BIM implementation and Adoption Process for an Architectural Practice

Y. Arayici, P. Coates, A. Kiviniemi L. Koskela & M. Kagioglou
The School of Built Environment, the University of Salford, Greater Manchester, UK

C. Usher & K. O'Reilly
John McCall's Architects, Liverpool, UK

ABSTRACT

Purpose: Building Information Modelling (BIM) has been implemented by large design and construction practices. However, it is not widely (if at all) used by SMEs (Small, Medium Enterprises). Furthermore, adoption and implementation of BIM to enable lean design process brings about changes and new challenges and investments for stakeholders. The aim of this paper is identify a roadmap for BIM adoption and implementation with lean design principles using the live experience of BIM adoption via a Knowledge Transfer Partnership (KTP) project for an architectural company.
Design/Methodology/Approach: The research was undertaken through a KTP (Knowledge transfer Partnership) project between the University of Salford and the John McCall Architects practising in housing and regeneration. The overall aim of the KTP was to develop lean design practice through BIM adoption, which used a socio-technical view that does not only consider the implementation of technology but also considers the socio-cultural environment to provide the context for its implementation. Thus, the action research oriented qualitative and quantitative research is used for discovery, comparison, and experimentation as it provides "learning by doing".
Findings: The BIM implementation process in the paper provides guidance for BIM adoption for SMEs. The key performance indicators and efficiency gains identified earlier in the project has been achieved through the piloting projects. The capacity building through the improvements in process, technological infrastructure and up skilling JMA staff has enabled the realisation to attain competitive advantages for the company.
Originality/Value: The paper presents a BIM implementation process for SMEs adopted in the case study project. It will also contribute to development of a BIM implementation adoption framework.

***Keywords*:** Building Information Modeling, Lean design process, Soft System Methodology, Information Engineering, Process Innovation

1 INTRODUCTION

The building industry is under great pressure to provide value for money, sustainable infrastructure, etc. and this has propelled the adoption of Building Information Modelling (BIM) technology (Mihindu and Arayici, 2008). Owners can anticipate greater efficiency and cost savings in the design, construction and operation of facilities with the adoption of BIM. From an architectural point of view the consequences of BIM depends on how the technology is implemented and integrated into the firm's business model. BIM offers many new financial and creative opportunities for most construction related organizations (e.g. architectural companies), but to realize these benefits firms will need to embrace the integration of design and construction that BIM will promote. This will require changes in project delivery methods and in the composition of the firm's staff. Properly implemented, BIM may also change the role of professions (e.g. architectural) an expanded role in the AEC/O industry. To realize the BIM benefits, an active role in guiding its implementation must be taken (Arayici et al, 2009) (Bernstein and Pittman, 2004).

There is enough evidence to suggest the architectural profession is beginning to come under pressure to adopt BIM. This information management technology has existed in some form for over 20 years. However during last few years, building owners are becoming aware that BIM promises to make the design, construction and operation of buildings much more streamlined and efficient (Coates et al, 2010). Owners are starting to enforce that architects and other design professionals, construction managers and construction companies adopt BIM. This trend gained enormous momentum when the General Services Administration (GSA) of USA announced that it would require all schematic design submittals to be in BIM format starting in 2006 (US-GSA, 2008). Many other similar uptakes from Europe and Australasia have followed (Mihindu and Arayici, 2008).

The productivity increases promised by BIM would seem to make it attractive to architects and other design professionals, contractors as well as to owners. The intensely competitive nature of building industry makes it likely that most if not all of any productivity gains realized by BIM will be passed through to owners and clients. This is what happened with CAD (Oakley, 2007).

2 THE CASE STUDY PROJECT OF BIM IMPLEMENTATION & ADOPTON

The John McCall Architects in Liverpool is focusing primarily on social housing and regeneration, private housing and one off homes and large extensions. JMA works with many stakeholders from design through to building construction process and the associated information is very fragmented. Projects in which JMA are involved include many stakeholders and need considerable interoperability and information exchange.

