasks in the BIM adoption process (BIM implementation components from Succar 2011)

At the stage level we need to define the change management functions required. These stages were mapped out to the BIM competency, maturity sets and the deliverables required by the practice. The mapping of these functions to competencies and levels of maturity and deliverables revealed the stages and activities required. At the activity level how each of the change management activities is to be undertaken in practice was defined. This resulted in a program of activities. This may be represented through a flowchart as shown or a project program. This resulted in the generation of flowchart (see figure 12.01). The framework is documented in tabular form below (Table 11.01).

Stage	Activity
Stage 1: Approvals and Controls	1.1 Developing the Outline Business Plan
	1.2 Setting up a Project Structure and Authorization
	1.3 Initial Project Mobilization
	1.4 Defining the Project Parameters
	1.5 Stage Review and Approval
Stage 2: Investigation and Definition	2.1 Analysis of Business objectives and business model generation
	2.2 Analysis of current processes
	2.3 Analysis of existing data handling methods
	2.4 Determination of Best practice and Benefit Analysis - Literature Review - Artefact Review - Review of Quality Objectives - Development of the informational model, information structuring and compliance - SWOT and PESTLE Analysis - Stakeholder Review - BIM tool review
	2.5 Stage review and approval
Stage 3: Defining the Vision	3.1 Defining what is required (Including capability, process and product improvements)
	3.2 Promoting the Vision
	3.3 Defining Benchmarking standards for the BIM implementation project
	3.4 Stage review and approval
Stage 4:	4.1. Developing a BIM implementation plan

Planning the execution	4.2 Determining the hardware and software to be used
	4.3 Development of a staff training plan
	4.4 Determining the pilot or prototype projects to be undertaken
	4.5 Stage Review and Approval
Stage 5: Mobilizing for the prototype projects	5.1 Preparation for the prototype projects
	5.2 Managing the PR and Marketing of BIM
	5.3 Purchase of hardware and software required to undertake the prototype projects
	5.4 Initial Hardware and software configuration
	5.5 Stage Review and Approval
Stage 6: Undertaking the Prototype Projects	6.1 Training Design and Development
	6.2 Training of the BIM Champion
	6.3 Undertaking the Prototype Projects
	6.4 Review of the Prototype Projects
	6.5 Stage Review and Approval
Stage 7: Mobilization for the live company projects	7.1 Execution of Staff Training
	7.2 Development of project procedures
	7.3 Development of a BIM execution plan, a BIM manual and a BIM capability matrix
	7.4 Software Optimisation - Setting up the working environment - Setting up Automation - Setting up View controls and rendering capabilities - Taking advantage of software features - Using models and multi models - Developing internal collaboration

	- Developing Object Libraries
	7.5 Developing Validation Methods
	7.6 Setting up a BIM group
	7.7 Developing Quality procedures
	7.8 Definition of BIM responsibilities and Roles
	7.9 Developing Interoperability
	7.10 Ensuring the necessary insurances are in place
	7.11 Stage Review and Approval
Stage 8: Undertaking live company projects using BIM	8.1 Undertake live company projects
	8.2 Stage Review and Approval
Stage 9: BIM implementation Review	9.1 Review finding and KPI's from the BIM implementation Project
	9.2 Project Review
	9.3 Identification of new uses and capabilities
	9.4 Adopt process to stabilise and standardise success
	9.5 Setup processes for continual improvement
	9.6 Verify the initial improvement principles were correct
	9.7 Disseminate Lessons Learnt

Table 11.01: Revised and improved BIM implementation framework

11.3 Amended stages of the BIM Implementation Framework

11.3.1 Stage 1 Approvals and Controls

For any project (BIM implementation) to be successful it needs approvals and controls to be in place. A clear business case also needs to be defined. Such activities were not part of the original framework as they were address before the

BIM implementation took place. They are added as a new initial stage here to ensure if in future this framework is use these critical tasks are undertaken.

It is important at this early stage that the key decision makers understand, what is possible. They also need to know, what are the external drivers, who will be affected and what may need to change as part of a BIM adoption.

There was no particular project at John McCall Architects at the time where BIM was mandatory. If the BIM adoption is being driven by project requirements these need to be clearly understood at the outset of the BIM adoption. If projects being undertaken necessitate the use of BIM, this will affect the business case statement, the implementation programme and the timescales available before the implementation stage. The steps for stage one setting up approvals and controls is illustrated below (see figure 11.03).

At John McCall Architects there was no great BIM expertise within the company. Depending on the expertise and the distribution of expertise different strategies will need to be considered.

Having the BIM Champion on board early in the project has major potential benefits. It provides a focus for the BIM implementation project. Selecting or developing the right BIM champion is one of the most important decisions that need to be made.

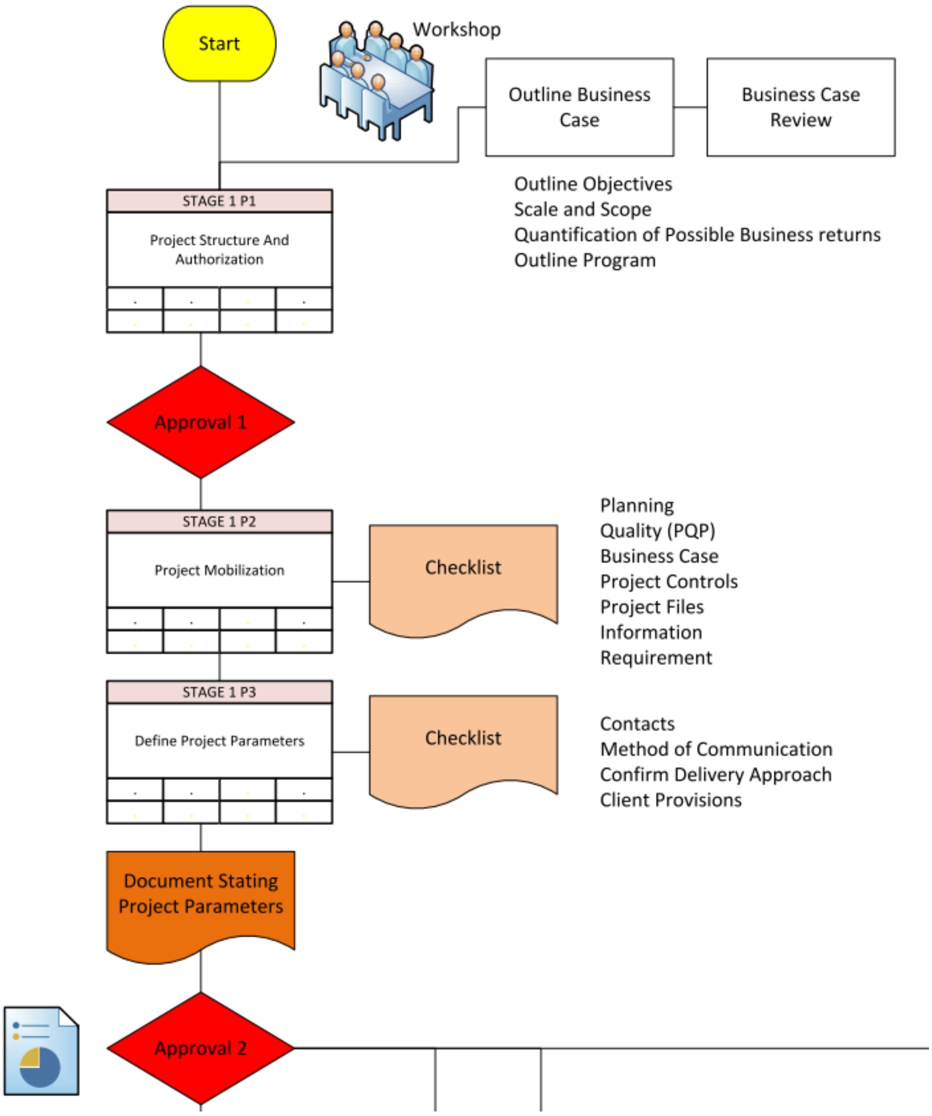


Figure 11.03: Flowchart of Stage one Setting up approvals and controls for a BIM implementation project

11.3.2 Stage 2 Investigation and definition

This suggested stage is very similar to the activities suggested in the original framework. Once the project mobilization is complete and the defined project parameters are approved then this stage can commence. This stage of investigation and definition should provide a foundation for why the BIM implementation should and needs to take place. This stage could be undertaken by an individual or an investigative team. Whichever is used, the findings from this stage need to be integrated into a holistic understanding of the issues.

It is necessary to make the necessary unknowns know so BIM implementation can progress based on appropriate resources and knowledge. Two options exist when adopting BIM knowledge, people process and technology maybe provided or developed within the organisation or these things maybe acquired from external sources. The decision of which of these two strategies to adopt may depend on the time scales, costs and the future organisational vision.

The acquisition of appropriate knowledge is critical for a successful BIM implementation. When the BIM implementation is project focused multiple organisations are likely to be involved. Many ways of acquiring knowledge maybe available but in all instances the most effective method should be sort.

There are many methods of finding out about a business. Brainstorming, focus groups, interviews, document analysis, process mapping, task analysis and reverse engineering were all methods successfully used at John McCall Architects. Such investigations take time and coordinating meetings was an important part of this stage to get access to the staff with the necessary knowledge. To ensure activities are correctly undertaken it is a good idea to develop checklist. Six activities were identified at this stage to provide the knowledge necessary to make the decisions required in order to commence stage 3 (see figure 11.04). These are:

- Establishing the business objectives
- Analysis of the current business process
- Analysis of Data Handling
- Artefact Review
- Determination of Current Best Practice
- BIM Tool review and selection

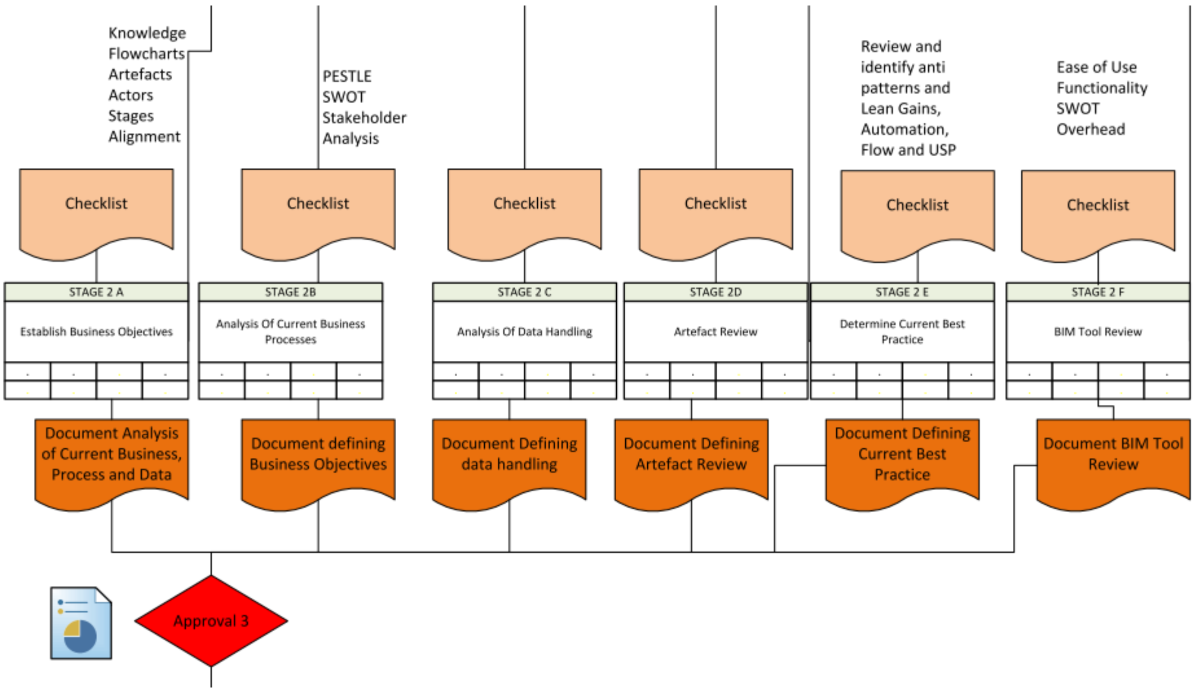


Figure 11.04: Flowchart of Stage 2 Investigation and Definition

Analysis of the BIM tool and BIM tool selection has been brought forward as a task to perform when compared with the original framework. This is because so many of the other decisions that are to be made and most of the training are dependent on the BIM tool or tools already being selected. An inability to make this decision at John McCall Architects resulted in reduced time available to conduct the later stages of the BIM implementation project.

Data handling analysis was not specifically identified with the initial BIM implementation framework. But considerations at a data level are the essence of BIM and it is necessary to consider this at an operational level. Now with the UK government COBie mandate there is a greater focus on delivering data.

Business analysis is a research discipline of identifying business needs and determining solutions to business problems. The PESTLE analysis is a useful approach in this respect. Trying to find what new ways should be adopted in the future is more difficult. This may require new ideas and concepts from other domains. Examples may exist many of the improvements are based on particular theories. Having established BIM as an interaction of people, process and technology and of business and design theories of improvement from all of these areas can be considered and applied.

The reality is that in stage two the activities may not be mutually exclusive. The knowledge does not just reside in one area. While considering the existing business, it processes and data handling and BIM tools, ideas about how they might work in future maybe generated. Ideas on how the business might run in the future may also be generated when considering current best practice. The investigations into BIM tools may also change the view on what should be regarded as best practice.

11.3.3 Stage 3 What is to be achieved, promoting the vision and developing a benchmarking strategy

At this stage of the BIM implementation what is required needs to be defined and agreed upon particularly by the project sponsors. Secondly the message needs to be got across to those who have the influence to enable or derail the BIM implementation project. This enables the decision to proceed to be made by consensus. Thirdly it must be decided on what criteria the BIM implementation is to be judged or benchmarked. All of these activities are important. These activities can and should run in parallel during this stage (see figure 11.05). Once these have been completed and approved it will be possible to move on to development of the BIM implementation plan stage four.

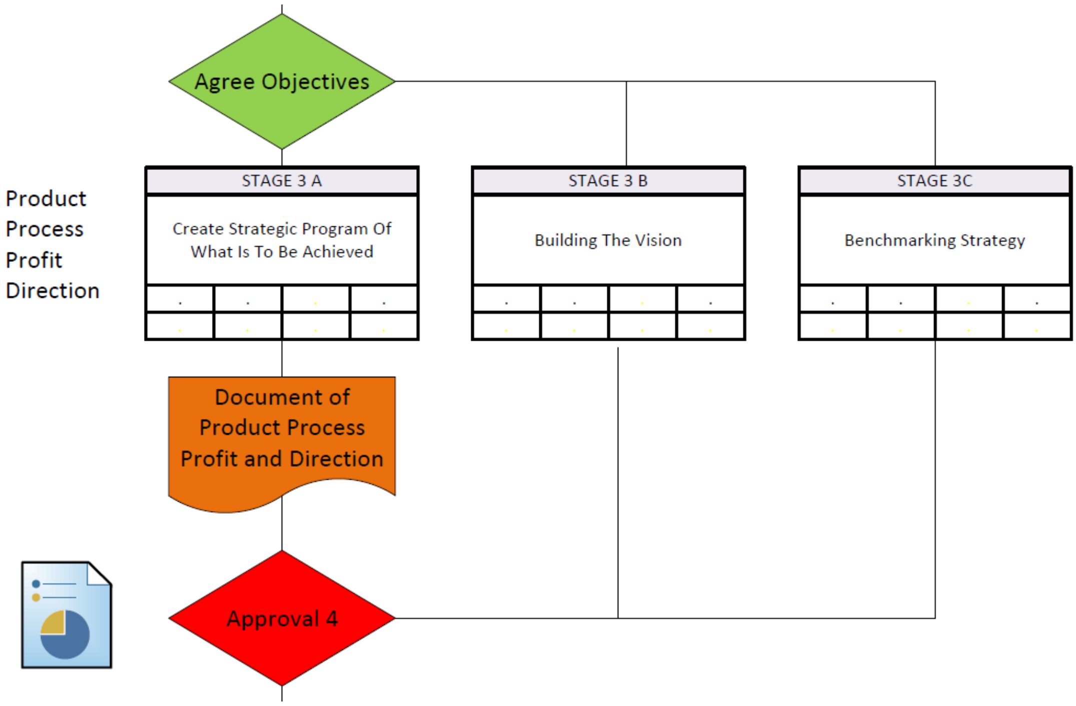


Figure 11.05: Flowchart of Stage 3 Defining Vision

11.3.4 Stage 4 Development of the BIM implementation plan

The major activity at this stage is to develop the BIM implementation plan. Also at this stage the software and hardware required should be determined following the BIM tool review in stage two. A staff training plan should also be developed and the pilot or prototype projects to be undertaken to be decided on. The particular lesson learnt here was the need to bring forward of the development of the staff training plan and it could be considered as a part of the overall development implementation plan. The staff training element of the project requires and major part of the time and resource spent on the project. Correct and appropriate implementation of the training is also critical to the overall success of the BIM implementation project.

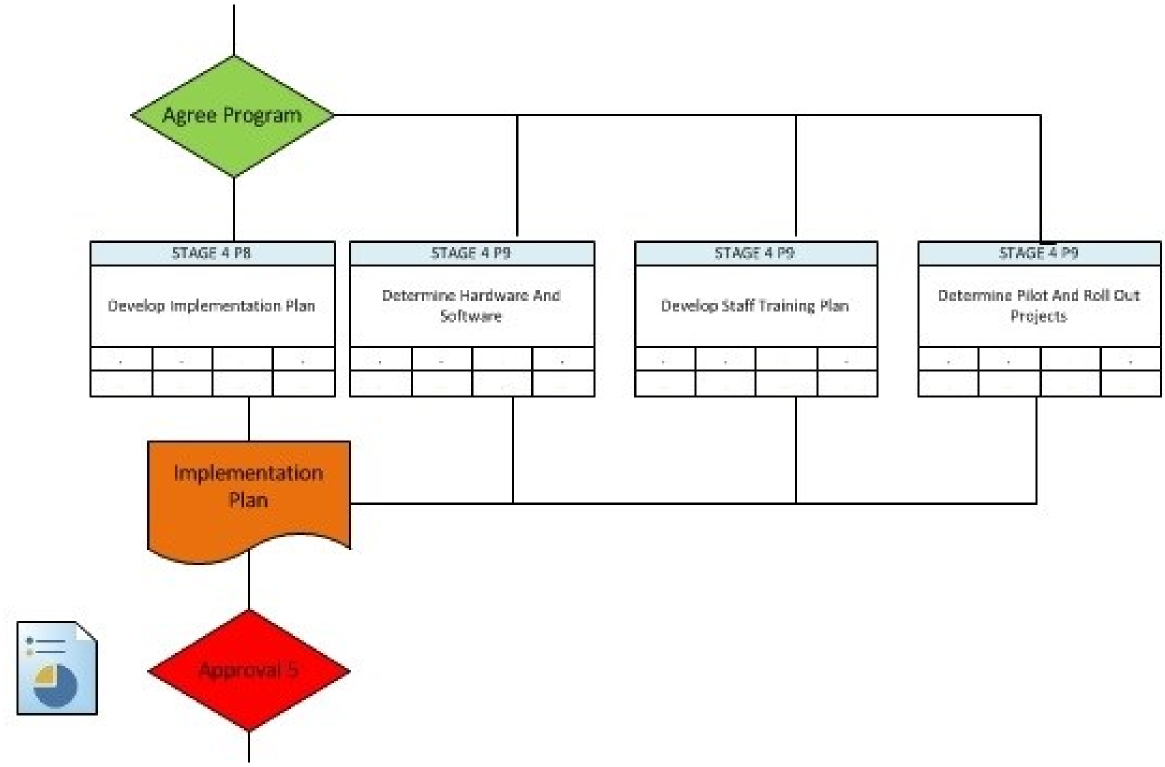


Figure 11.06: Flowchart of Stage 4 Planning the execution of a BIM implementation

11.3.5 Stage 5 Mobilization for prototype projects

There is mobilization to undertake the pilot projects and there is mobilization to undertake the live projects. This section describes the mobilization for the prototype projects. This stage involves several tasks (see figure 11.07).

This mobilization stage is an additional stage which was not included in the original framework. The activities in this stage can only take place once approvals are gained from the previous stage. In order for mobilization for the prototype projects to take place financial commitments for hardware, software and resources are necessary. The marketing implications of BIM adoption are also considered and developed during this stage.

It is preferable if the BIM champion is employed at the stage one of the BIM implementation although it is possible that they are employed during the mobilization for BIM implementation.

Again review and approval should take place once the tasks in this stage are completed.

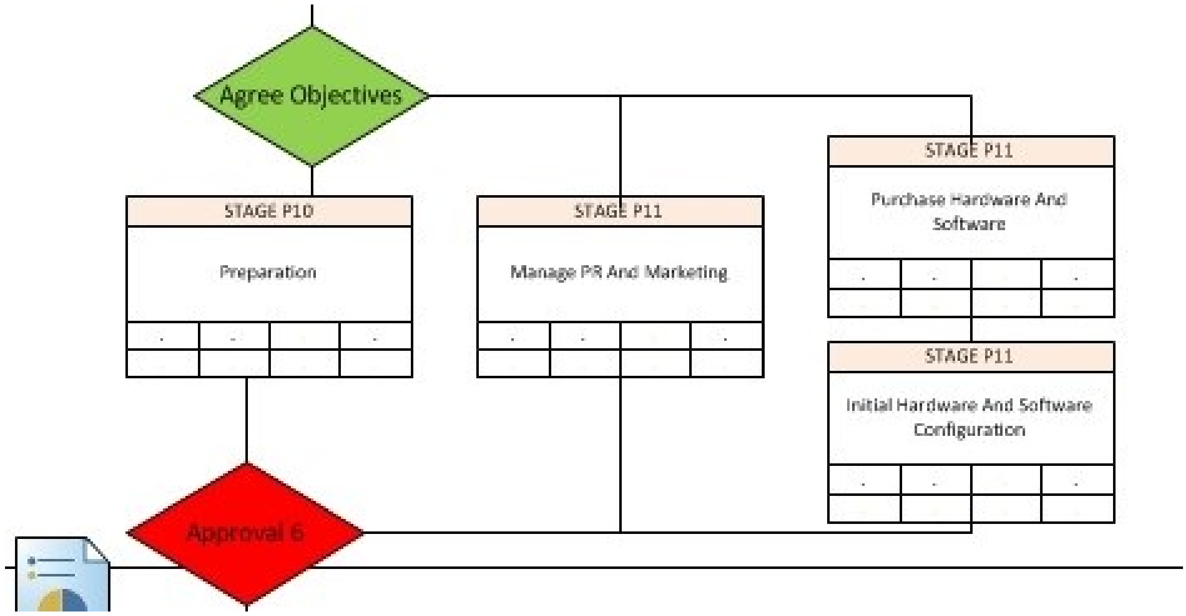


Figure 11.07: Flowchart of Stage 5 the mobilization stage of BIM implementation

11.3.6 STAGE 6 Undertaking Prototype Projects

The major task at this stage was undertaking the prototype projects. But staff enthusiasm for the project must be maintained during this stage. Activities of selling the vision and some initial training maybe built into this stage. The flowchart for this stage is shown (see figure 11.08).

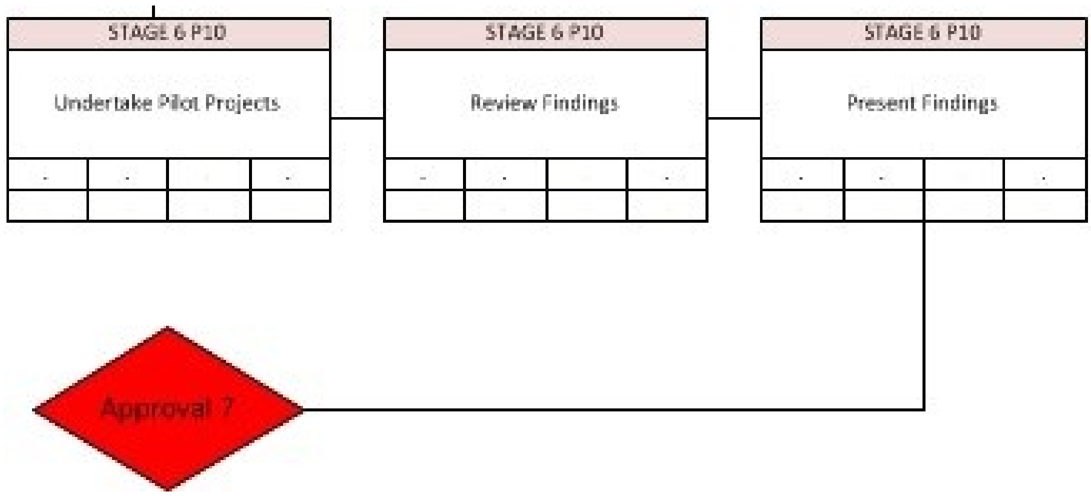


Figure 11.08: Flowchart of Stage 6 Undertaking the Prototype Projects

There are two types of prototype project recommended:

- Redo a typical project already done by the old process (this allow the results to be compared

- Undertake new pilot projects to demonstrate new capabilities

As the prototypes projects formed the basis of internal training given in the practice the records kept of these projects were important. An important step added to the framework at this stage was training design and development which needs to take place alongside the prototype projects.

11.3.7 Stage 7 Mobilization for undertaking the live projects

It is necessary to mobilize for the active (business critical) BIM projects. There are many tasks to be performed here applying the knowledge collected from previous stages. The importance and time and effort required during this stage was not recognised within the original framework. In reality many of the activities here overlapped with the stage before and the stage after. This does not represent a particular problem if the activities are effectively managed as they were at John McCall Architects.

If gap analysis has been performed as recommended in an earlier stage it is a good idea to revisit this analysis at this time. Referring to gap analysis can ensure that all the important issues are dealt with before undertaking business critical projects.

When the BIM approach is adopted on business critical projects it is vital that it meets or exceeds the expectations that are in place. Failure to deliver and deliver in the appropriate form may result in credibility loss within the industry and financial and legal penalties. Even after undertaking pilot projects it is a good idea to consider fall back positions when BIM is implemented on mission critical projects. Ideally CAD staff and CAD tools should remain available as a possible fall-back position as was the case at John McCall Architects. Although in the case of John McCall Architects they were not required.

It is important to understand how BIM models and objects are expected to interact with other disciplines. None of the other disciplines were using BIM when John McCall Architects were adopting BIM. This is unlikely to be the case in the future were more and more companies from a range of disciplines are adopting BIM. The tasks identified for this stage is illustrated on the flowchart (see figure 11.09).

Perhaps the most important task here is to make sure that by changing the practices method of production to BIM the practices existing insurance remains valid.

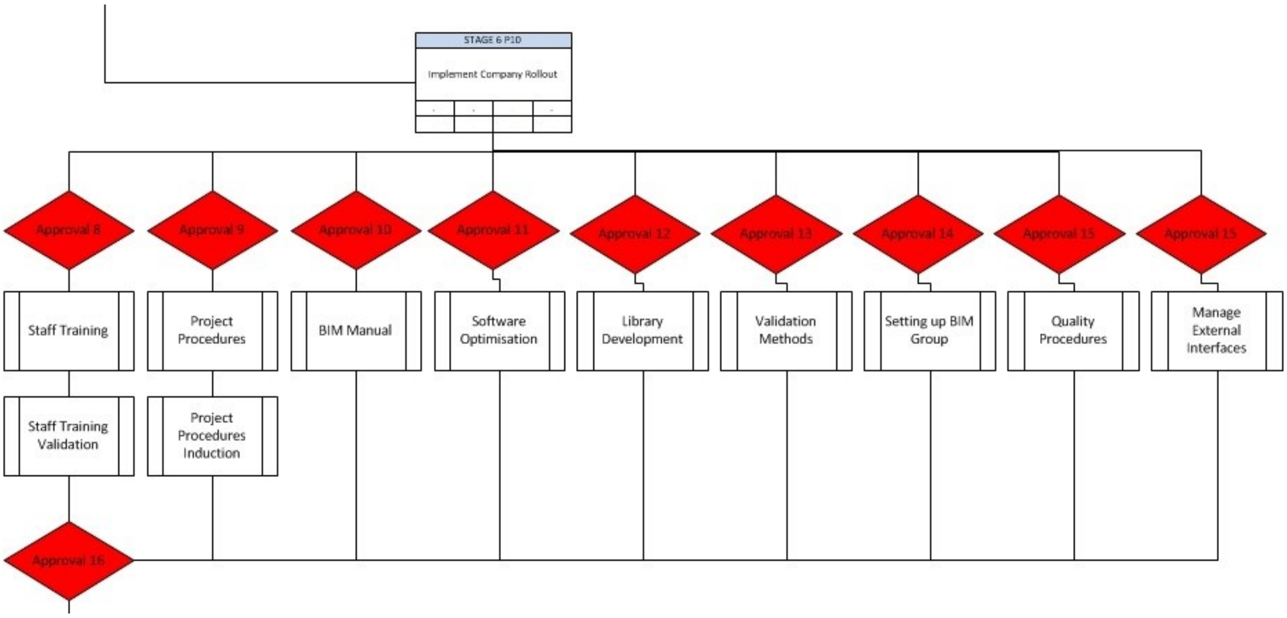


Figure 11.09: Flowchart of Stage 7 Implementation – Active Project Mobilization

11.3.8 Stage 8 Undertaking live projects using BIM

There were several live projects undertaken using BIM during the time of the research. By live projects we are referring to fee earning projects with fixed deliverables. Before undertaking these projects the directors of John McCall Architects had confirmed with the clients that BIM was to be used on these projects. Also that the output of these projects, would be the same, if not better than, projects using traditional processes. This approval is important. In reality undertaking the live projects using BIM is an on-going phase. How BIM is rolled out will be determined by the project requirements both from inside and outside of the practice and also the software and staff available.

Before commencing the live BIM projects it is recommended a meeting take place to determine the following factors:

1) What are we intending to do?

2) What functionality do we intend to demonstrate?

3) What do we intend to issue to other disciplines?

4) To confirm the software and hardware provision?

5) To confirm if software training by external parties is to take place at this time?

6) To discuss the level of detail to be provided

7) To discuss if a group presentation to the project team is necessary and how it should take place?

11.3.9 Stage 9 BIM implementation Review

Review is and exercise that should take place. It is important to verify the improvement principles set out at the outset were correct. This review is both in terms of the projects and capabilities that have been achieved. Taking the KPI's that have been established and reviewing before and after metric will allow a more in depth understanding of the success of otherwise of the BIM implementation. BIM competences, BIM metrics and maturity can also be reviewed at this stage. A stakeholder satisfaction review would also be helpful at this stage. New capabilities and markets should also be considered at this stage. Methods of facilitating continuous improvement of the BIM system that has been developed should also be put in place. An important activity that has been added to this stage is the dissemination of the lessons learnt as part of the BIM implementation project.

The tasks required at this have been illustrated in flowchart form (see figure 11.10).

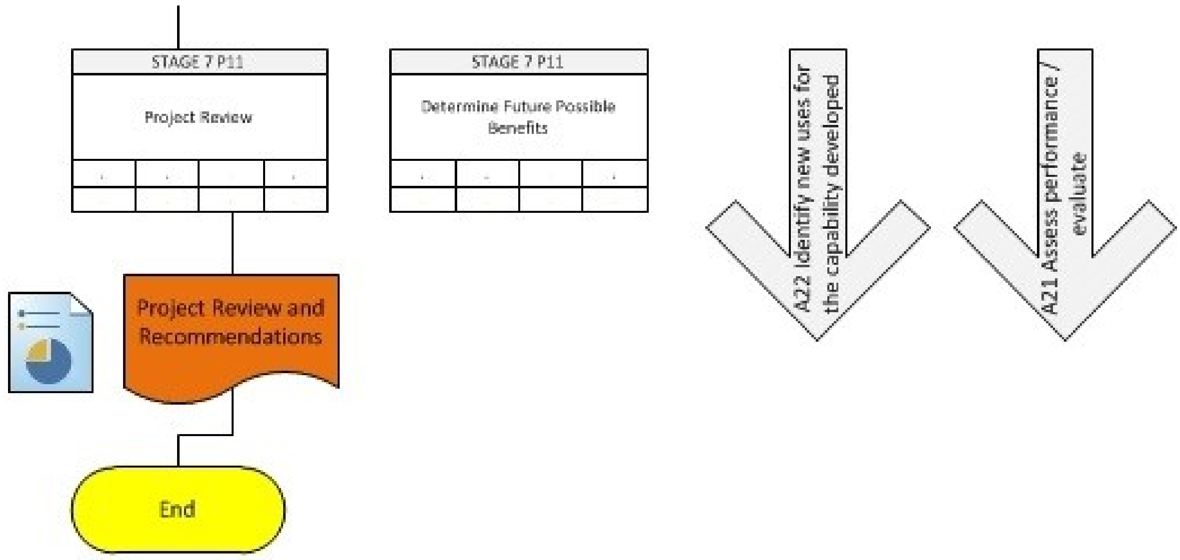


Figure 11.10: Flowchart of Stage 9 Review of the BIM implementation project

11.4 Summary of Chapter 11

The purpose of this chapter was to describe the development of the BIM implementation framework which was developed through a process of action research. This has been done at an overall level and the individual stages have been described in greater detail and the activities identified. It is believed this will provide a better more developed framework which can be used for small architectural practices starting down the road to BIM adoption.

Chapter 12

Chapter 12: This chapter draws up the conclusion the research into how BIM should be implemented in small architectural practices. The contribution to knowledge of this research is documented. Then the potential areas of future research following on from this thesis are suggested. The more fundamental question of if BIM should be implemented in small architectural practices is also touched on in this chapter.

CHAPTER 12: CONCLUSION

12.1 Introduction

This thesis has presented the results of a period of two years action research into the adoption of BIM in small architectural practices and the literature research associate with this endevour. This research formed the basis from which to propose an improved BIM implementation framework.

In this chapter how the objectives of this research were achieved is recorded. Then the contribution to knowledge of this thesis is documented. The main findings of this research are reiterated. Undertaking this research raised issues questions and concerns and these are also recorded here. This chapter concludes with possible future areas of research which were identified during the period this research.

The benefits of BIM have been documented as part of this research. Small architectural practices that do not adopt BIM are likely to be challenged in terms of the levels of productivity they can achieve and also be restricted to a reducing range projects in the UK were BIM is not mandated by their clients.

Through undertaking research into BIM implementation it has revealed how poorly served architects and in fact the wider construction industries are at this time when implementing BIM. The complexities and nuances of the BIM adoption process were experienced first-hand, documented and reflected upon as part of this research.

Practitioners not only have difficulty getting information related to BIM adoption, they may also be being fed information that is misleading or incorrect. The information available tends to explains why BIM should be adopted it fails to describe how BIM should be adopted. The issues are as much in the domain of business change management as they are strictly related to BIM.

Architects in small architectural practices have limited time to investigate the nuances and complexities of BIM, yet the implications are likely to be business critical. The lessons learnt and documented in this thesis aims to assist such practitioners when adopting BIM. The revised framework developed sets out the stages, activities and tasks that can be used to adopting BIM taking advantage of the experience and learning of those who have been through the process in the past (case based reasoning).

The framework tested and the refined framework subsequently proposed have been developed based on best practice research in relation to BIM and project management practices. The sequence of activities has been considered in terms of people, process and technology and the deliverables they need to achieve. This consideration has taken place at a practice and project level and also at a framework, stage and activity levels. By giving consideration at all of these levels a robust framework embracing socio technical issues has been produced.

Built into BIM adoption should be an enhanced knowledge and understand of the operation of the practice and methods of process improvement and change management. Such knowledge relates to BIM but also future change management programmes the practice may decide to undertake.

Listed are the journal and conference papers that have been written documenting the research that has been undertaken (see Table 12.01 Appendix B). These represent one method by which the knowledge acquired through this research was disseminated.

12.2 Achievement of the Research Aim and Objectives

The overall aim of this thesis was to develop a BIM Implementation strategy framework for small architectural practices in the UK. To pursue this aim five objectives were developed, which were addressed as applicable through literature review, data collection and action research. During this research the following research objectives were achieved in full. The findings associated with each objective are discussed throughout this thesis and are noted below.

Objective A - To explore the current practice and experience in small organisations in the Construction Industry and specifically architectural practices looking into challenges and issues of bringing in innovation was the objective here. Knowledge and understanding in this area was gained through literature review but also working for a time within a small architectural practice. The existing and future demands being placed on the profession were also documented.

Objective B - To review literature related to BIM and BIM implementation was the objective here. The shortfall in the guidance concerning BIM implementation became apparent through the period of research. To understand the concepts behind BIM was only possible by attending a range of different conferences, vendor presentations, professional body presentations, best practice forums and various Build Smart meetings. What became clear is the vast range of often difficult to reconcile viewpoints. Collectively these provided an understanding of what is BIM and the current state of the art in terms of BIM implementation.

There is considerably more literature on how to implement BIM on a project rather than to imbed BIM into a company. When BIM is implemented into a company it needs to mesh with the people and process necessary to deliver a successful product. Also developing the skills on techniques to optimise the tool or tools selected is also critical to success. A single literature resource is not available that adequately describes and explains the issues when implementing BIM. This is particularly true in relation to small architectural practices and the issues and problems they face. Secondly much of the literature particular in the media repeat what has already been said. Many of the statements do not flag up the issues and problem or indicate insights that are associated with various BIM tasks. While much of the academic literature provides a theoretical perspective, this alone cannot be relied upon to implemented BIM in practice.

Objective C - To understand the concepts behind BIM and the potential benefits of BIM was the objective here. Research into the concepts behind BIM raised as many questions. The confusion in this area relates to the differences between concepts and reality. What architectural practices need to deal with is the reality of what the tools and technologies will provide which fall short of what the concepts promise. Through the review of case studies an understanding of the benefit of BIM was achieved.

Objective D - To specify a framework of BIM implementation strategy to make the practice of architecture more effective and efficient. Identifying the key aspects of the framework. Using project management, change management and BIM deployment guidance an initial BIM implementation framework was developed. This was a specific framework for the adoption of BIM at John McCall Architects.

Objective E - To refine and enhance the initial BIM implementation framework by using the measures and results from the testing and experimentation on a real BIM implementation project was the objective here. This was achieved through testing the BIM implementation framework through action research at John McCall Architects. This proved to be challenging, problematic and rewarding. Testing in a real situation revealed the true issues when implementing BIM. The result was a generic framework applicable to small architectural practices adopting BIM.

Validation was also achieved theoretically through the presentation of the research at professional forums, workshops and publications. (Please see Appendix B for the list of publications). However, further empirical validation and improvement can be possible by monitoring the implementation of BIM in other small architectural practices.

12.3 The Contribution to Knowledge

There are those that suggest that the fundamental aim of action research is to improve practice rather than produce knowledge (Elliot 1991). Reason and Bradbury (2006) suggest, the primary purpose of action research is to produce practical knowledge. This thesis lays out a structure for BIM implementation.

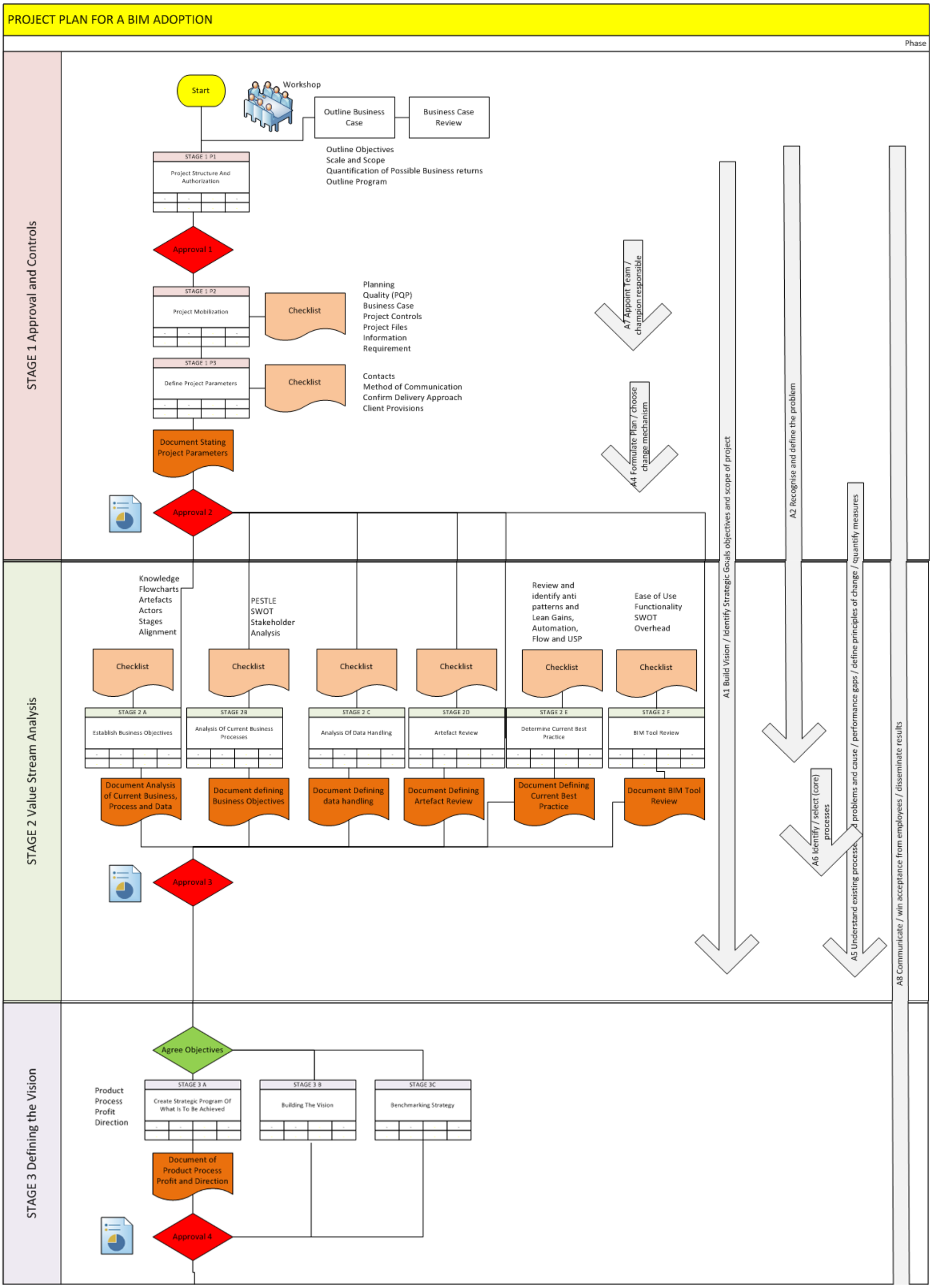
This research consolidates the main aspect of BIM affecting small architectural practices thus assisting the wider implementation of BIM in the UK in practical terms. It adds to the body of knowledge for developing a sound BIM strategy and guidance. This is supported by a wide range of literature result covering areas not traditional addressed in BIM implementation literature. An attempt has been made particular using FAST analysis to understand the root of the issues involved. In the case of this thesis the focus is on small architectural practices, a key component of construction industry. Architectural practice is a complex and demanding activity. When BIM is adopted it needs to meet those complex demands and address them effectively.

Although the primarily research was undertaken in an individual company, the implementation framework can be also applicable to other practices and situations. As part of the evaluation of the BIM implementation the research was able to consider the findings at the case study company again his personal experience working within other architectural companies or organisation.

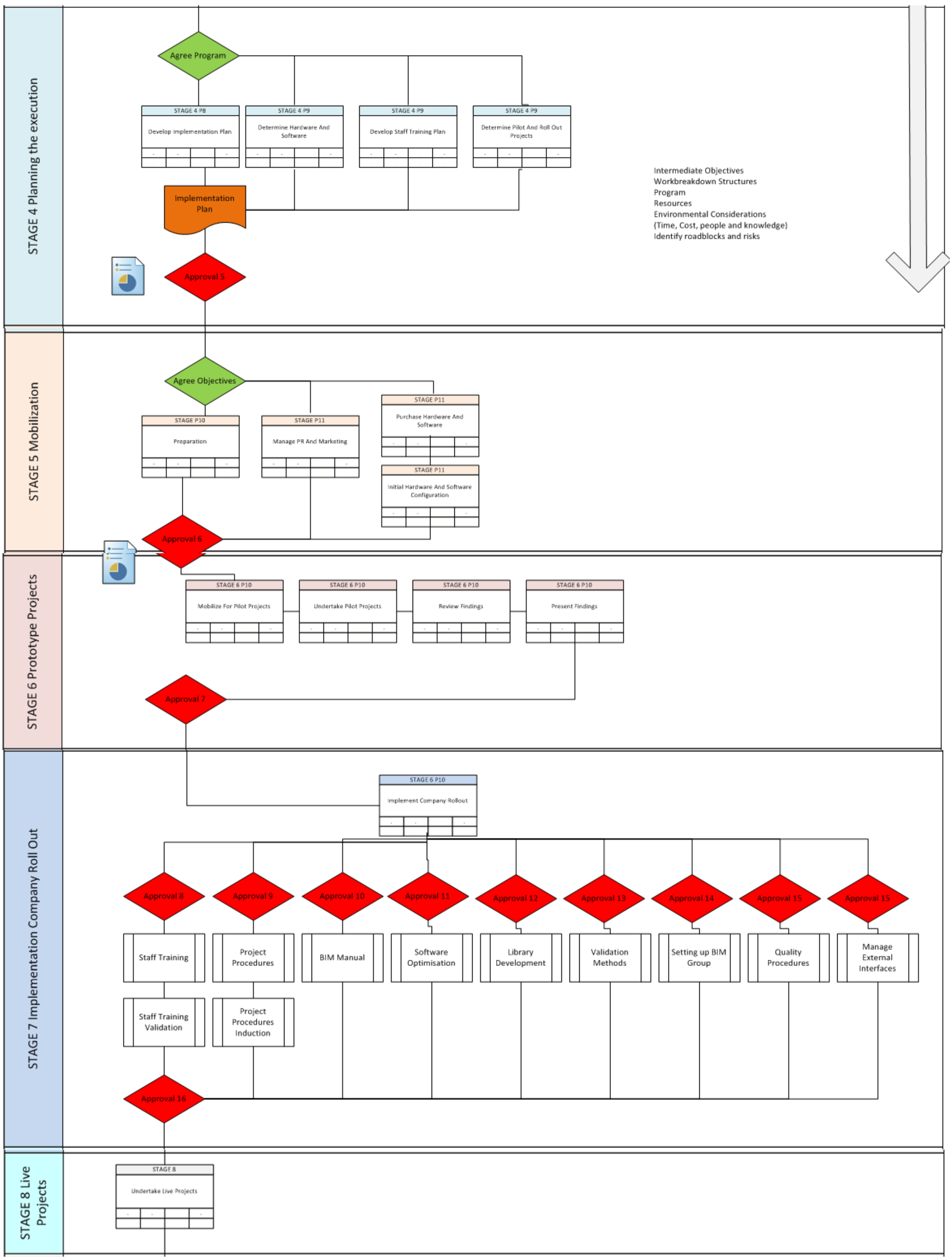
This thesis makes a number of significant and original contributions in the area of BIM implementation. As explained in chapter one this research is transitional research aiming to at take theory and making it usable in practice. Here lies the major contribution of this research. The basic concepts of BIM are illustrated and then it is shown how by undertaking certain management approaches and methods how BIM can be adopted in practice.

Through process analysis and soft system research this thesis sheds new light on the processes and problems that currently take place within architectural practices and the issues they face.

An important element of this thesis is to place BIM implementation into a project management framework. This framework identifies key stages and task necessary in the adoption of BIM (see figure 12.01). The significance of the various stages are described in depth in the previous chapter.



PROJECT PLAN FOR A BIM ADOPTION
Phase
STAGE 1 Approval and Controls
Start
Workshop
Outline Business Case
Business Case Review
Outline Objectives
Scale and Scope
Quantification of Possible Business returns
Outline Program
STAGE 1 P1
Project Structure And Authorization
Approval 1
STAGE 1 P2
Project Mobilization
Checklist
Planning
Quality (PQP)
Business Case
Project Controls
Project Files
Information
Requirement
STAGE 1 P3
Define Project Parameters
Checklist
Contacts
Method of Communication
Confirm Delivery Approach
Client Provisions
Document Stating Project Parameters
Approval 2
A7 Appoint Team / champion responsible
A4 Formulate Plan / choose change mechanism
A1 Build Vision / Identify Strategic Goals objectives and scope of project
A2 Recognise and define the problem
A5 Understand existing processes and problems and cause / performance gaps / define principles of change / quantify measures
A8 Communicate / win acceptance from employees / disseminate results
A6 Identify / select (core) processes
STAGE 2 Value Stream Analysis
Knowledge
Flowcharts
Artefacts
Actors
Stages
Alignment
PESTLE
SWOT
Stakeholder
Analysis
Review and identify anti patterns and Lean Gains, Automation, Flow and USP
Ease of Use
Functionality
SWOT
Overhead
Checklist
Checklist
Checklist
Checklist
Checklist
Checklist
STAGE 2 A
Establish Business Objectives
STAGE 2B
Analysis Of Current Business Processes
STAGE 2 C
Analysis Of Data Handling
STAGE 2D
Artefact Review
STAGE 2 E
Determine Current Best Practice
STAGE 2 F
BIM Tool Review
Document Analysis of Current Business, Process and Data
Document defining Business Objectives
Document Defining data handling
Document Defining Artefact Review
Document Defining Current Best Practice
Document BIM Tool Review
Approval 3
STAGE 3 Defining the Vision
Agree Objectives
Product
Process
Profit
Direction
STAGE 3 A
Create Strategic Program Of What Is To Be Achieved
STAGE 3 B
Building The Vision
STAGE 3C
Benchmarking Strategy
Document of Product Process Profit and Direction
Approval 4



STAGE 4 Planning the execution
Agree Program
STAGE 4 P8
Develop Implementation Plan
STAGE 4 P9
Determine Hardware And Software
STAGE 4 P9
Develop Staff Training Plan
STAGE 4 P9
Determine Pilot And Roll Out Projects
Implementation Plan
Approval 5
Intermediate Objectives
Workbreakdown Structures
Program
Resources
Environmental Considerations
(Time, Cost, people and knowledge)
Identify roadblocks and risks
STAGE 5 Mobilization
Agree Objectives
STAGE P10
Preparation
STAGE P11
Manage PR And Marketing
STAGE P11
Purchase Hardware And Software
STAGE P11
Initial Hardware And Software Configuration
Approval 6
STAGE 6 Prototype Projects
STAGE 6 P10
Mobilize For Pilot Projects
STAGE 6 P10
Undertake Pilot Projects
STAGE 6 P10
Review Findings
STAGE 6 P10
Present Findings
Approval 7
STAGE 7 Implementation Company Roll Out
STAGE 6 P10
Implement Company Rollout
Approval 8
Approval 9
Approval 10
Approval 11
Approval 12
Approval 13
Approval 14
Approval 15
Approval 15
Staff Training
Project Procedures
BIM Manual
Software Optimisation
Library Development
Validation Methods
Setting up BIM Group
Quality Procedures
Manage External Interfaces
Staff Training Validation
Project Procedures Induction
Approval 16
STAGE 8 Live Projects
STAGE 8
Undertake Live Projects

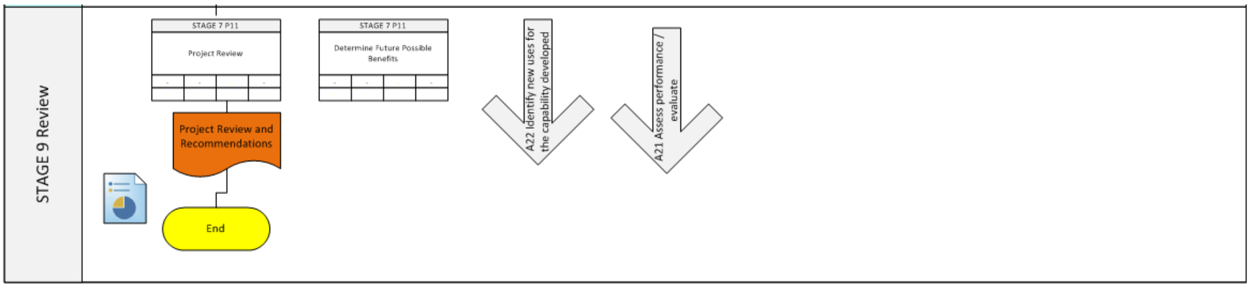


Figure 12.01: The flowchart of the BIM implementation Framework

Strategies for developing best practice review in architectural practice have also been documented in detail.

Methods of BIM tool evaluation were developed as part of this research. This methodology should be particular helpful those practices that need to make a similar BIM tool selection.

The task of BIM tool optimisation has also be documented enabling practices and organisations adopting BIM to get the most from the technology they adopt.

The evaluation, development and execution of the training necessary to adopt BIM have been described in detail. This should help those who need to undertake similar tasks.

New technologies gain traction when their benefits are meaningful and sustainable to their users. What has been shown is not just how BIM may be adopted but by analysis and prototyping also how it can be tailored to the needs of a specific architectural organisation.

This thesis also provides guidance how internal standards and manuals and training regimes for architectural practice can be developed. These are all critical to a successful BIM adoption.

Although this research is to develop a framework for the UK many of its findings and contents are likely to be applicable to small architectural practices working in other countries and also to larger architectural organisations.

12.4 The Main Conclusions

The main conclusion of this research is to note the complexity of implementing BIM. This is because of the number, variety and interdependence of the tasks necessary and the wide range of skills called on. Adopting BIM is a change that requires a change in people skills, process and technology. BIM adoptions are also likely to take place within constrains on time, finance and resources and also demand quality deliverable as to final output. In order to architectural practices to effectively adopt BIM they have to understand their existing business processes, unique selling points and business drivers.

This thesis has provided information on a change management model for BIM implementation model validated through action research. But as part of this research the ineffectiveness of interoperability between certain BIM tools has be shown as a major stumbling block to effective BIM implementation.

The main conclusions from this work were as follows:

- BIM implementation needs to address the specific needs of the company, while BIM projects needs to address the needs of the project
- BIM adoption is about leadership applied in the correct direction with an appropriate level of knowledge
- BIM implementation needs to integrate with the schedules and requirements of the practice and the projects being undertaken.
- BIM implementation will be influenced by legacy systems and ideas which exist or have existed in the company.
- Through BIM implementation, many additional opportunities and problem which cannot be predicted at the outset maybe found.
- There are many different options and routes by which BIM implementation maybe achieved. But new processes need to be developed which enable best practice. These then need to be standardized and embedded into the company.
- The business case should be central to any BIM implementation strategy.
- BIM implemental involves issues at the micro and the macro level.
- External stakeholders should be a major consideration in the BIM adoption process.
- In adopting BIM people, process and technological capabilities must be developed in parallel to achieve appropriate results
- Small architectural firms have little time to research so relevant information about BIM adoption needs to be easily available, comprehendible and in a form that can be instigated.
- When considering a project how well tools integrate together should form an important part of the selection process. The selection of software needs to be made to allow the appropriate documentation to be developed.

Adopting BIM can be a highly complex issue and task. It is business critical effecting production and revenue. Papanek (1985) in his book "Design for the Real World" expressed the view that first it is important to get things to work, later they can be made to work better. This represents an agile approach. External deliverables will continue to demand a level of acceptability determined by common practice within the profession in general. This is what sets the legal threshold determining professional negligence and liability. Yet when adopting BIM it is unlikely to be possible to get the internal operation 100 % correct the first time. Ideally using investigative action research the way BIM is used in the company will gravitate to more effective methods. The methods should continue enabling a system of learning circles and continual improvement to be put in place.

The aim of this research was to show how BIM can be adopted in small architectural practices. This has been demonstrated. What was achieved at John McCall Architects was very much prescribe and limited by vision of the directors.

At a more fundamental level the question can be asked should BIM be adopted by small architectural practices. The BIM adoption approach adopted at John McCall Architects was based on a benefit analysis. But findings from the case study company were inconclusive. Productivity gains were achieved but at a cost. A cost few small architecture practices can risk at a time of reducing workloads and fees.

The skills sets developed in order to use BIM must be weight against the other skill sets architectural practitioners need to develop. Architects primary focus must be on maintaining professional skill to deflect or mitigate potential liabilities.

John McCall Architects benefited from considerable academic input which facilitated the BIM adoption. Such help is unlikely to be available for other small practices. However BIM adoption is handled it represents a major disruption to processes and practices. It could also be suggested that many of the management exercises suggested as part of the BIM adoption are too sophisticated for small companies with limited resources.

BIM gave John McCall Architects a certain marketing kudos. But unless John McCall develops interoperability with other organisations the major shared benefits of BIM remain untapped. Taking the longer term view the adoption of BIM has the potential to pay dividends but few small practices can afford that luxury at this time.

These statements do no negate the value of this research but would suggest that BIM adoption and the approaches adopted at this time are more viable related to larger practices operating on more complex larger projects. In time as software and systems develop, a stronger argument to use BIM in small architectural practice is likely to develop.

12.5 Recommendations for Future Improvements

The major recommendation for the case study company is to develop interoperability with its stakeholders to achieve the collaborative benefits of BIM. Suggestions how this can be achieved are contained within the main body of the thesis. Also the greater standardization of objects and processes has the potential to develop increased efficiencies. The range of lean wastes were identified in chapter 4 of this thesis. An on-going search for lean efficiency in relation to BIM is likely to provide additional benefits. BIM is a rapidly developing approach and a continued review of external development is necessary in order to stay abreast of developments.

BIM is a data orientated technology as opposed to a knowledge orientated technology. Data is a low level resource which requires development to become information or knowledge. If it is possible to facilitate this transition of data to information and knowledge then the true power of BIM can be utilized.

Knowledge is never complete; all answers are provisional and open to critique. Future development will come from practitioners who ask questions and encourage others to do the same. My intent is that this research may continue to develop and evolve as social and technological changes occur with regard to BIM in architectural practice. There is ample scope for this study's research methodology to be taken up by other researchers.

This thesis focuses on BIM implementation in small architectural practices. The issues surrounding BIM adoption, organisational change, and the full utilization of BIM could each be a thesis topic in and of themselves and offer areas for future research.

Central to this thesis is bringing about organisational change with associated improvements in production and product (housing design). The strategies shown in the thesis are applicable to the adoption of BIM. But they are also applicable to other areas of organisational change. The strategic framework suggested could also be used, and tested against for other areas of practice improvement and other forms of product.

The use of BIM needs to be aligned both to the scientific and artistic needs of the architectural process as well as the wider development lifecycle. Although a process analysis was undertaken into the operation of architectural practice there is still much to be learnt about the way architectural practices operate. By undertaking further analysis on the specific tasks undertaking in architectural practice e.g. brief taking or site analysis, better alignment of BIM may be achieved. Further research is needed to better align BIM implementation to the RIBA stages or other project stages a project is required to progress through.

The BIM tool selected in the case study practice had a major impact on the way BIM was implemented. Future comparative research could be conducted to understand the significance and implications the BIM tool exerts on the overall BIM implementation framework.

Lean was an underlying theme to this research. Further research to the interactions of Lean and BIM could provide valuable knowledge and allow the development of better BIM tools. Also research BIM as part of wider adoption of enterprise architecture also offers an area of future research.

Design is the unique selling point of many architects and the BIM tools and practices available have a long way to go to adequately service this area of work. That having been said models particularly those that are based on a quantitative analysis can be build or developed to run alongside BIM authoring tools.

Further validation of the framework developed could be researched adopting a range of approaches. (The author is currently in discussion with BIM4SME's a group sponsored by the UK Government. It is hoped that this will provide a vehicle for further dialogue, dissemination and validation of this research.)

Successful BIM usage depends on collective adoption of BIM across the different disciplines and support by the client. Collaboration, working with others, the use of integrated data, between construction disciplines is recognised as a major benefit of BIM. Realising these interfaces other than in theory did not happen as part of the case study research.

As part of the BIM implementation project at John McCall Architects it was hoped to develop interoperability with other disciplines. Simple tests were undertaken issuing structural models to Alan Johnson structural engineers in Liverpool. This was the extent to the interoperability tested. This is an important are that needs to be investigated through action research.

Knowledge Management (KM) which comprises a range of practices used in an organization to identify, create, represent, distribute and enable adoption of insights and experiences. This could and should be investigated further as a facet of BIM.

12.6 Conclusion

Developing this thesis has been a journey. As an action researcher the author has been both a witness and been part of the changes taking place. Both the researcher and the practice have experienced change and been introduced to new areas of understanding and knowledge. Insights have been gained through being activity involved in the process that would not have been possible through observation alone.

Input has been sort from many sources. Change management, project management, future needs analysis, soft system analysis, lean thinking, architectural practices, lifecycle concerns, BIM development and interoperable technologies have all had their role to play. Gratitude for help from many sources is justified.

Many of the insights gained revealed how knowledge is available from many domains. But usually the knowledge set applied in a particular profession or industry is very focused. Best practice concepts and translatable technologies are available with the potential to provide major benefits. But as witnessed the drive in practices at all levels is production as opposed to developing better methods of production. Major benefit to the construction industry would be achieved if all operatives along with production where encourage to develop methods of better production. The workforce culture needs to be transformed to one that contributes ideas freely to proactively improve the process. Using this approach BIM and other potential benefits can be more easily realized in practice.

One problem when writing about BIM adoption is that BIM is a rapidly developing field. What is BIM and the expectations that are placed on BIM have and will change overtime. The reality is by changing building information into a machine readable form many technologies can and will coalesce with the BIM. New roles and even new disciplines may develop. Whatever framework is developed for BIM implementation it cannot be a substitute for professional and practice judgement in determining activities and techniques.

From this research it is also clear that architecture as a profession is not well served by technology, processes and skills required for the changes that are taking place. The achievement of widespread change within the construction industry will take time as participants learn the potential of IT and adopt the processes and skills necessary to utilize the same. There is a need not just to embrace IT but also to become an active initiating element in it development to achieve enhanced operation and deliverables. In this way the technology can enhance the human endeavours that are necessary as opposed to forcing those involved to adopted misaligned processes and methods.

Many traditional embedded concepts need to change. There is a need to change from 2d thinking to 3d thinking, to change from thinking about documents to thinking about data, to change from immediate deliverable consideration to lifecycle consideration. Vendors in both PLM and BIM domains need to take a note and re-think the way software works. Painless adoption, user experience and adaptive behaviour related to potential change are the elements need to become a priority for the next wave of BIM / PLM software.

The primary focus of our attention in the AEC industry with respect to technology is building information modelling (BIM). But dramatically improving productivity and efficiency in the building industry will not be achieved through BIM alone. We need to look beyond the building-specific and project-specific information that can be compiled in a BIM model to the entire information flow, workflow, and business processes needed to create and sustain the built environment. Thus we need to consider the enterprise architecture of architectural practice.

The interesting question is now how will the small architectural practice look five or ten years from now? It is possible that the things that are regarded as innovative as part of this thesis will be regarded as the traditional approach at this time. In the future new products (resulting in computer aided innovation) will be developed and more efficient methods of operation will emerge.

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Appendix A – Figures and Illustrations

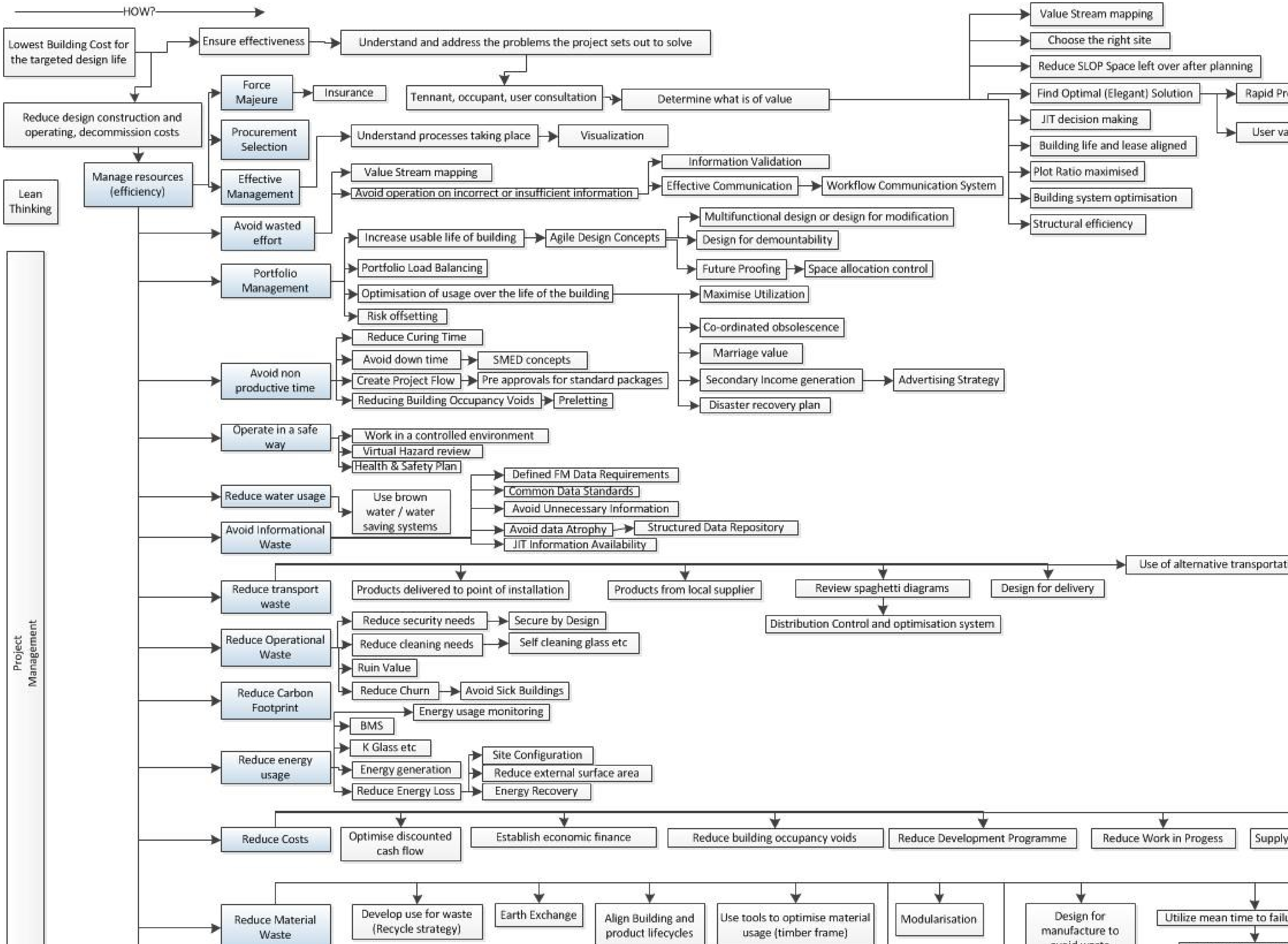
	Theme	Objective	Specific Actions and Timescales				Measures	Commentary
			2011	2012	2013	2014		
								EU procurement directives.
7.	**Building Information Modelling ("BIM")**	7(i) To introduce a progressive programme of mandated use of fully collaborative Building Information Modelling for Government projects by 2016.	7.1.1 Creation of the implementation plan and team to deliver. **(July 2011)**	7.1.2 Begin phased roll out to all Government Projects. **(From Summer 2012)**			Completion of agreed pilots.	Detailed implementation plan developed, published and team established. Projects identified in MOJ as early adopter. 4 sub groups established. The Construction Industry Council is providing support.
				7.2.2 Commence roll out of four MOJ pathfinder projects. All projects live. **(end 2012)**				Projects identified and in various stages of implementation.
				7.3.2 Define and mandate the expected standard (information set) for Government projects. **(April 2012)**			Commencement of roll out achieved.	UK Government structured data set, COBie UK 2012 is complete and templates have been published on the BIM Task Group website: www.bimtaskgroup.org
7.	**Building Information Modelling ("BIM")**							along with example files. PAS1192-2:2012 "Building Information Management – Information requirements for the capital delivery phase of construction projects" drafted and currently undergoing consultation. Once published in Summer 2012 it will be uploaded onto the website.
				7.4.2 Identify trial projects in multiple Departments to achieve delivery via 3D fully collaborative BIM. **(July 2012)**			Complete built record of the project available for the purposes of asset management.	Quick start cross departmental BIM workshops and surgeries ongoing.
					7.5.3 BIM strategy and execution programme			

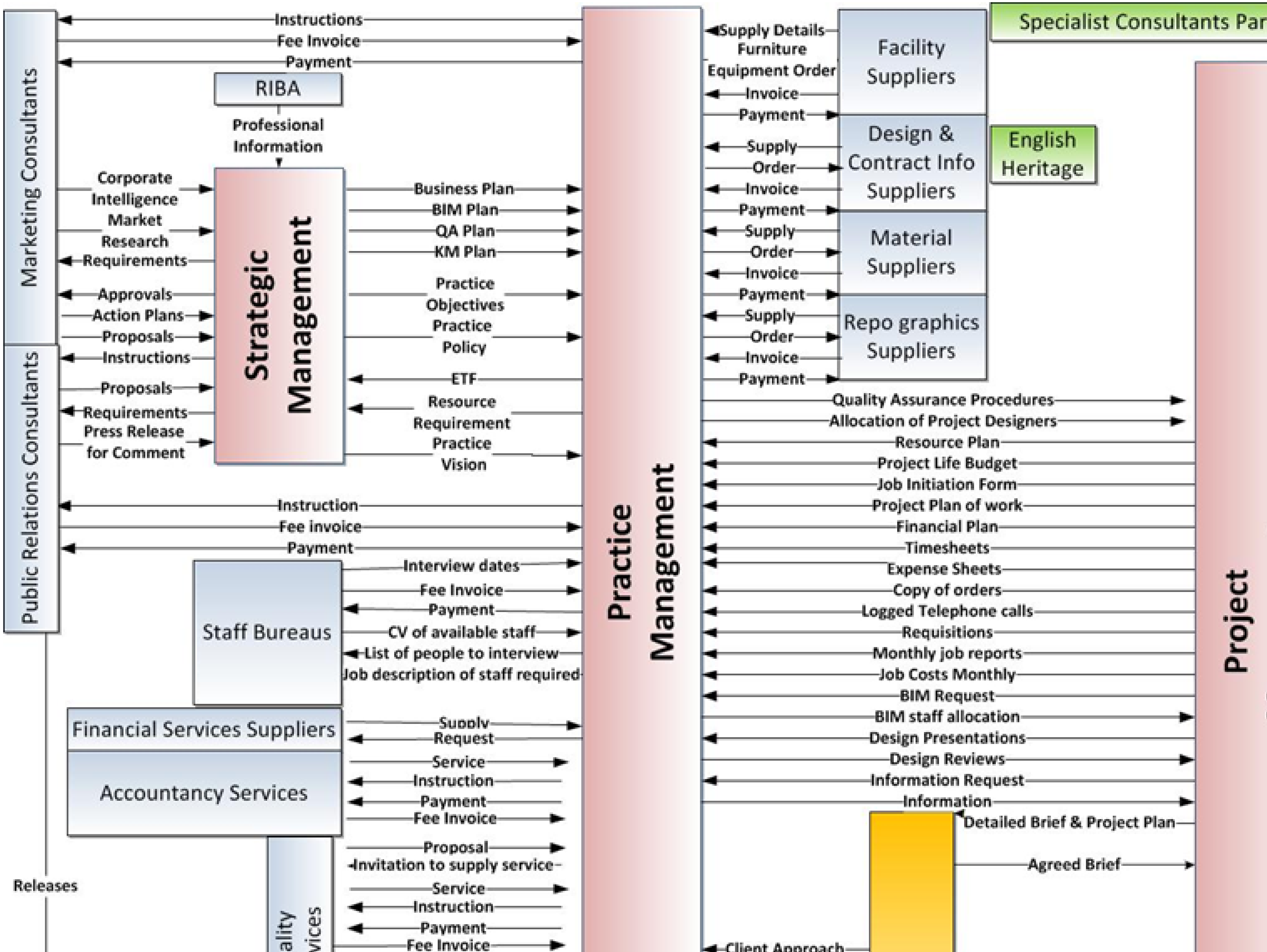
Table 3.03a: Extract from the Government Strategy Action (Revised July 2012) Item 7

	Theme	Objective	Specific Actions and Timescales				Measures	Commentary
			2011	2012	2013	2014		
7.	**Building Information Modelling ("BIM")**				created by 2 departments **(Spring 2013)** Additional 2 departments **(July 2013)** Remaining key spending departments **(end 2013)**			
				7.6.2 Creation of explicit departmental embarkation plans illustrating ramped maturity towards the 2016 horizon **(August 2012)**			Seven key spending departments to have embarkation plans.	
				7.7.2 BIM legal, commercial and insurance protocols crafted **(Autumn 2012)**				
				7.8.2 Regional BIM hubs go live enabling industry to deliver Government BIM requirements **(from Autumn 2012)**				The Construction Industry Council (C.I.C.) will be facilitating the roll out and management of the BIM Task Group Regional
7.	**Building Information Modelling ("BIM")**							Hub Network. These anchor networks are being mobilised and will go live Autumn 2012.
				7.9.2 Evaluate trial projects and make recommendations. **(Ongoing)**	7.9.2 Evaluate trial projects and make recommendati ons.	7.9.2 Evaluate trial projects and make recommendatio ns.		Criteria and standards being established against which trial projects will be evaluated.

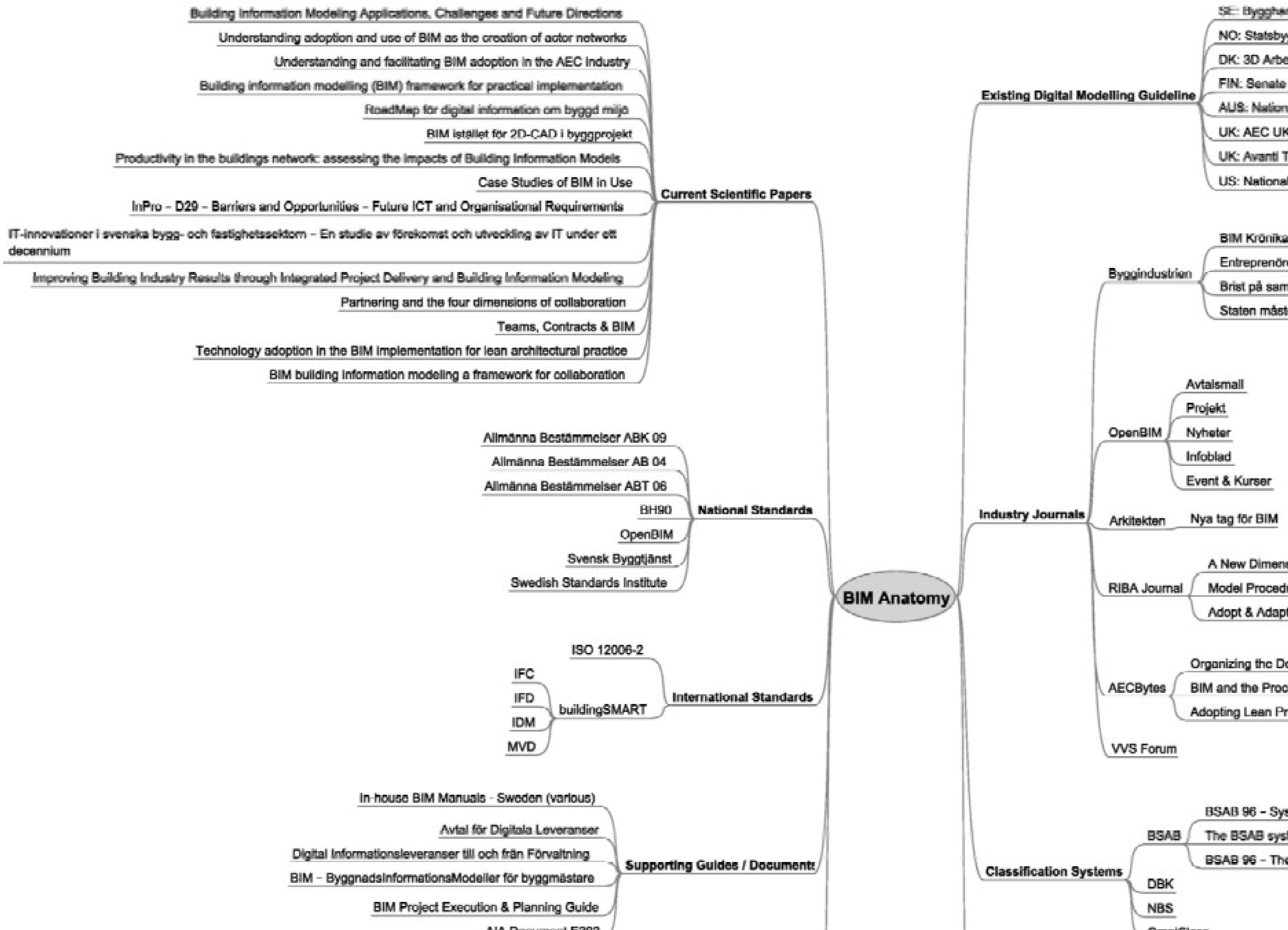
Key: Blue text: work stream completed
Green text: work stream ongoing
Purple text: work stream taken forward in an alternative way
Orange text: new work stream

Table 3.03b: Extract from the Government Strategy Action (Revised July 2012) Item 7


HOW?
Lowest Building Cost for the targeted design life
Ensure effectiveness
Understand and address the problems the project sets out to solve
Tennant, occupant, user consultation
Determine what is of value
Value Stream mapping
Choose the right site
Reduce SLOP Space left over after planning
Find Optimal (Elegant) Solution
Rapid Pr
User va
JIT decision making
Building life and lease aligned
Plot Ratio maximised
Building system optimisation
Structural efficiency
Reduce design construction and operating, decommission costs
Force Majeure
Insurance
Procurement Selection
Understand processes taking place
Visualization
Effective Management
Value Stream mapping
Avoid operation on incorrect or insufficient information
Information Validation
Effective Communication
Workflow Communication System
Lean Thinking
Manage resources (efficiency)
Avoid wasted effort
Multifunctional design or design for modification
Increase usable life of building
Agile Design Concepts
Design for demountability
Portfolio Management
Portfolio Load Balancing
Future Proofing
Space allocation control
Optimisation of usage over the life of the building
Maximise Utilization
Risk offsetting
Co-ordinated obsolescence
Reduce Curing Time
Marriage value
Avoid down time
SMED concepts
Avoid non productive time
Create Project Flow
Pre approvals for standard packages
Secondary Income generation
Advertising Strategy
Reducing Building Occupancy Voids
Preletting
Disaster recovery plan
Operate in a safe way
Work in a controlled environment
Virtual Hazard review
Health & Safety Plan
Defined FM Data Requirements
Reduce water usage
Use brown water / water saving systems
Common Data Standards
Avoid Unnecessary Information
Avoid Informational Waste
Avoid data Atrophy
Structured Data Repository
JIT Information Availability
Use of alternative transportati
Reduce transport waste
Products delivered to point of installation
Products from local supplier
Review spaghetti diagrams
Design for delivery
Distribution Control and optimisation system
Reduce security needs
Secure by Design
Reduce Operational Waste
Reduce cleaning needs
Self cleaning glass etc
Ruin Value
Reduce Carbon Footprint
Reduce Churn
Avoid Sick Buildings
Energy usage monitoring
BMS
K Glass etc
Site Configuration
Reduce energy usage
Energy generation
Reduce external surface area
Reduce Energy Loss
Energy Recovery
Reduce Costs
Optimise discounted cash flow
Establish economic finance
Reduce building occupancy voids
Reduce Development Programme
Reduce Work in Progess
Supply
Project Management
Reduce Material Waste
Develop use for waste (Recycle strategy)
Earth Exchange
Align Building and product lifecycles
Use tools to optimise material usage (timber frame)
Modularisation
Design for manufacture to
Utilize mean time to failu



Marketing Consultants
Public Relations Consultants
Instructions
Fee Invoice
Payment
RIBA
Professional Information
Corporate Intelligence
Market Research
Requirements
Approvals
Action Plans
Proposals
Instructions
Proposals
Requirements
Press Release for Comment
Strategic Management
Business Plan
BIM Plan
QA Plan
KM Plan
Practice Objectives
Practice Policy
ETF
Resource Requirement
Practice Vision
Instruction
Fee invoice
Payment
Staff Bureaus
Interview dates
Fee Invoice
Payment
CV of available staff
List of people to interview
Job description of staff required
Financial Services Suppliers
Supply
Request
Accountancy Services
Service
Instruction
Payment
Fee Invoice
Proposal
Invitation to supply service
Service
Instruction
Payment
Fee Invoice
ality
vices
Releases
Practice Management
Supply Details
Furniture
Equipment Order
Invoice
Payment
Facility Suppliers
Specialist Consultants Par
Supply
Order
Invoice
Payment
Design & Contract Info Suppliers
English Heritage
Supply
Order
Invoice
Payment
Material Suppliers
Supply
Order
Invoice
Payment
Repo graphics Suppliers
Quality Assurance Procedures
Allocation of Project Designers
Resource Plan
Project Life Budget
Job Initiation Form
Project Plan of work
Financial Plan
Timesheets
Expense Sheets
Copy of orders
Logged Telephone calls
Requisitions
Monthly job reports
Job Costs Monthly
BIM Request
BIM staff allocation
Design Presentations
Design Reviews
Information Request
Information
Detailed Brief & Project Plan
Agreed Brief
Client Approach
Project


BIM Anatomy
Current Scientific Papers
Building Information Modeling Applications, Challenges and Future Directions
Understanding adoption and use of BIM as the creation of actor networks
Understanding and facilitating BIM adoption in the AEC Industry
Building information modelling (BIM) framework for practical implementation
RoadMap för digital information om byggd miljö
BIM istället för 2D-CAD i byggprojekt
Productivity in the buildings network: assessing the impacts of Building Information Models
Case Studies of BIM in Use
InPro – D29 – Barriers and Opportunities – Future ICT and Organisational Requirements
IT-innovationer i svenska bygg- och fastighetssektorn – En studie av förekomst och utveckling av IT under ett decennium
Improving Building Industry Results through Integrated Project Delivery and Building Information Modeling
Partnering and the four dimensions of collaboration
Teams, Contracts & BIM
Technology adoption in the BIM implementation for lean architectural practice
BIM building information modeling a framework for collaboration
National Standards
Allmänna Bestämmelser ABK 09
Allmänna Bestämmelser AB 04
Allmänna Bestämmelser ABT 06
BH90
OpenBIM
Svensk Byggtjänst
Swedish Standards Institute
International Standards
ISO 12006-2
buildingSMART
IFC
IFD
IDM
MVD
Supporting Guides / Documents
In-house BIM Manuals - Sweden (various)
Avtal för Digitala Leveranser
Digital Informationsleveranser till och från Förvaltning
BIM – ByggnadsInformationsModeller för byggmästare
BIM Project Execution & Planning Guide
Existing Digital Modelling Guideline
SE: Byggha
NO: Statsby
DK: 3D Arbe
FIN: Senate
AUS: Nation
UK: AEC UK
UK: Avanti T
US: National
Industry Journals
Byggindustrien
BIM Krönika
Entreprenör
Brist på sam
Staten måst
OpenBIM
Avtalsmall
Projekt
Nyheter
Infoblad
Event & Kurser
Arkitekten
Nya tag för BIM
RIBA Journal
A New Dimen
Model Proced
Adopt & Adapt
AECBytes
Organizing the D
BIM and the Proc
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BSAB
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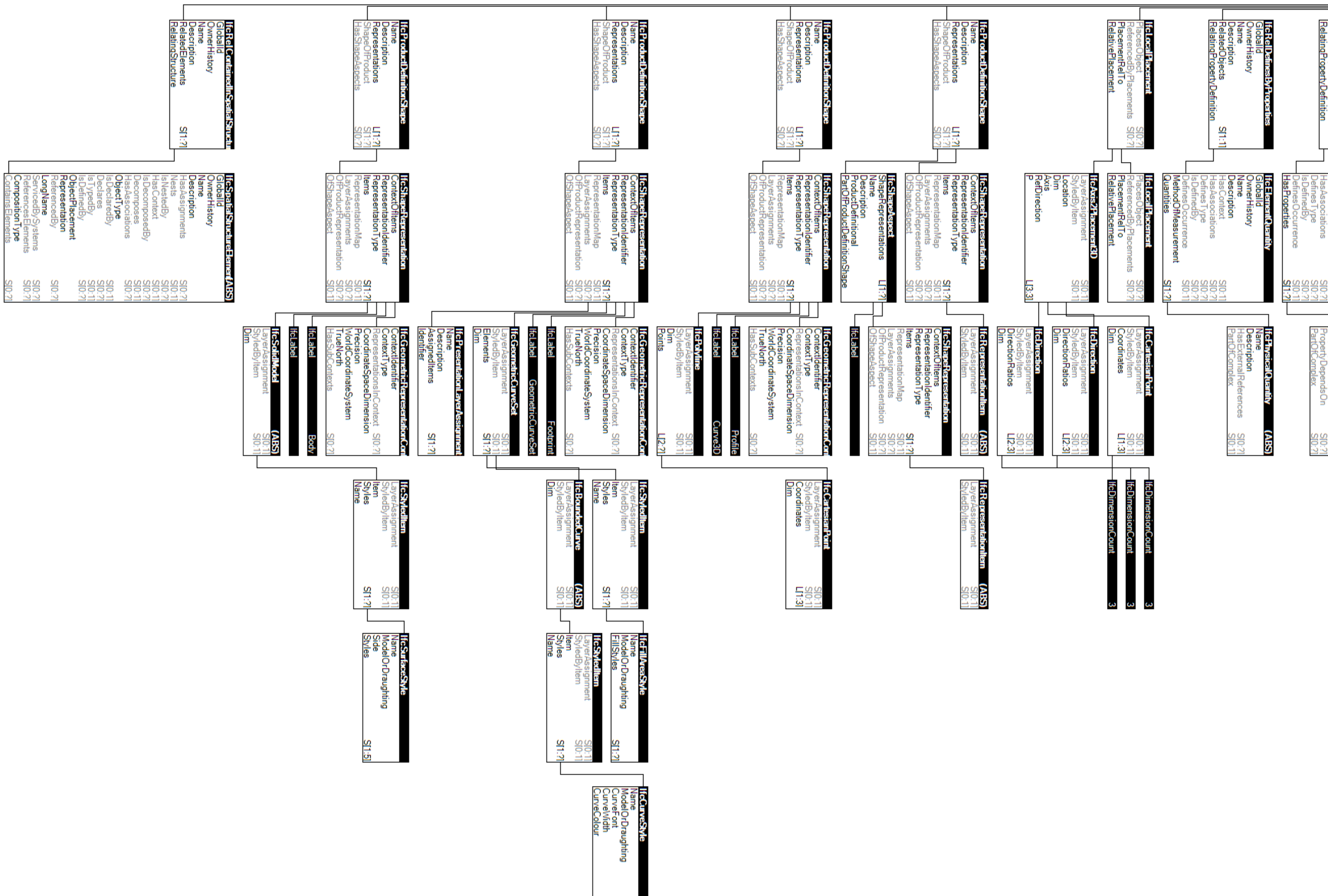
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Footprint
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Curve3D
Profile
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IfcStyledItem
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IfcSurfaceStyle
IfcFillAreaStyle
IfcCurveStyle

COBie Responsibility Matrix

version	1
COBie version	2.4
date	25-Aug-11

purpose: this worksheet can be used to identify the party responsible to complete COBie worksheet infomration during the course of a project

instructions:
1. list every company participating in the creation of COBie data in the "company" column of the legend
   if needed add additional rows until all companies are listed
2. for each company provide point of contact information to ensure accountability
3. provide a different color code for each company
4. follow the process of the job from concept through handover and paint the approriate color code in the cells
5. cells remaining should be checked to see if they are not required, if not required code as noted in the legend.
6. save and date the file as PDF and distribute to the team

legend

Company	POC Name	POC Email	POC Phone	Color Code
owner				paint color to use
designer				paint color to use
consultant				paint color to use
prime contractor				paint color to use
Owner O&M Champion				paint color to use
Data Integrator				paint color to use
sub contractor A				paint color to use
sub contractor B				paint color to use
commissioning				paint color to use
not used or n/a	-	-	-	paint color to use

Worksheet -> / Column	Contact	Facility	Floor	Space	Zone	Type	Component	System	Assembly	Connection	Spare	Resource	
1	Email	Name	Name	Name	Name	Name	Name	Name	Name	Name	Name	Name	Na
2	CreatedBy	CreatedBy	CreatedBy	CreatedBy	CreatedBy	CreatedBy	CreatedBy	CreatedBy	CreatedBy	CreatedBy	CreatedBy	CreatedBy	Cr
3	CreatedOn	CreatedOn	CreatedOn	CreatedOn	CreatedOn	CreatedOn	CreatedOn	CreatedOn	CreatedOn	CreatedOn	CreatedOn	CreatedOn	Cr
4	Category	Category	Category	Category	Category	Category	TypeName	Category	SheetName	ConnectionType	Category	Category	Ca
5	Company	ProjectName	ExtSystem	FloorName	SpaceNames	Description	Space	ComponentNames	ParentName	SheetName	TypeName	ExtSystem	St
6	Phone	SiteName	ExtObject	Description	ExtSystem	AssetType	Description	ExtSystem	ChildNames	RowName1	Suppliers	ExtObject	Ty
7	ExtSystem	LinearUnits	ExtIdentifier	ExtSystem	ExtObject	Manufacturer	ExtSystem	ExtObject	AssemblyType	RowName2	ExtSystem	ExtIdentifier	De
8	ExtObject	AreaUnits	Description	ExtObject	ExtIdentifier	ModelNumber	ExtObject	ExtIdentifier	ExtSystem	RealizingElement	ExtObject	Description	Du
9	ExtIdentifier	VolumeUnits	Elevation	ExtIdentifier	Description	WarrantyGuarantorParts	ExtIdentifier	Description	ExtObject	PortName1	ExtIdentifier		Du
10	Department	CurrencyUnit	Height	RoomTag		WarrantyDurationParts	SerialNumber		ExtIdentifier	PortName2	Description		St
11	OrganizationCode	AreaMeasurement		UsableHeight		WarrantyGuarantorLabor	InstallationDate		Description	ExtSystem	SetNumber		Ta
12	GivenName	ExternalSystem		GrossArea		WarrantyDurationLabor	WarrantyStartDate			ExtObject	PartNumber		Fr
13	FamilyName	ExternalProjectObject		NetArea		WarrantyDurationUnit	TagNumber			ExtIdentifier			Fr
14	Street	ExternalProjectIdentifier				ExtSystem	BarCode			Description			Ex
15	PostalBox	ExternalSiteObject				ExtObject	AssetIdentifier						Ex
16	Town	ExternalSiteIdentifier				ExtIdentifier							Ex
17	StateRegion	ExternalFacilityObject				ReplacementCost							Ta
18	PostalCode	ExternalFacilityIdentifier				ExpectedLife							Pr
19	Country	Description				DurationUnit							Re
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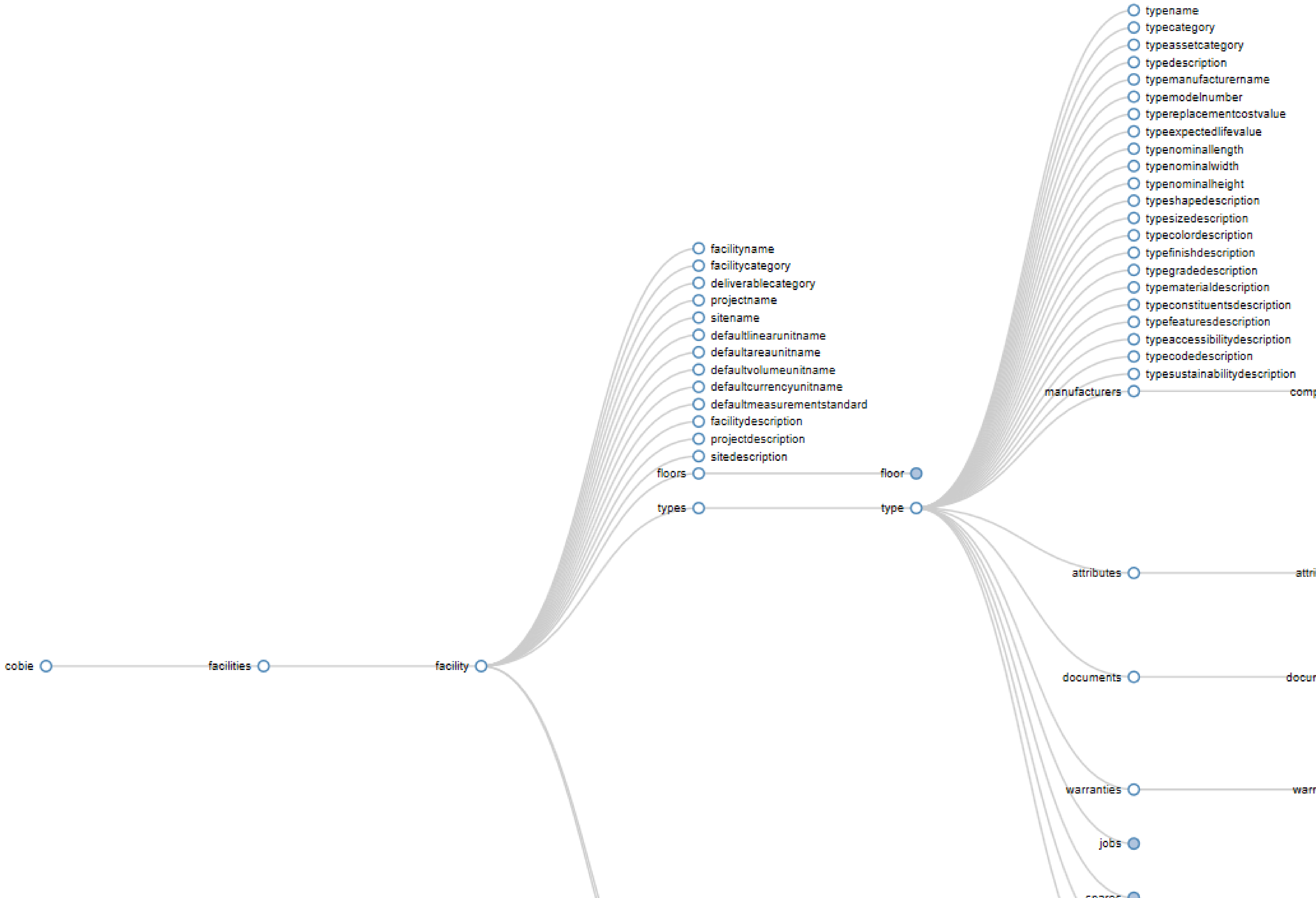
21		SiteDescription				NominalLength							
22		Phase				NominalWidth							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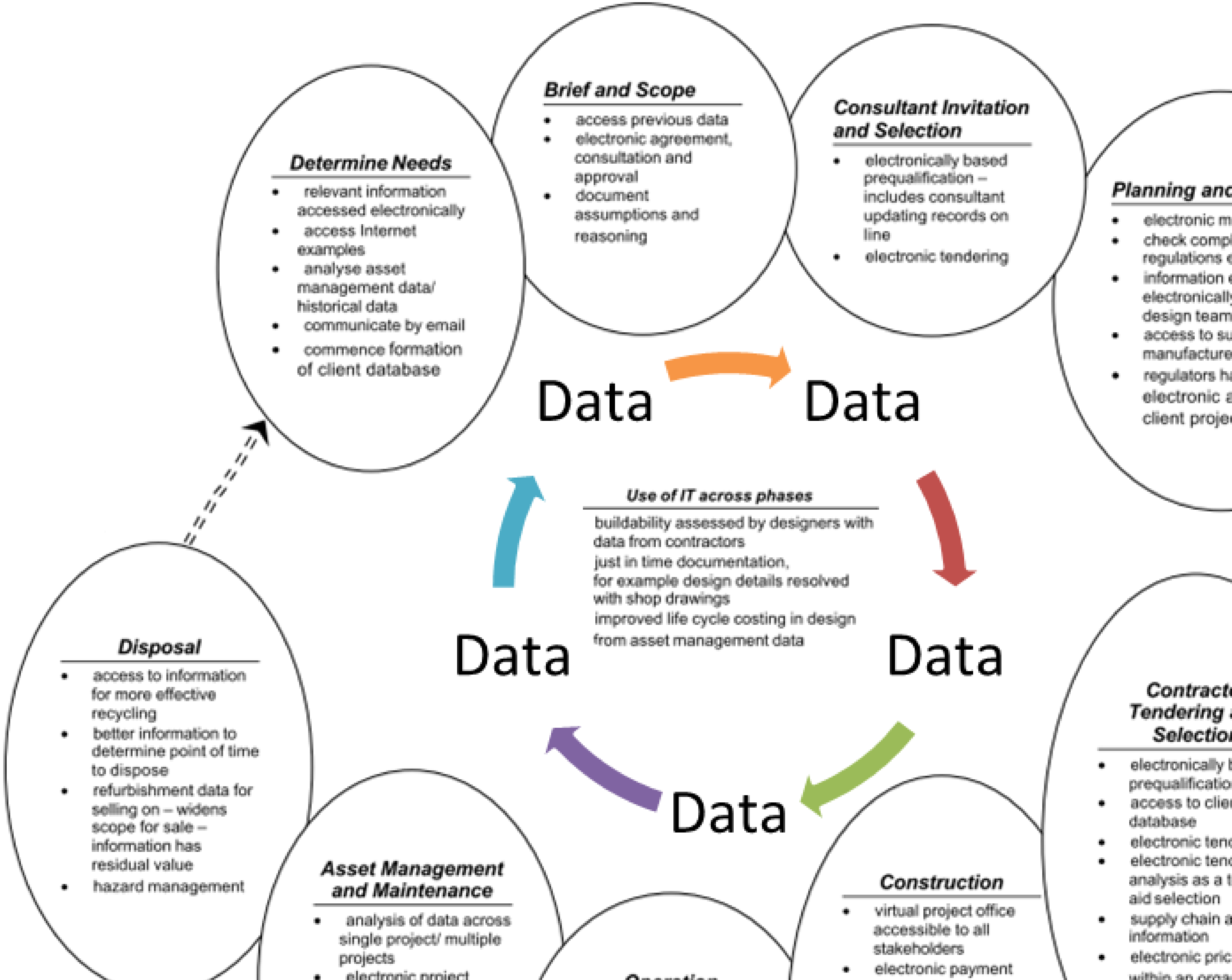
warranties
jobs



Determine Needs
relevant information accessed electronically
access Internet examples
analyse asset management data/ historical data
communicate by email
commence formation of client database
Brief and Scope
access previous data
electronic agreement, consultation and approval
document assumptions and reasoning
Consultant Invitation and Selection
electronically based prequalification – includes consultant updating records on line
electronic tendering
Data
Data
Data
Data
Data
Use of IT across phases
buildability assessed by designers with data from contractors
just in time documentation, for example design details resolved with shop drawings
improved life cycle costing in design from asset management data
Disposal
access to information for more effective recycling
better information to determine point of time to dispose
refurbishment data for selling on – widens scope for sale – information has residual value
hazard management
Asset Management and Maintenance
analysis of data across single project/ multiple projects
Construction
virtual project office accessible to all stakeholders
electronic payment

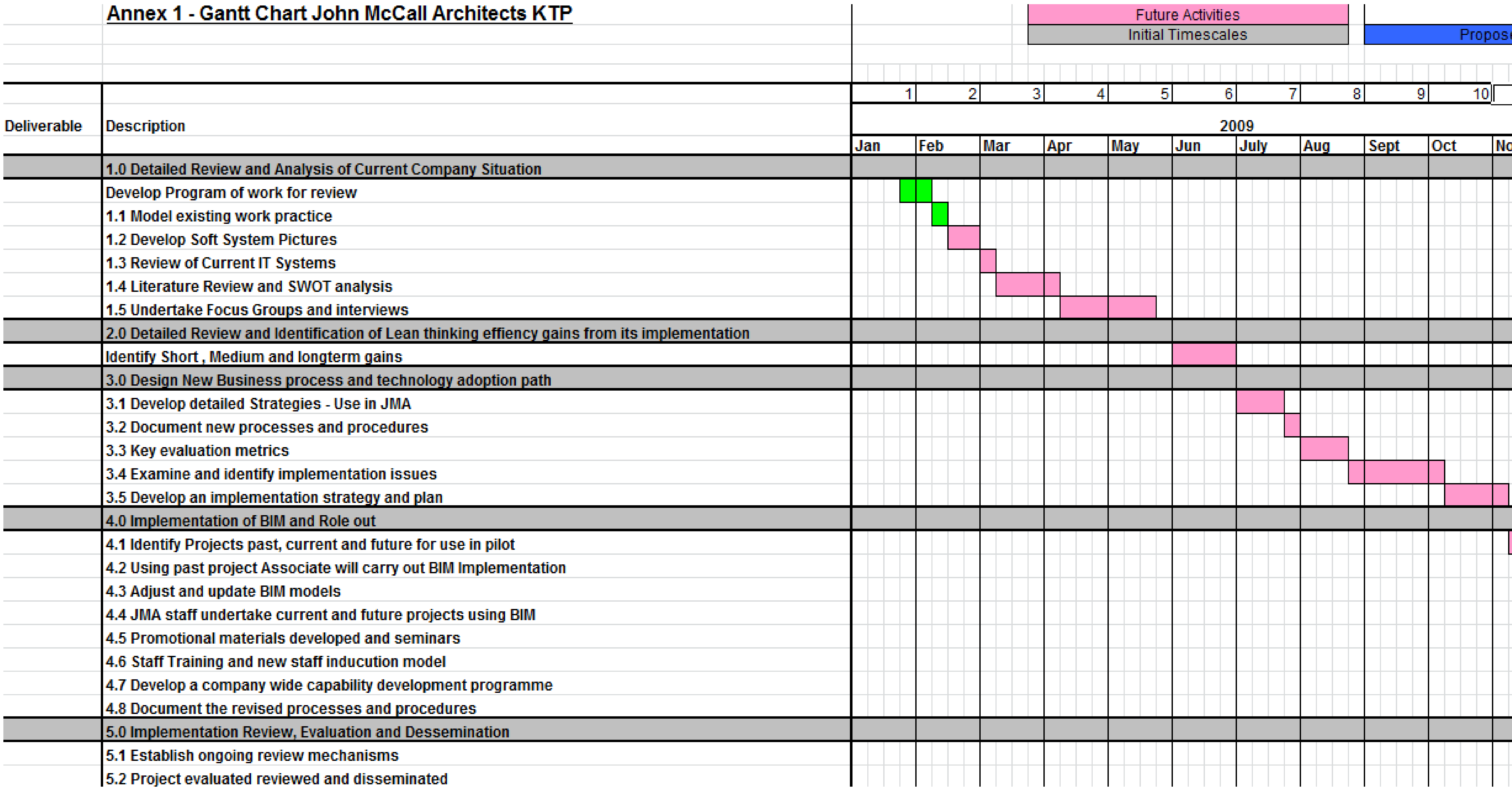
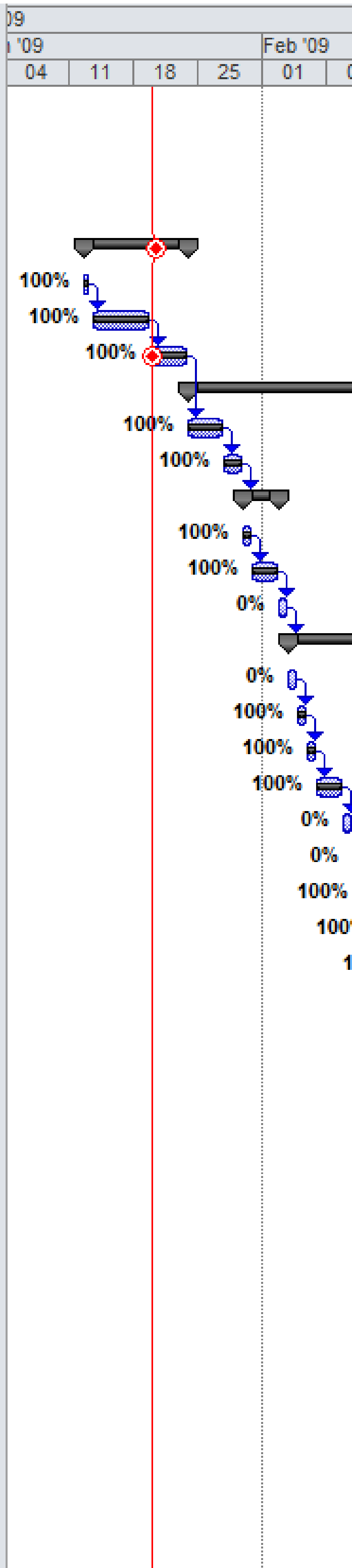
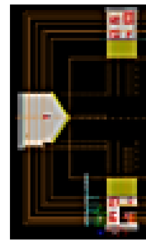


Figure 6.06: A simple Program Used at John McCall Architect to implement BIM

	Task Name	Duration	Resource Names	Start		Finish	P	Add New Co
1	Executive Summery Report for LNC to KTP Office	1 day?		Mon 16/02/09		Mon 16/02/09		
2	LMC Meeting	1 day?		Tue 24/02/09		Tue 24/02/09		
3	LJMU Regional KTP Associate Event	1 day?		Wed 18/03/09		Wed 18/03/09		
4	KTP Associates Conference in Brighton	1 day	Paul KTP	Wed 29/04/09		Wed 29/04/09		
5	**Ojective 1 - Detailed Review and Analysis of Current Company Situation**	**10 days?**	**Paul KTP**	**Mon 12/01/09**		**Fri 23/01/09**		
6	Review with University Supervisor	1 day?	Paul KTP	Mon 12/01/09		Mon 12/01/09		
7	Initial company review by KTP	5 days?	Paul KTP	Tue 13/01/09		Mon 19/01/09	6	
8	Develop Program of work for review	4 days	Paul KTP	Mon 19/01/09		Fri 23/01/09	7	
9	**1.1 Model existing work practice**	**23 days?**	**Paul KTP**	**Fri 23/01/09**		**Wed 25/02/09**		
10	Communication flow diagrams	2 days	Paul KTP	Fri 23/01/09		Tue 27/01/09	8	
11	Activity Sequence Diagrams	2 days	Paul KTP	Tue 27/01/09		Thu 29/01/09	10	
12	**Cultural Aspect Diagrams**	**2 days?**	**Paul KTP**	**Thu 29/01/09**		**Mon 02/02/09**	**11**	
13	Organisational Identity	1 day?	Paul KTP	Thu 29/01/09		Fri 30/01/09		
14	Organisational Mission	1 day?	Paul KTP	Fri 30/01/09		Mon 02/02/09	13	
15	Review of Current Costing / Pricing and tender structure	1 day?	Paul KTP	Mon 02/02/09		Tue 03/02/09	14	
16	**Artefact Diagrams (Architectural Only)**	**11 days?**	**Paul KTP**	**Tue 03/02/09**		**Wed 18/02/09**	**15**	
17	Housing Grant Aplications	1 day?	Paul KTP	Tue 03/02/09		Wed 04/02/09		
18	Competitions	1 day?	Paul KTP	Wed 04/02/09		Thu 05/02/09	17	
19	Bid Documents	1 day?	Paul KTP	Thu 05/02/09		Fri 06/02/09	18	
20	Preliminary Sketch designs	1 day?	Paul KTP	Fri 06/02/09		Mon 09/02/09	19	
21	Final Sketch designs	1 day?	Paul KTP	Mon 09/02/09		Tue 10/02/09	20	
22	Planning Drawings	1 day?	Paul KTP	Tue 10/02/09		Wed 11/02/09	21	
23	Building Control	2 days	Paul KTP	Wed 11/02/09		Fri 13/02/09	22	
24	Tender Information	1 day?	Paul KTP	Fri 13/02/09		Mon 16/02/09	23	
25	Construction Information	1 day?	Paul KTP	Mon 16/02/09		Tue 17/02/09	24	
26	As built information	1 day?	Paul KTP	Tue 17/02/09		Wed 18/02/09	25	
27	Model current organisational Structure / Project Structure	2 days	Paul KTP	Wed 18/02/09		Fri 20/02/09	26	
28	Model IT infrastructure	2 days	Paul KTP	Fri 20/02/09		Tue 24/02/09	27	
29	**Output 1A (Current System Flow Charts) Complete**	1 day?	Paul KTP	Tue 24/02/09		Wed 25/02/09	28	
30	**1.2 Develop Soft System Pictures**	**13 days?**	**Paul KTP**	**Wed 25/02/09**		**Mon 16/03/09**	**29**	
31	Soft Systems Analysis (Identify networks, critical linkages, internal stakeholders and key partners)	5 days	Paul KTP	Wed 25/02/09		Wed 04/03/09		
32	Influence Diagrams (Identify networks, critical linkages, internal stakeholders and key partners)	3 days	Paul KTP	Wed 04/03/09		Mon 09/03/09	31	
33	Rich Pictures (Identify networks, critical linkages, internal stakeholders and key partners)	4 days	Paul KTP	Mon 09/03/09		Fri 13/03/09	32	
34	**Output 1B Soft System Analysis Report Produced**	1 day?	Paul KTP	Fri 13/03/09		Mon 16/03/09	33	
35	Develop Steering Group and Communications Plan	8 days	Paul KTP	Mon 16/03/09		Thu 26/03/09	34	
36	**1.3 Review of Current IT Systems**	**7 days?**	**Paul KTP**	**Thu 26/03/09**		**Mon 06/04/09**	**35**	
37	Review current IT (Discuss with Adam)	1 day	Paul KTP	Thu 26/03/09		Fri 27/03/09		
38	Review JMA current IT infrastructure	1 day	Paul KTP	Fri 27/03/09		Mon 30/03/09	37	
39	Review current CAD setup and skills	1 day?	Paul KTP	Mon 30/03/09		Tue 31/03/09	38	
40	Consider changes to the IT system that the BIM will require	1 day	Paul KTP	Tue 31/03/09		Wed 01/04/09	39	
41	Produce Draft report	1 day?	Paul KTP	Wed 01/04/09		Thu 02/04/09	40	

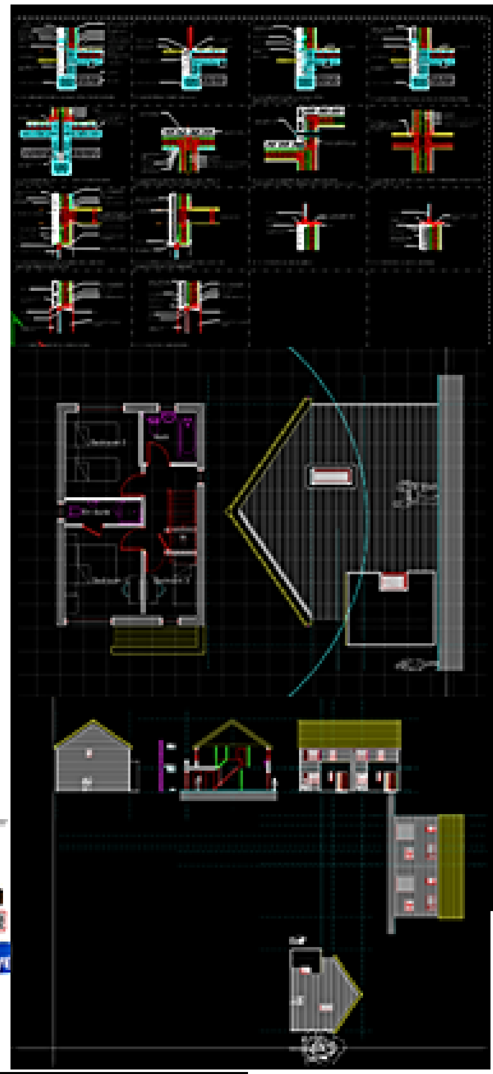


A3 Analysis – **Proposal for Model generated Production Information**

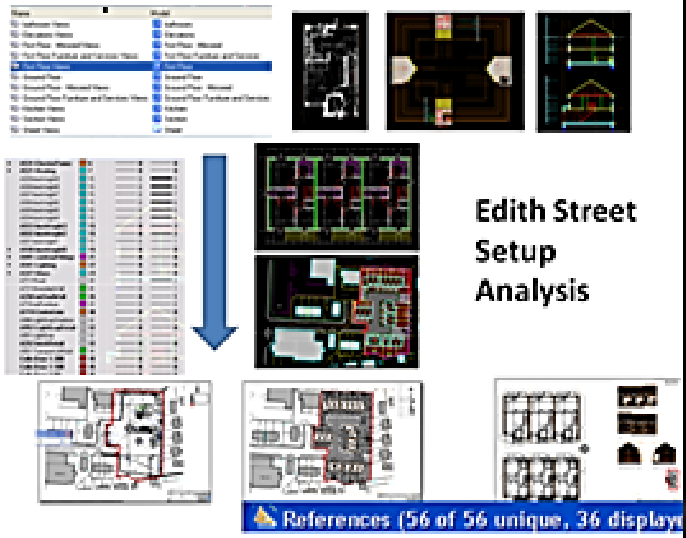


Background

JMA uses Microstation V8i and Powerdraft to produce their production information to enable the contractor and other to understand the design requirements. This method of production has been used since the inception of the practice almost 20 years ago.



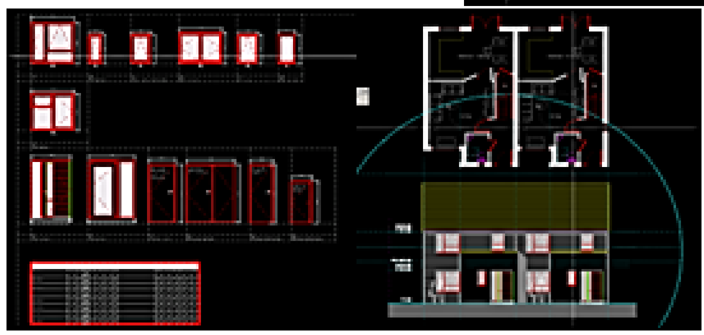
Current Situation



Edith Street Setup Analysis

Elevations /Sections projected manually from plans using construction lines.

Schedules Produced Manually.

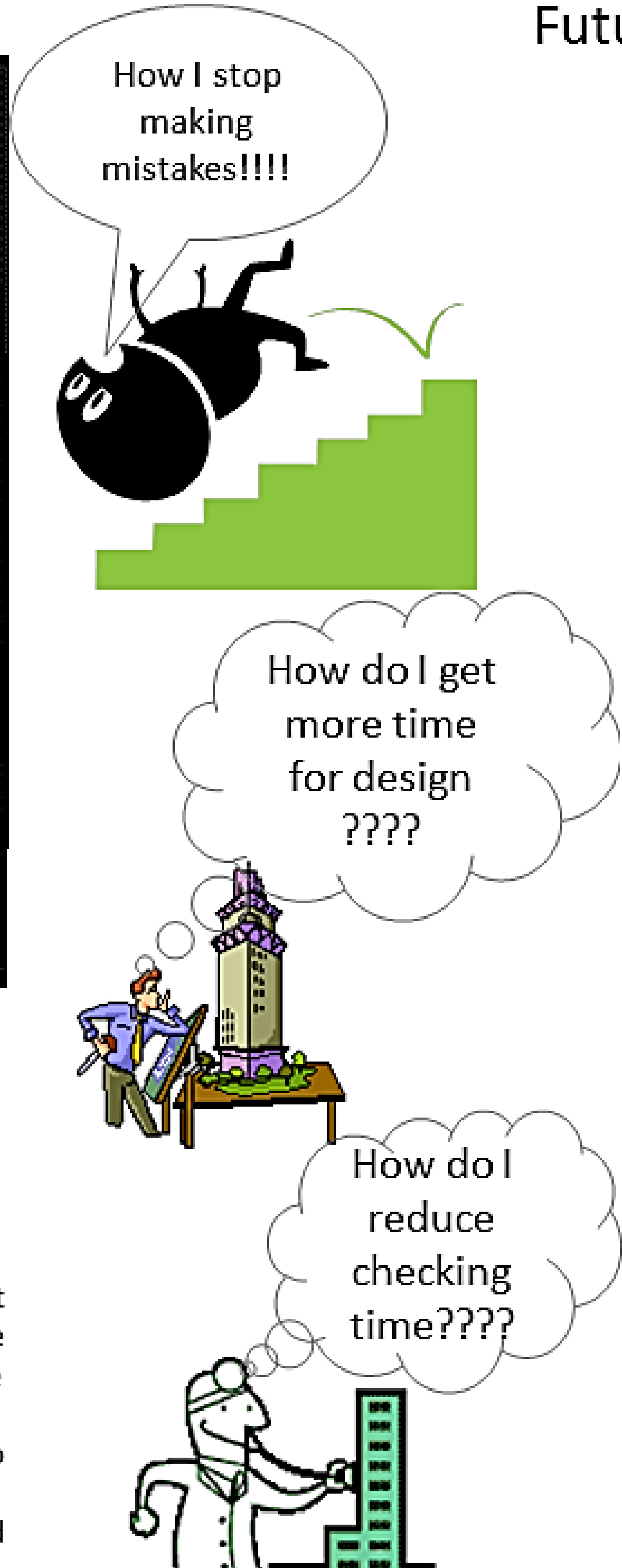


Analysis

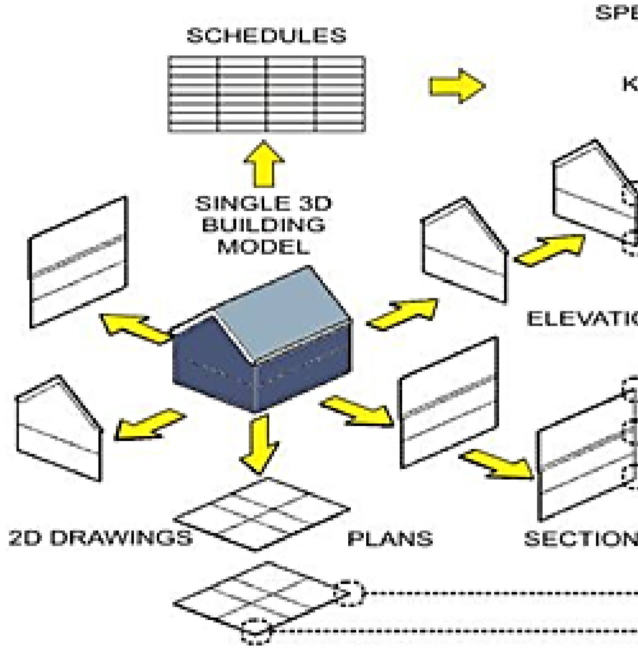
. The problem is that the plans, sections and elevations generated on a project are not dynamically linked and therefore inconsistencies between the representations can arise. These can lead to costly mistakes if they are constructed on site.

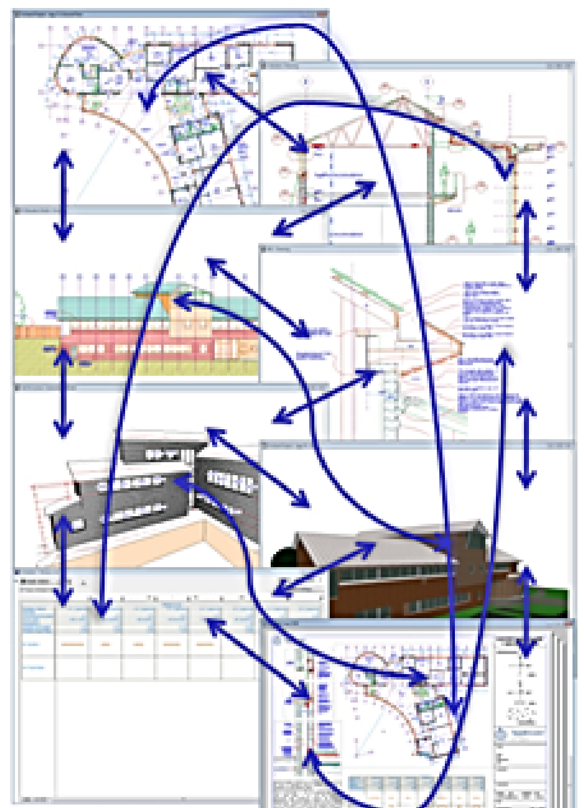
. The process of creating the plans, section and elevations separately is also time consuming.

. Using the current method the 3d from may not be correctly represented within the 2d representations.

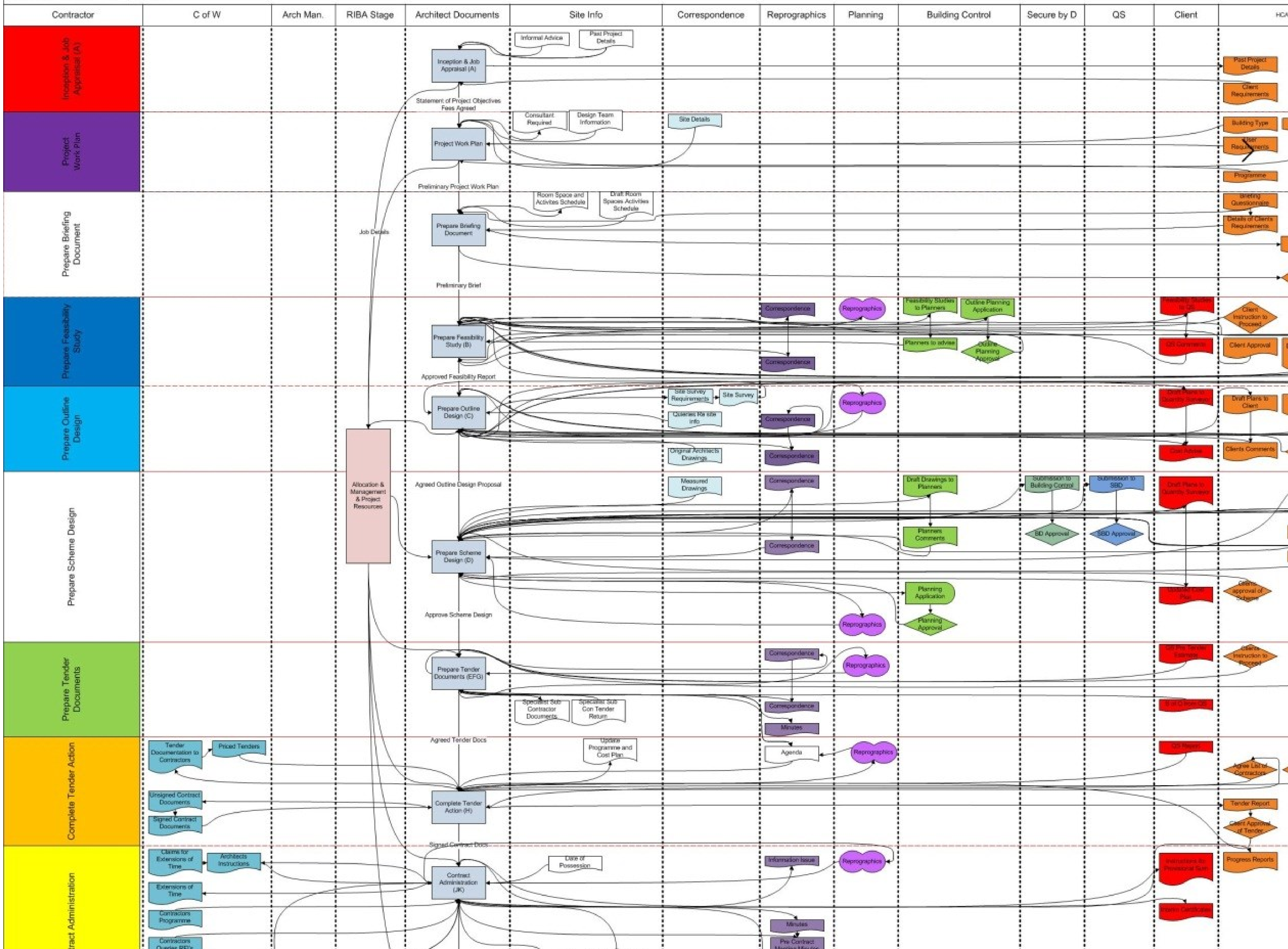


Future State





Informational Flows at Project Level



A3 Analysis – **Scanning of Incoming Mail**

Archiving Hardcopy

Company	John McCall Arc		
Date		30 No	
For Info	CU	PM	DS
For Action			

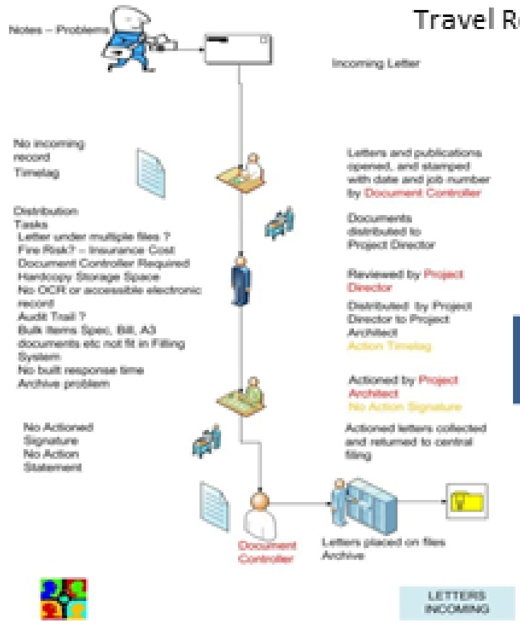
File Name date

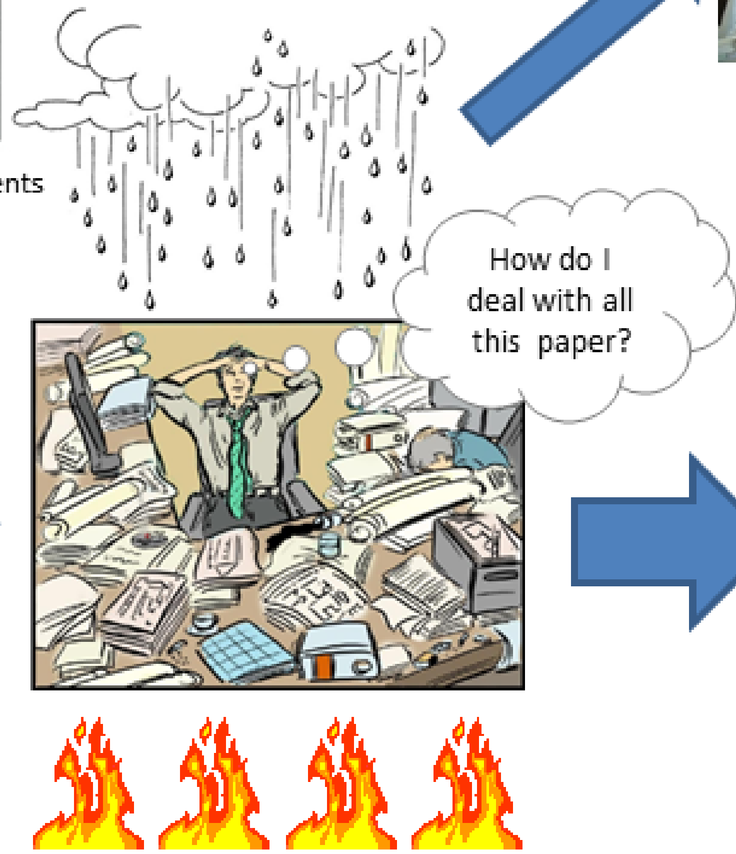
Background

- JMA operates a traditional method of dealing with letter etc.
-

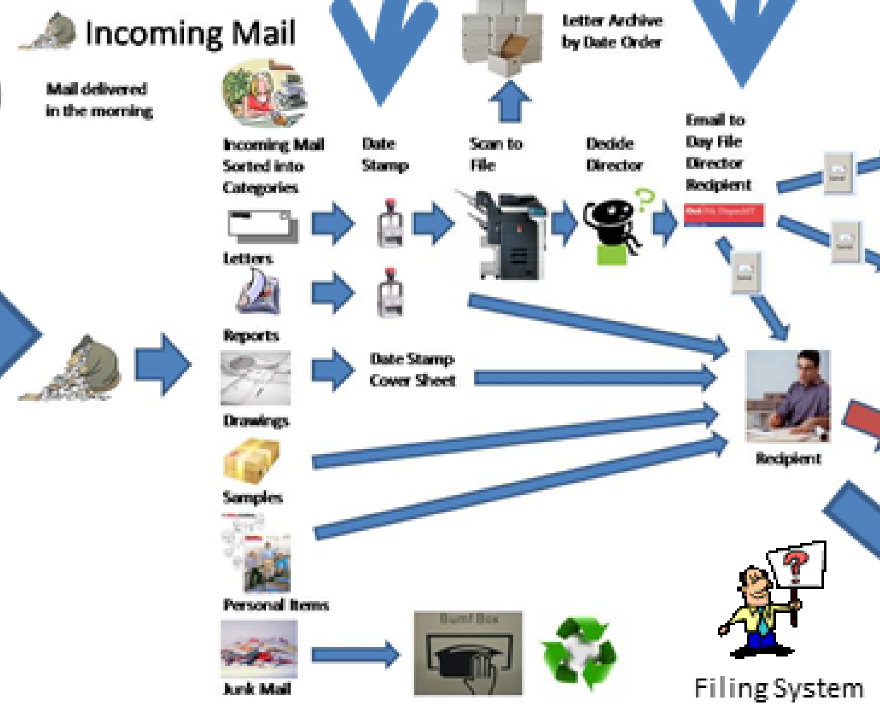
Travel Route of Documents

Current Situation





Future State



Filing System to be agreed

Analysis / Existing Problem

- One letter may need filing under several topics - Multiple filing requires photocopies
- Hardcopy is venerable ,(loss, flooding, fire)
- Hardcopy requires storage space and time is taken by the director review

Legal Requirements

1. Representation of Information (i.e. an information management policy)
2. A Duty of Care
3. Business Procedures and Processes
4. Enabling Technologies
5. Audit Trails

Secure
Backu

Goals

Reduction in paper costs & staff time – no need for photocopies for multiple readers. They simply look at the screen image.

Improved productivity – with information at their finger tips fee earners don't waste time looking for files. It's amazing the difference the absence of clutter makes.

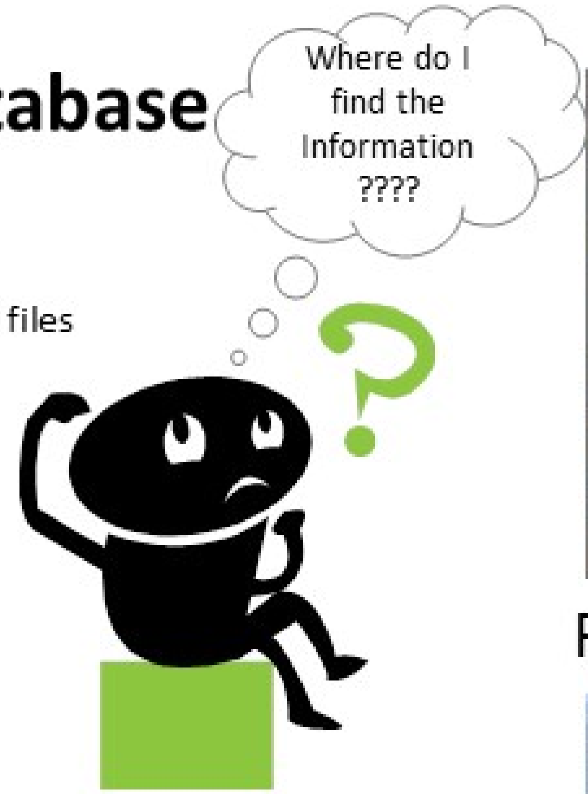
Reduced telephone costs – when a client telephones you can take the call knowing all information is available to you at the click of your mouse. How often now do you need to call back when you've found her file?

Follow up

- Document Process
- Test on pilot project
- Train reception staff

Please n
electroni
does tra

A3 Analysis – **Change to Database**



Background

. Items of Data are distributed through many none connected files
. Items of data maybe difficult to locate
. Data many not be consistent across files
. Review of data from multiple projects is difficult
. Time is wasted searching for information

Current Situation

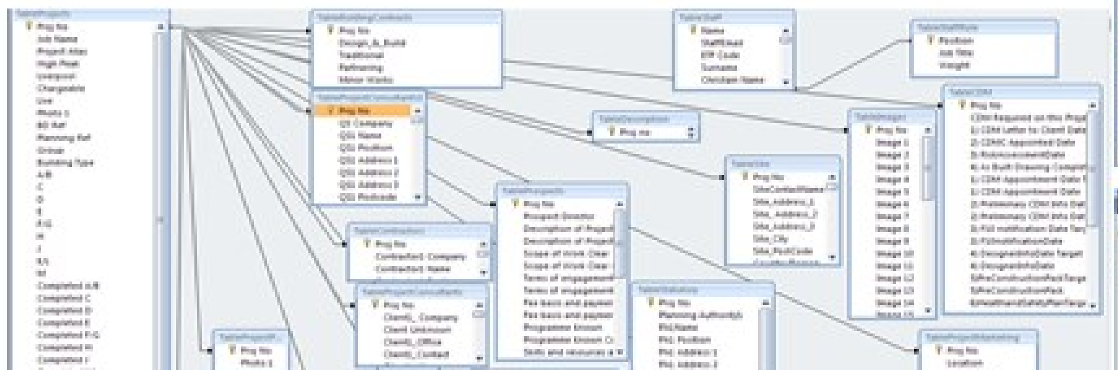
- Job Number
- Job Name
- Project Architect
- Email Address
- Project Location
- Project Start Dates
- Project Description
- Project Costings
- Project Sectors

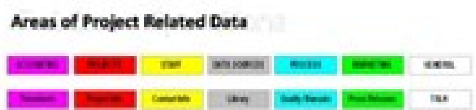
Some of the common items of data.

. Multiple files and file type containing common data
. Simultious searches of multiple projects is not possible.
. Projects are delayed from archive because important data would be more difficult to find.
. Time is spent searching for historic information for future Marketing and submissions.

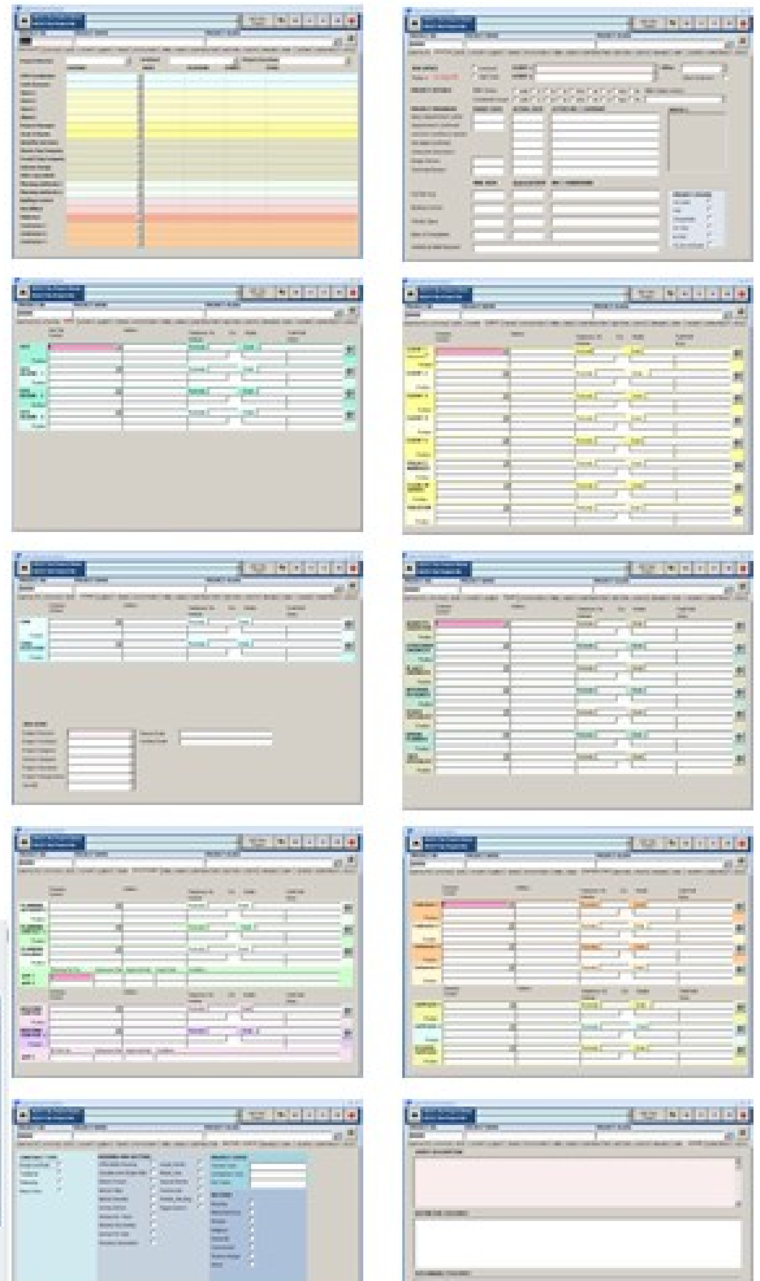
Analysis

. The primary key that links the different data together is the project number.



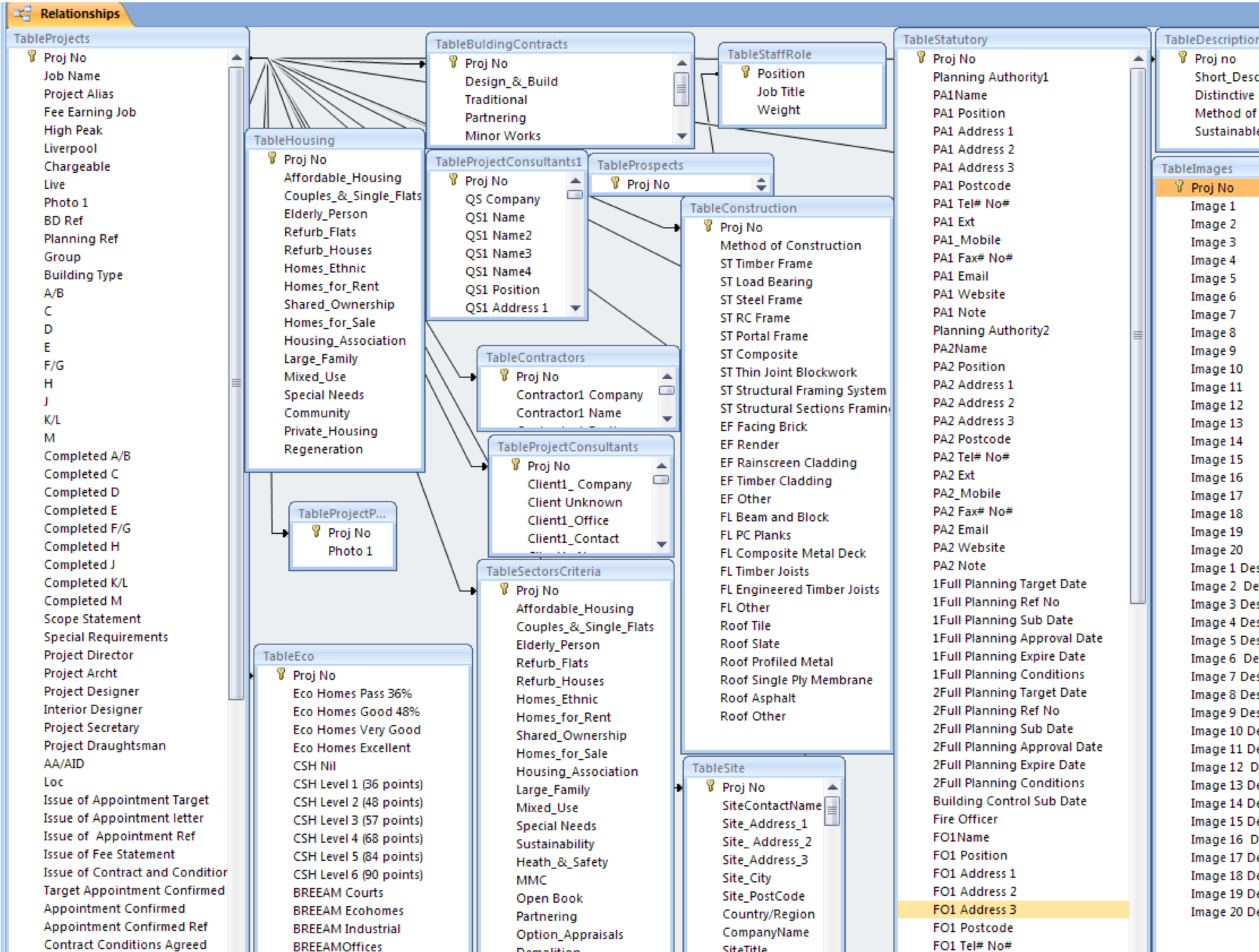


Future State

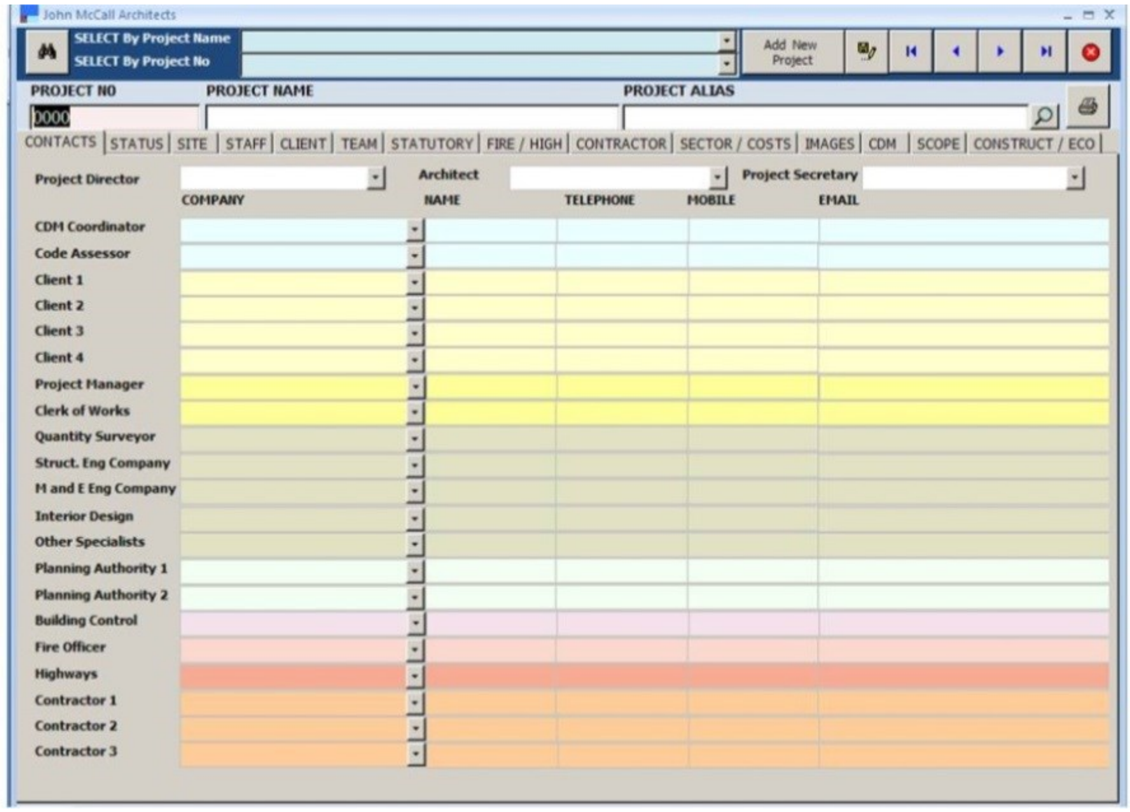


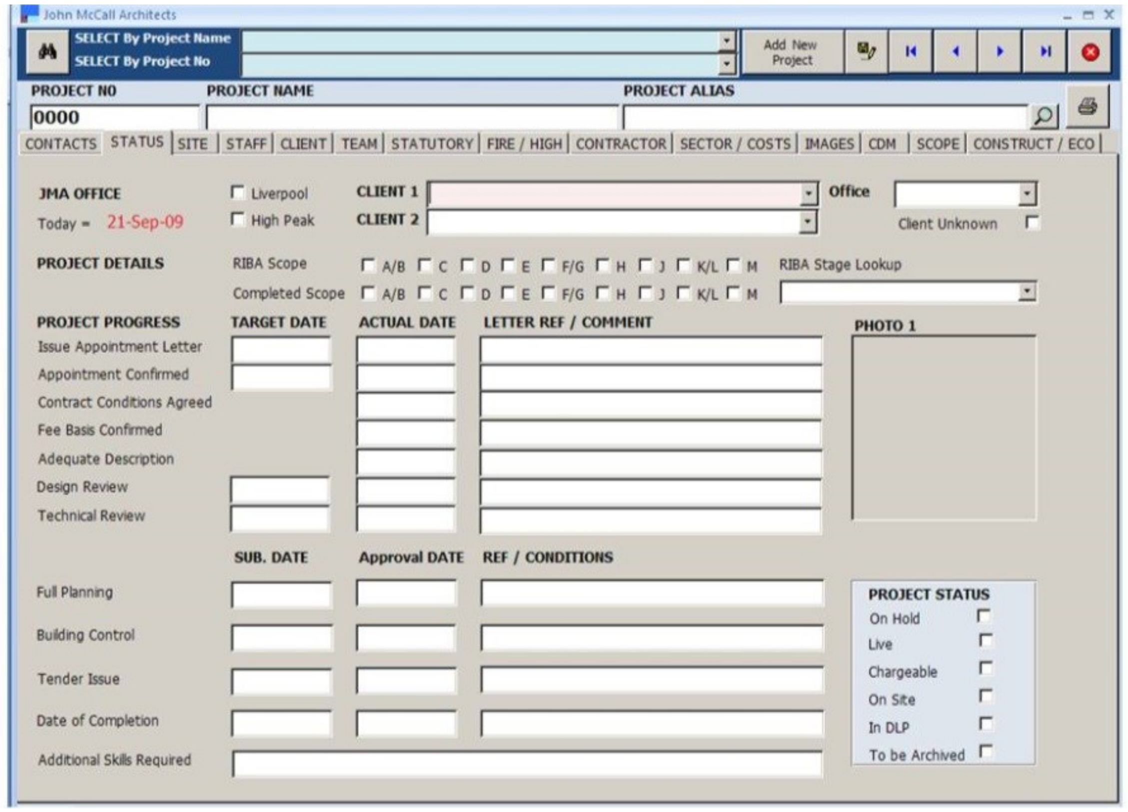
Jobs in t

Example Input Sc



Relationships
TableProjects
Proj No
Job Name
Project Alias
Fee Earning Job
High Peak
Liverpool
Chargeable
Live
Photo 1
BD Ref
Planning Ref
Group
Building Type
A/B
C
D
E
F/G
H
J
K/L
M
Completed A/B
Completed C
Completed D
Completed E
Completed F/G
Completed H
Completed J
Completed K/L
Completed M
Scope Statement
Special Requirements
Project Director
Project Archt
Project Designer
Interior Designer
Project Secretary
Project Draughtsman
AA/AID
Loc
Issue of Appointment Target
Issue of Appointment letter
Issue of Appointment Ref
Issue of Fee Statement
Issue of Contract and Conditior
Target Appointment Confirmed
Appointment Confirmed
Appointment Confirmed Ref
Contract Conditions Agreed
TableHousing
Proj No
Affordable_Housing
Couples_&_Single_Flats
Elderly_Person
Refurb_Flats
Refurb_Houses
Homes_Ethnic
Homes_for_Rent
Shared_Ownership
Homes_for_Sale
Housing_Association
Large_Family
Mixed_Use
Special Needs
Community
Private_Housing
Regeneration
TableProjectP...
Proj No
Photo 1
TableEco
Proj No
Eco Homes Pass 36%
Eco Homes Good 48%
Eco Homes Very Good
Eco Homes Excellent
CSH Nil
CSH Level 1 (36 points)
CSH Level 2 (48 points)
CSH Level 3 (57 points)
CSH Level 4 (68 points)
CSH Level 5 (84 points)
CSH Level 6 (90 points)
BREEAM Courts
BREEAM Ecohomes
BREEAM Industrial
BREEAMOffices
TableBuldingContracts
Proj No
Design_&_Build
Traditional
Partnering
Minor Works
TableProjectConsultants1
Proj No
QS Company
QS1 Name
QS1 Name2
QS1 Name3
QS1 Name4
QS1 Position
QS1 Address 1
TableContractors
Proj No
Contractor1 Company
Contractor1 Name
TableProjectConsultants
Proj No
Client1_ Company
Client Unknown
Client1_Office
Client1_Contact
TableSectorsCriteria
Proj No
Affordable_Housing
Couples_&_Single_Flats
Elderly_Person
Refurb_Flats
Refurb_Houses
Homes_Ethnic
Homes_for_Rent
Shared_Ownership
Homes_for_Sale
Housing_Association
Large_Family
Mixed_Use
Special Needs
Sustainability
Heath_&_Safety
MMC
Open Book
Partnering
Option_Appraisals
TableStaffRole
Position
Job Title
Weight
TableProspects
Proj No
TableConstruction
Proj No
Method of Construction
ST Timber Frame
ST Load Bearing
ST Steel Frame
ST RC Frame
ST Portal Frame
ST Composite
ST Thin Joint Blockwork
ST Structural Framing System
ST Structural Sections Framin
EF Facing Brick
EF Render
EF Rainscreen Cladding
EF Timber Cladding
EF Other
FL Beam and Block
FL PC Planks
FL Composite Metal Deck
FL Timber Joists
FL Engineered Timber Joists
FL Other
Roof Tile
Roof Slate
Roof Profiled Metal
Roof Single Ply Membrane
Roof Asphalt
Roof Other
TableSite
Proj No
SiteContactName
Site_Address_1
Site_ Address_2
Site_Address_3
Site_City
Site_PostCode
Country/Region
CompanyName
TableStatutory
Proj No
Planning Authority1
PA1Name
PA1 Position
PA1 Address 1
PA1 Address 2
PA1 Address 3
PA1 Postcode
PA1 Tel# No#
PA1 Ext
PA1_Mobile
PA1 Fax# No#
PA1 Email
PA1 Website
PA1 Note
Planning Authority2
PA2Name
PA2 Position
PA2 Address 1
PA2 Address 2
PA2 Address 3
PA2 Postcode
PA2 Tel# No#
PA2 Ext
PA2_Mobile
PA2 Fax# No#
PA2 Email
PA2 Website
PA2 Note
1Full Planning Target Date
1Full Planning Ref No
1Full Planning Sub Date
1Full Planning Approval Date
1Full Planning Expire Date
1Full Planning Conditions
2Full Planning Target Date
2Full Planning Ref No
2Full Planning Sub Date
2Full Planning Approval Date
2Full Planning Expire Date
2Full Planning Conditions
Building Control Sub Date
Fire Officer
FO1Name
FO1 Position
FO1 Address 1
FO1 Address 2
FO1 Address 3
FO1 Postcode
FO1 Tel# No#
TableDescription
Proj no
Short_Desc
Distinctive
Method of
Sustainable
TableImages
Proj No
Image 1
Image 2
Image 3
Image 4
Image 5
Image 6
Image 7
Image 8
Image 9
Image 10
Image 11
Image 12
Image 13
Image 14
Image 15
Image 16
Image 17
Image 18
Image 19
Image 20


John McCall Architects
SELECT By Project Name
SELECT By Project No
Add New Project
PROJECT NO
PROJECT NAME
PROJECT ALIAS
0000
CONTACTS | STATUS | SITE | STAFF | CLIENT | TEAM | STATUTORY | FIRE / HIGH | CONTRACTOR | SECTOR / COSTS | IMAGES | CDM | SCOPE | CONSTRUCT / ECO
Project Director
Architect
Project Secretary
COMPANY
NAME
TELEPHONE
MOBILE
EMAIL
CDM Coordinator
Code Assessor
Client 1
Client 2
Client 3
Client 4
Project Manager
Clerk of Works
Quantity Surveyor
Struct. Eng Company
M and E Eng Company
Interior Design
Other Specialists
Planning Authority 1
Planning Authority 2
Building Control
Fire Officer
Highways
Contractor 1
Contractor 2
Contractor 3


John McCall Architects
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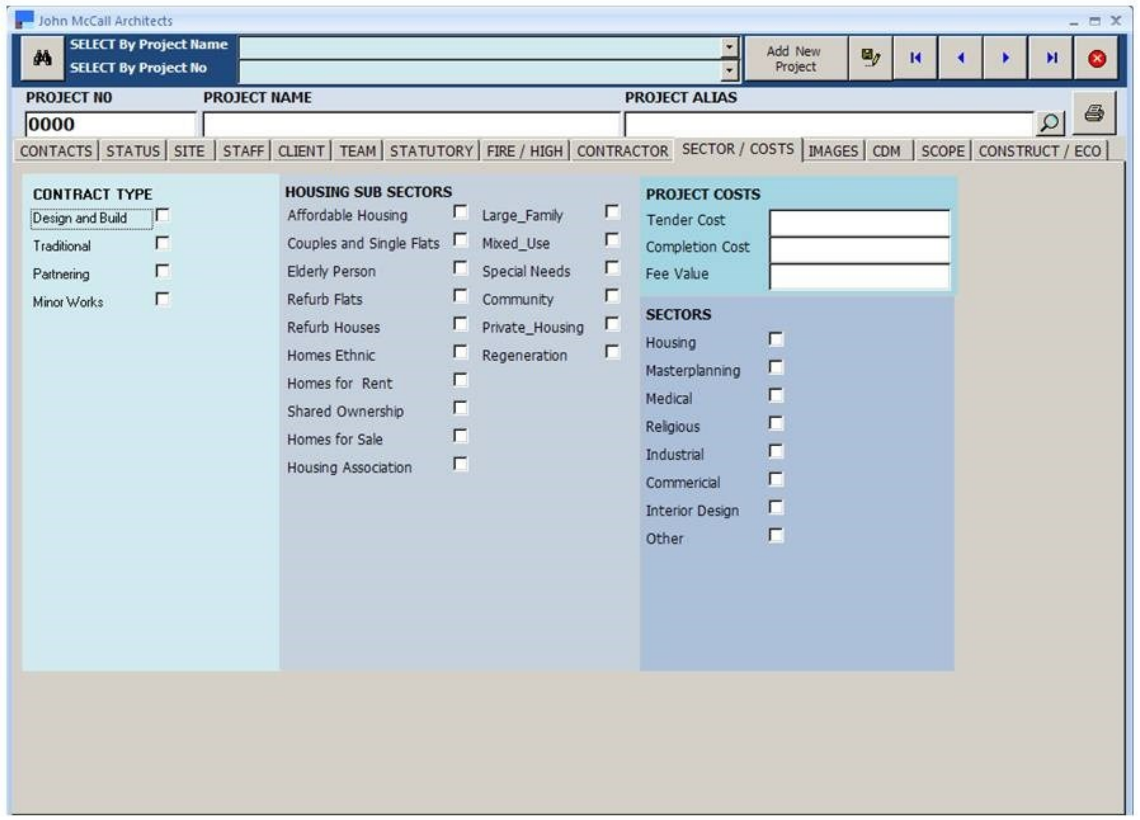
Add New Project
PROJECT NO
PROJECT NAME
PROJECT ALIAS
0000
CONTACTS | STATUS | SITE | STAFF | CLIENT | TEAM | STATUTORY | FIRE / HIGH | CONTRACTOR | SECTOR / COSTS | IMAGES | CDM | SCOPE | CONSTRUCT / ECO
JMA OFFICE
Liverpool
High Peak
Today = 21-Sep-09
CLIENT 1
CLIENT 2
Office
Client Unknown
PROJECT DETAILS
RIBA Scope
Completed Scope
A/B C D E F/G H J K/L M
RIBA Stage Lookup
PROJECT PROGRESS
TARGET DATE
ACTUAL DATE
LETTER REF / COMMENT
PHOTO 1
Issue Appointment Letter
Appointment Confirmed
Contract Conditions Agreed
Fee Basis Confirmed
Adequate Description
Design Review
Technical Review
SUB. DATE
Approval DATE
REF / CONDITIONS
Full Planning
Building Control
Tender Issue
Date of Completion
Additional Skills Required
PROJECT STATUS
On Hold
Live
Chargeable
On Site
In DLP
To be Archived


John McCall Architects
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SELECT By Project No
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PROJECT NO
PROJECT NAME
PROJECT ALIAS
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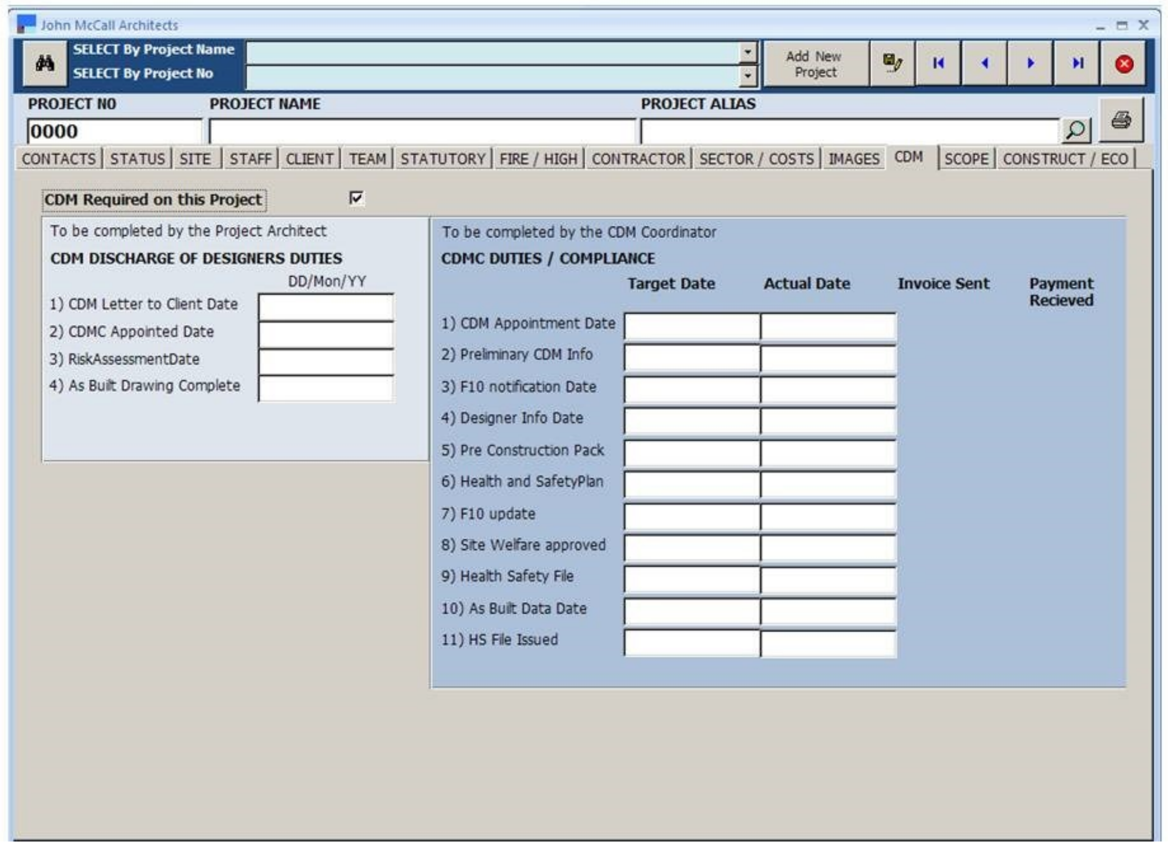
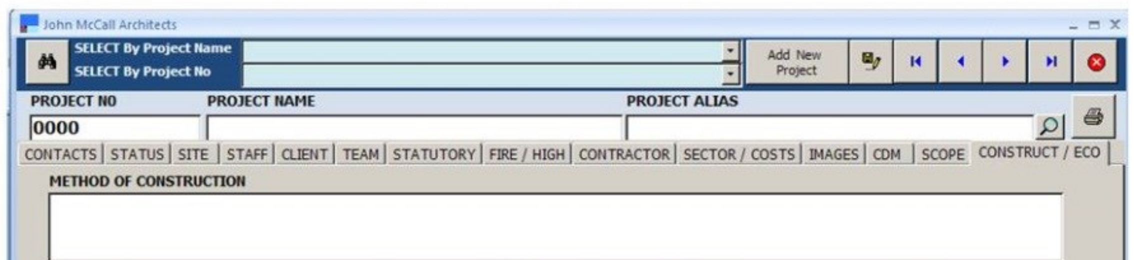
CONTACTS | STATUS | SITE | STAFF | CLIENT | TEAM | STATUTORY | FIRE / HIGH | CONTRACTOR | SECTOR / COSTS | IMAGES | CDM | SCOPE | CONSTRUCT / ECO
CONTRACT TYPE
Design and Build
Traditional
Partnering
Minor Works
HOUSING SUB SECTORS
Affordable Housing
Couples and Single Flats
Elderly Person
Refurb Flats
Refurb Houses
Homes Ethnic
Homes for Rent
Shared Ownership
Homes for Sale
Housing Association
Large_Family
Mixed_Use
Special Needs
Community
Private_Housing
Regeneration
PROJECT COSTS
Tender Cost
Completion Cost
Fee Value
SECTORS
Housing
Masterplanning
Medical
Religious
Industrial
Commercial
Interior Design
Other


John McCall Architects
SELECT By Project Name
SELECT By Project No
Add New Project
PROJECT NO
PROJECT NAME
PROJECT ALIAS
0000
CONTACTS | STATUS | SITE | STAFF | CLIENT | TEAM | STATUTORY | FIRE / HIGH | CONTRACTOR | SECTOR / COSTS | IMAGES | CDM | SCOPE | CONSTRUCT / ECO
CDM Required on this Project
To be completed by the Project Architect
CDM DISCHARGE OF DESIGNERS DUTIES
DD/Mon/YY
1) CDM Letter to Client Date
2) CDMC Appointed Date
3) RiskAssessmentDate
4) As Built Drawing Complete
To be completed by the CDM Coordinator
CDMC DUTIES / COMPLIANCE
Target Date
Actual Date
Invoice Sent
Payment Recieved
1) CDM Appointment Date
2) Preliminary CDM Info
3) F10 notification Date
4) Designer Info Date
5) Pre Construction Pack
6) Health and SafetyPlan
7) F10 update
8) Site Welfare approved
9) Health Safety File
10) As Built Data Date
11) HS File Issued


John McCall Architects
SELECT By Project Name
SELECT By Project No
Add New Project
PROJECT NO
PROJECT NAME
PROJECT ALIAS
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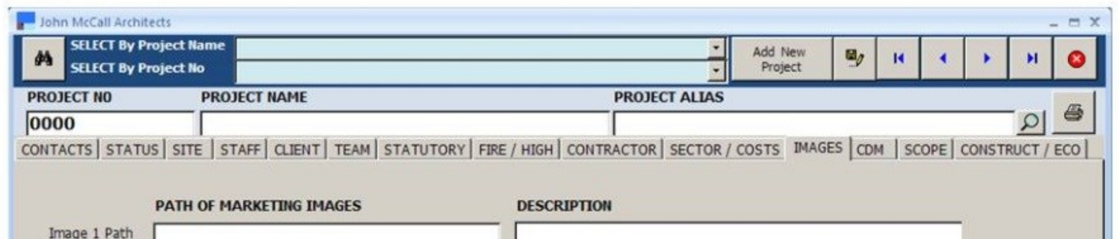
CONTACTS | STATUS | SITE | STAFF | CLIENT | TEAM | STATUTORY | FIRE / HIGH | CONTRACTOR | SECTOR / COSTS | IMAGES | CDM | SCOPE | CONSTRUCT / ECO
METHOD OF CONSTRUCTION


John McCall Architects
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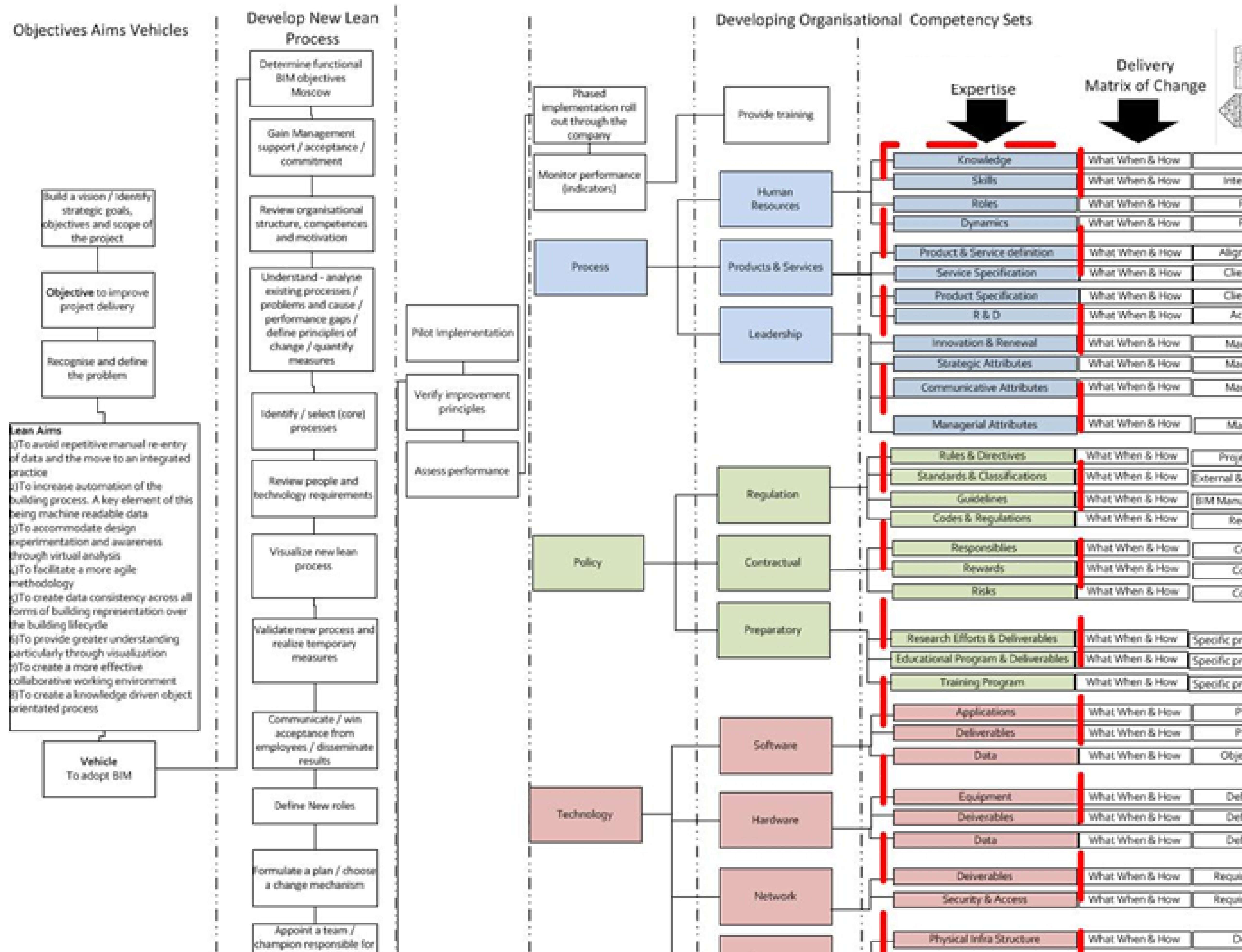
SELECT By Project No
Add New Project
PROJECT NO
PROJECT NAME
PROJECT ALIAS
0000
CONTACTS | STATUS | SITE | STAFF | CLIENT | TEAM | STATUTORY | FIRE / HIGH | CONTRACTOR | SECTOR / COSTS | IMAGES | CDM | SCOPE | CONSTRUCT / ECO
PATH OF MARKETING IMAGES
DESCRIPTION
Image 1 Path

No.	Facet	Facet Weight		Archicad 13	Score	Weight	Revit 2010	Score	Weight	Allplan	Score	Weight	Bentley Archit
	BIM for Social Housing												
	Score 1 to 5 5=Good 1=Bad Facet wieght to be confirmed												
	Facet tested on trial JMA project												NOT ENOUGH T
1	Ease of creating concept models		Review	Imports Sketchup Models			Concept model module in the software			Imports Sketchup			Import from Sketchu
			Comment	No internal facility	2	0		4	0	No internal facility	2	0	
2	The ability to input a range of windows, doors, and wall types		Review	OK some difficulty with odd windows			Difficulty with complex window			Very Good			Doors not in walls
			Comment		4	0		2	0	Flexible dialogue boxes	5	0	
3	The ability to input data to dimensional accuracy		Review	Yes			Yes - easy line up with existing elements			Yes			
			Comment		4	0	Dimension show automatically	5	0	Yes	4	0	
4	The ability to use geographic origins		Review	OK			Had some difficulty with dxf provided			Seemed OK			Not tested
			Comment		4	0		2	0	OK	4	0	
5	The ability to address complex construction shapes curved walls etc		Review	Yes			Yes including complex geometries			Can do windows of complex shapes			Not tested
			Comment	Yes	3	0	Yes	4	0	Yes	3	0	
6	Adding in of street furniture		Review	Yes			Object found			2d 3d representation			Not tested
			Comment	Yes	3	0	Large online object libraries - archiseek	4	0	Can import 3d entities from other systems	3	0	
7	Input and modification of stairs		Review	Input OK			Good			Input OK			
			Comment	Needs to be ammended	3	0		4	0	Needs to be ammended	3	0	
8	The ability to schedule doors, windows doors etc		Review	Well demonstrated intial formats good			Good Many schedules set up			OK but format may want revising			
			Comment		4	0	Bidirectional	5	0	Can be cutomised	3	0	
9	Easy of setting up drawing sets		Review	Good			Good			Need to input the dwgs name			
			Comment		4	0		4	0	On a one standard set this is fine	3	0	
10	Ease of navigation around the BIM model		Review	Fine			View cube			Fine			
			Comment		4	0		5	0	Fine	3	0	
11	Ease of input of land topography		Review	Built into the program			Built into the program			Good but separate package			
			Comment		4	0		4	0		2	0	
12	Ease of multiple people working on a single model		Review	Very Good			Worksets			Not tested			Product designed fo
			Comment		5	0		4	0		2	0	
13	Ease of creation of site models with building units referenced in		Review	Modules allows a flexible way of working			Good			Referenced ground and first floors separately			
			Comment		4	0		4	0	No mirrored xrefs - but good xref control	2	0	
14	Ease of control of the visibility of graphics		Review	Layer Based not object based			Visibility Graphics			Layer Control			
			Comment		3	0		4	0	Not object based	3	0	
15	Ease of input of constrains eg fixed stair widths or corridor widths		Review	Limited			Good at this			Limited constrains ie window positions			
			Comment		2	0		4	0		2	0	
16	Ease of export to other file forms and re import accuracy		Review	Half trip - IFC to Revit not that good			Not proven			No problems noted			
			Comment		2	0		2	0		4	0	
17	Easy input of dgn, skp, dwg, ifc, dxf, pdf and model file		Review	Also does dgn			DGN , DWG, DWF, DXF, IFC, SAT, SKP , AVI , ODBC,			Many formats available including V8			
			Comment		4	0	gbXML, BMP, JPG, TGA, and TIF need PDF2DWG	2	0		4	0	
18	Ease of creation of fixed export eg PDF etc		Review	Can generate PDF and other formats			External addon required to generate PDF's			Allows creation of PDF's while printing			Supports PDF
			Comment		4	0	PDF995.com	2	0		4	0	
19	Drawing issue management		Review	Good			Drawing List Function			OK but no drawing register created			Links with Projectwi
			Comment		4	0		4	0		4	0	
20	Print management		Review	OK			Files separate directories - Free batch printer			Good			Not tested
			Comment		4	0		3	0		4	0	
21	Ease of changing one wall or window type to another		Review	OK			OK			OK			Not tested
			Comment		4	0		4	0		4	0	
22	Parametric ability to alter floor levels and walls		Review	OK			Good			Not shown			
			Comment		4	0		5	0		3	0	
23	New material input		Review	Demonstrated			Demonstrated			OK			
			Comment		4	0		4	0		4	0	
24	Development of details Jambs, Heads etc		Review	Yes			Yes			Yes			
			Comment		4	0		4	0		4	0	
25	Revision control management and Clash detection		Review	No Clash detection - Revision control manual			Built in Clash detection and revise instantly			No Clashed detection			Clash detction separ
			Comment		2	0		4	0		1	0	
26	Presentation quality control and line weights etc		Review	Good - LOD			Filters OK - LOD			Elevation lineweight poor on print			
			Comment		4	0		4	0		3	0	
27	Demonstration of size of exist object types and libraries available		Review	Some libraries			The Most catalog of information by far.			Some libraries			Some libraries
			Comment		3	0	Developed by suppliers	5	0		3	0	
28	File size of models created		Review	21mb			7mb			15mb			
			Comment	OK	3	0	This was one unit	3	0		4	0	
29	Ease of setting up standards, templates and macros		Review	Good			Good			No programming			
			Comment		4	0		4	0		3	0	
30	Demonstrate rendered image quality		Review	Good			Mental ray render good			Not as good as others			Very Good
			Comment		4	0	No render farm	5	0		3	0	
	Other Facets												
31	Can the BIM info be issued to other consultants		Review	IFC transfer to R Structural not proven			RVT files can be used to transfer to R Structural			IFC transfer to R Structural not proven			IFC transfer to R Stru
			Comment		2	0		5	0		2	0	
32	Network capabilities		Review	Good / also on Mac			Good			Server licience, licience logout - roaming			Yes
			Comment		5	0		4	0		4	0	
33	Cost of Licence		Review	Rental option / £3662 assuming 12						£4,780			


Objectives Aims Vehicles
Build a vision / identify strategic goals, objectives and scope of the project
Objective to improve project delivery
Recognise and define the problem
Lean Aims
1)To avoid repetitive manual re-entry of data and the move to an integrated practice
2)To increase automation of the building process. A key element of this being machine readable data
3)To accommodate design experimentation and awareness through virtual analysis
4)To facilitate a more agile methodology
5)To create data consistency across all forms of building representation over the building lifecycle
6)To provide greater understanding particularly through visualization
7)To create a more effective collaborative working environment
8)To create a knowledge driven object orientated process
Vehicle
To adopt BIM
Develop New Lean Process
Determine functional BIM objectives Moscow
Gain Management support / acceptance / commitment
Review organisational structure, competences and motivation
Understand - analyse existing processes / problems and cause / performance gaps / define principles of change / quantify measures
Identify / select (core) processes
Review people and technology requirements
Visualize new lean process
Validate new process and realize temporary measures
Communicate / win acceptance from employees / disseminate results
Define New roles
Formulate a plan / choose a change mechanism
Appoint a team / champion responsible for
Pilot implementation
Verify improvement principles
Assess performance
Phased implementation roll out through the company
Monitor performance (indicators)
Developing Organisational Competency Sets
Provide training
Human Resources
Process
Products & Services
Leadership
Policy
Regulation
Contractual
Preparatory
Technology
Software
Hardware
Network
Expertise
Delivery Matrix of Change
Knowledge
Skills
Roles
Dynamics
Product & Service definition
Service Specification
Product Specification
R & D
Innovation & Renewal
Strategic Attributes
Communicative Attributes
Managerial Attributes
Rules & Directives
Standards & Classifications
Guidelines
Codes & Regulations
Responsiblies
Rewards
Risks
Research Efforts & Deliverables
Educational Program & Deliverables
Training Program
Applications
Deliverables
Data
Equipment
Deiverables
Data
Deiverables
Security & Access
Physical Infra Structure
What When & How

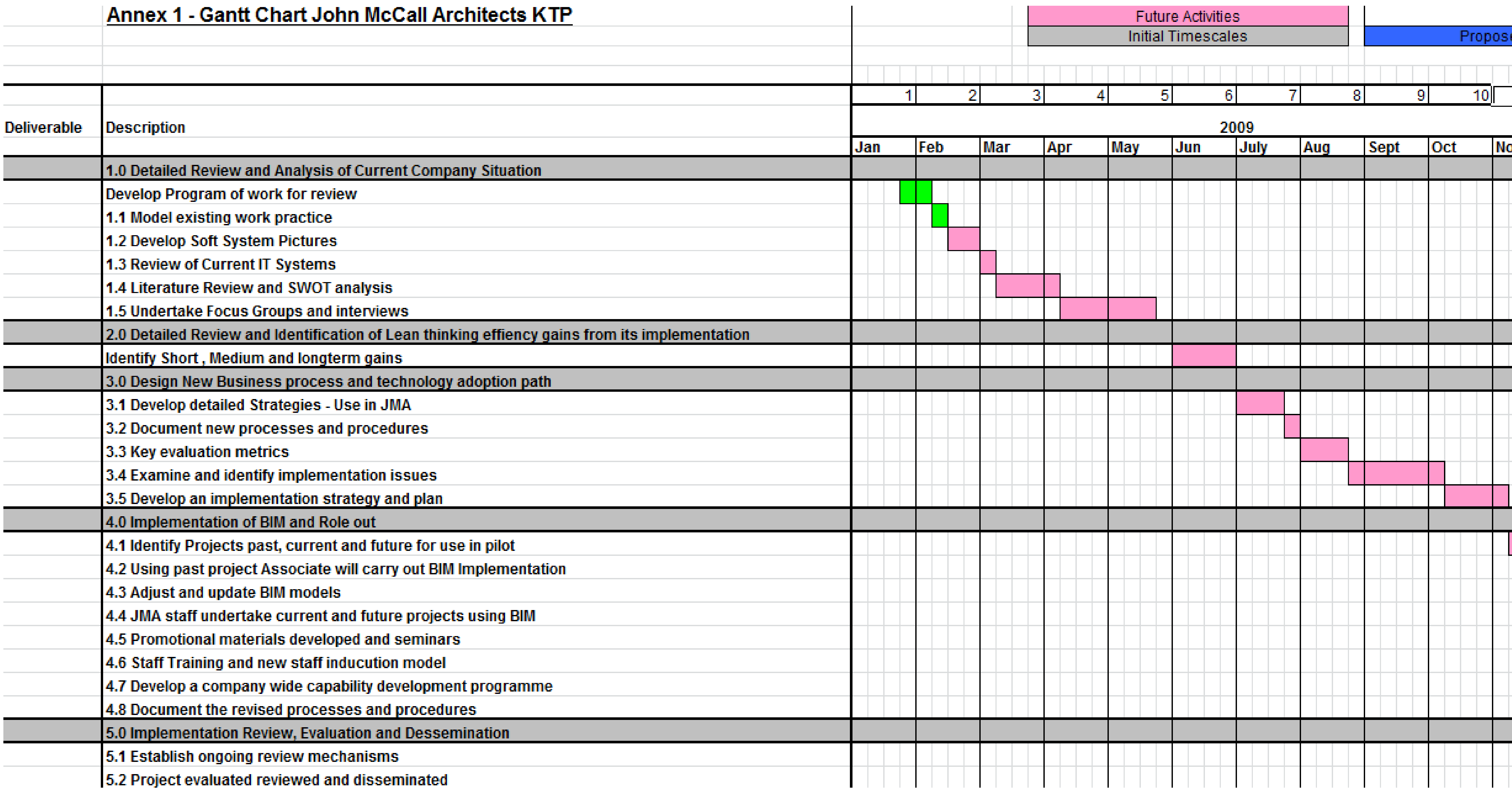
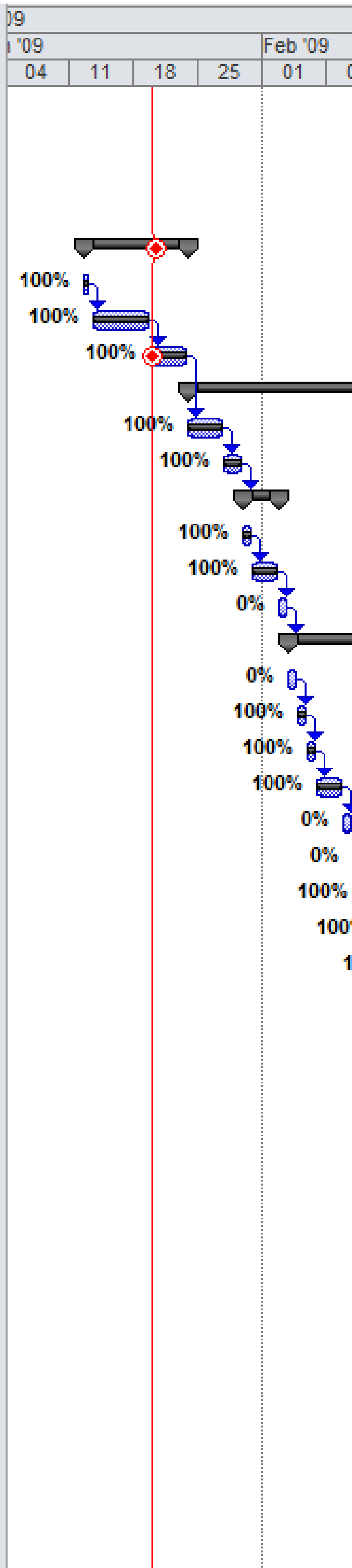


Figure 8.14: A simple Program Used at John McCall Architect to implement BIM

	Task Name	Duration	Resource Names	Start	Finish	P	Add New Co
1	Executive Summery Report for LNC to KTP Office	1 day?		Mon 16/02/09	Mon 16/02/09		
2	LMC Meeting	1 day?		Tue 24/02/09	Tue 24/02/09		
3	LJMU Regional KTP Associate Event	1 day?		Wed 18/03/09	Wed 18/03/09		
4	KTP Associates Conference in Brighton	1 day	Paul KTP	Wed 29/04/09	Wed 29/04/09		
5	**Ojective 1 - Detailed Review and Analysis of Current Company Situation**	**10 days?**	**Paul KTP**	**Mon 12/01/09**	**Fri 23/01/09**		
6	Review with University Supervisor	1 day?	Paul KTP	Mon 12/01/09	Mon 12/01/09		
7	Initial company review by KTP	5 days?	Paul KTP	Tue 13/01/09	Mon 19/01/09	6	
8	Develop Program of work for review	4 days	Paul KTP	Mon 19/01/09	Fri 23/01/09	7	
9	**1.1 Model existing work practice**	**23 days?**	**Paul KTP**	**Fri 23/01/09**	**Wed 25/02/09**		
10	Communication flow diagrams	2 days	Paul KTP	Fri 23/01/09	Tue 27/01/09	8	
11	Activity Sequence Diagrams	2 days	Paul KTP	Tue 27/01/09	Thu 29/01/09	10	
12	**Cultural Aspect Diagrams**	**2 days?**	**Paul KTP**	**Thu 29/01/09**	**Mon 02/02/09**	**11**	
13	Organisational Identity	1 day?	Paul KTP	Thu 29/01/09	Fri 30/01/09		
14	Organisational Mission	1 day?	Paul KTP	Fri 30/01/09	Mon 02/02/09	13	
15	Review of Current Costing / Pricing and tender structure	1 day?	Paul KTP	Mon 02/02/09	Tue 03/02/09	14	
16	**Artefact Diagrams (Architectural Only)**	**11 days?**	**Paul KTP**	**Tue 03/02/09**	**Wed 18/02/09**	**15**	
17	Housing Grant Aplications	1 day?	Paul KTP	Tue 03/02/09	Wed 04/02/09		
18	Competitions	1 day?	Paul KTP	Wed 04/02/09	Thu 05/02/09	17	
19	Bid Documents	1 day?	Paul KTP	Thu 05/02/09	Fri 06/02/09	18	
20	Preliminary Sketch designs	1 day?	Paul KTP	Fri 06/02/09	Mon 09/02/09	19	
21	Final Sketch designs	1 day?	Paul KTP	Mon 09/02/09	Tue 10/02/09	20	
22	Planning Drawings	1 day?	Paul KTP	Tue 10/02/09	Wed 11/02/09	21	
23	Building Control	2 days	Paul KTP	Wed 11/02/09	Fri 13/02/09	22	
24	Tender Information	1 day?	Paul KTP	Fri 13/02/09	Mon 16/02/09	23	
25	Construction Information	1 day?	Paul KTP	Mon 16/02/09	Tue 17/02/09	24	
26	As built information	1 day?	Paul KTP	Tue 17/02/09	Wed 18/02/09	25	
27	Model current organisational Structure / Project Structure	2 days	Paul KTP	Wed 18/02/09	Fri 20/02/09	26	
28	Model IT infrastructure	2 days	Paul KTP	Fri 20/02/09	Tue 24/02/09	27	
29	Output 1A (Current System Flow Charts) Complete	1 day?	Paul KTP	Tue 24/02/09	Wed 25/02/09	28	
30	**1.2 Develop Soft System Pictures**	**13 days?**	**Paul KTP**	**Wed 25/02/09**	**Mon 16/03/09**	**29**	
31	Soft Systems Analysis (Identify networks, critical linkages, internal stakeholders and key partners)	5 days	Paul KTP	Wed 25/02/09	Wed 04/03/09		
32	Influence Diagrams (Identify networks, critical linkages, internal stakeholders and key partners)	3 days	Paul KTP	Wed 04/03/09	Mon 09/03/09	31	
33	Rich Pictures (Identify networks, critical linkages, internal stakeholders and key partners)	4 days	Paul KTP	Mon 09/03/09	Fri 13/03/09	32	
34	Output 1B Soft System Analysis Report Produced	1 day?	Paul KTP	Fri 13/03/09	Mon 16/03/09	33	
35	Develop Steering Group and Communications Plan	8 days	Paul KTP	Mon 16/03/09	Thu 26/03/09	34	
36	**1.3 Review of Current IT Systems**	**7 days?**	**Paul KTP**	**Thu 26/03/09**	**Mon 06/04/09**	**35**	
37	Review current IT (Discuss with Adam)	1 day	Paul KTP	Thu 26/03/09	Fri 27/03/09		
38	Review JMA current IT infrastructure	1 day	Paul KTP	Fri 27/03/09	Mon 30/03/09	37	
39	Review current CAD setup and skills	1 day?	Paul KTP	Mon 30/03/09	Tue 31/03/09	38	
40	Consider changes to the IT system that the BIM will require	1 day	Paul KTP	Tue 31/03/09	Wed 01/04/09	39	
41	Produce Draft report	1 day?	Paul KTP	Wed 01/04/09	Thu 02/04/09	40	



APPENDIX B – Papers for Conferences and Journals

Papers for Conferences and Journals already completed

Arayici, Y. Coates, P. Koskela, LJ, Kagioglou, M, Usher, C and O'Reilly, K (2009)	BIM implementation for an architectural practice , in: 26th International Conference on IT in construction, 1/10/09 - 3/10/09, Istanbul Technical University, Turkey
Coates, P. Arayici, Y. Koskela, L. and Usher, C. (2010)	The changing perception in the artefacts used in the design practice through BIM adoption, in: CIB 2010, 10/5/10 - 13/5/10, University of Salford.
Coates, P. Arayici, Y. and Koskela, L. (2010),	Using the knowledge transfer partnership model as a method of transferring BIM and lean process related knowledge between academia and industry: A case study approach , in: International Conference of Ecobuild America: Sustainable, High Performance & Technology Solutions for Built Environment, 6-10 December, 2010, Washington DC, USA.
Coates, P. Arayici, Y. Koskela, K. Kagioglou, M. Usher, C. and O'Reilly, K. (2010)	The key performance indicators of the BIM implementation process, in: The International Conference on Computing in Civil and Building Engineering June 30 - July 2 2010, Nottingham, UK.
Coates, P. Arayici, Y. Koskela, L. Kagioglou, M. Usher, C. O' Reilly, K. (2010)	The limitations of BIM in the architectural process , in: First International Conference on Sustainable Urbanization (ICSU 2010), 15-17 December 2010, Hong Kong, China
Coates, P. Arayici, Y. Koskela, L. Kagioglou, M. Usher, C. O' Reilly, K. (2010)	BIM implementation to develop lean design best practice for design practice: A Case Study Approach
Arayici, Y. Coates, P. Koskela, L.	Technology adoption in the BIM

Kagioglou, M. Usher, C. and O'Reilly, K. (2011),	implementation for lean architectural practice', Automation in Construction, 20 (2), pp. 189-195.
Coates, P, Arayici, Y. Ozturk, Z (2011),	New concepts of Post Occupancy Evaluation (POE) utilizing BIM benchmarking techniques and sensing devices , in: SEB 11 Sustainability in Energy and Buildings, 1-3 June 2011, Marseilles
Ozturk, Z. Arayici, Y. Coates, P. (2012),	Post occupancy evaluation (POE) in residential buildings utilizing BIM and sensing devices: Salford energy house example , in: Retrofit 2012, Tuesday 24 Jan - Thursday 26 Jan, 2012, The Lowry, Salford Quays, Greater Manchester
Arayici, Y. Coates, P. Koskela, L. and Kagioglou, M. (2011),	Knowledge and technology transfer from universities to industries: a case study approach from the built environment field' , Journal of Higher Education, 1 (2) , pp. 103-110
Arayici, Y. Coates, P. Koskela, L. and Kagioglou, M (2011),	Knowledge and technology transfer from universities to industries: a case study approach from the built environment field , in: International Higher Education Congress: New Trends and Issues, 27-29 May, 2011, Istanbul, Turkey.
Arayici, Y. Coates, P, Koskela, LJ, Kagioglou, M, Usher, C OReilly, K (2011),	BIM adoption and implementation for architectural practices', Structural Survey, 29 (1), pp. 7-25.
Arayici, Y. Kiviniemi, AO, Coates, P, Koskela, LJ, Kagioglou, M, Usher, C O'Reilly, K (2011),	BIM implementation and adoption process for an architectural practice, in: FIATECH Conference, April 2011, USA.
Arayici, Y. Egbo, C. Coates, P. (2012)	Building information modelling (BIM)implementation and remote construction projects: Issues, Challenges and Critiques, Journal of Information Technology in Construction (ITcon), Vol. 17, pg. 75 -92,

	http://www.itcon.org/2012/5
Coates, P., Arayici, Y. (2012)	Optimization of the BIM Authoring Tool in Architectural Practice: A Case Study Approach. International Journal of 3-D Information Modeling (IJ3DIM), 1(2), 30-45. doi:10.4018/ij3dim.2012040103
Arayici, Y. Coates, P. (2012)	Operational Knowledge for BIM Adoption and implementation for Lean efficiency gains
Book Chapters already completed	
Arayici, Y. Coates, P. (2012)	A systems engineering perspective to knowledge transfer: A case study approach to BIM adoption Chapter 9, Virtual Reality and Human Interaction, Intech

Table 12.01: Summary of research (journals, conferences and book chapters) publications