Historically JMA used 2D CAD tool for two decades. The company also has its own procedures, templates to optimize its practice. However, the current practice with this 2D CAD tool brings about some inefficiency such as timescales, deadline pressures, duplications, lead times, lack of continuity in the supply chain, over processing, reworking, overproduction, distractive parallel tasks, reliability of data and plan predictability, lack of rigorous design process, lack of effective design management and communication. Hence, the company need to improve its capacity for i) greater integration and collaboration with other disciplines in the production process, ii) adopting technology change to provide a more effective business process, iii) effective intelligent real time response, iv) moving into related building sectors.

This BIM adoption and implementation was undertaken under a DTI funded Knowledge Transfer Partnership (KTP) scheme. It aims not only to implement BIM and therefore assess the degree of the successful implementation, but rather to position this within the context of value-add offerings that can help the company place itself at the high-end knowledge-based terrain of the sector. Therefore, it adopts a socio-technical view of BIM implementation in that it does not only consider the implementation of technology but also considers the socio-cultural environment that provides the context for its implementation.

3 BIM ADOPTION AND IMPLEMENTATION PROCESS

The action research oriented qualitative and quantitative research for discovery, comparison, and experimentation has been employed in the research. This is because, the KTP project with JMA also provide an environment for “learning by doing” (Boshyk and Dilworth, 2009). Further, action research provides dual commitments; i) to study a system, which is JMA’s architectural practice and ii) concurrently to collaborate with the members of the system, which is JMA’s staff, in changing the system towards a desirable direction. Accomplishing this twin goal requires the active collaboration of researchers and practitioners, and thus it stresses the importance of co-learning as a primary aspect of the research process (O'Brien, 2001). Several attributes justify the research methodology as action research and separate it from other types of research. Primarily, its focus is on turning the people involved into researchers; people learn best and more willingly apply what they have learnt when they do it by themselves (Coghlan and Brannick, 2001). It also has a social dimension; the research takes place in real world situations and aims to solve real problems. It is illustrated in figure 1 below.

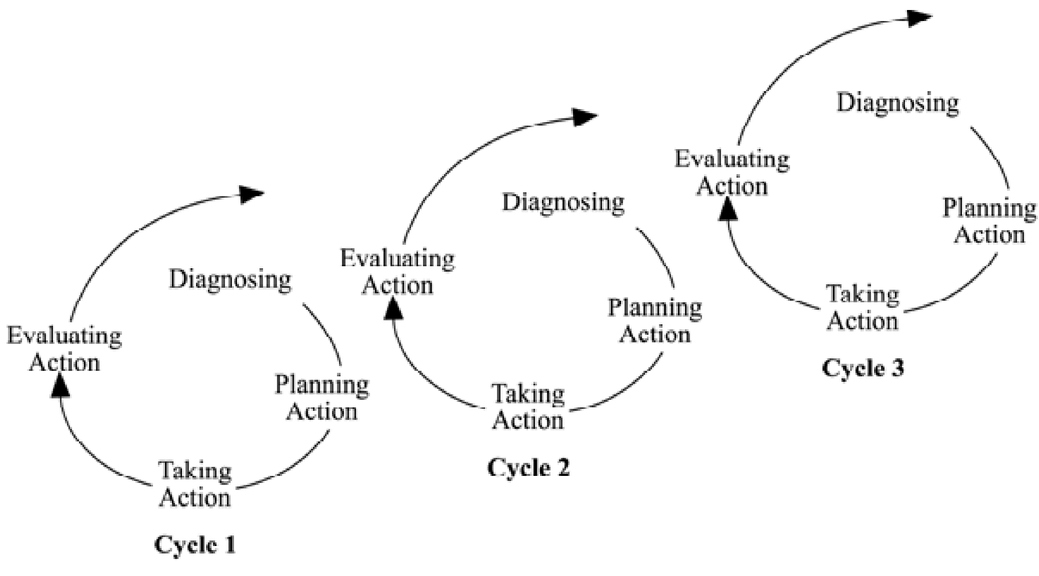

Figure 1 Iterative Action Research Process adopted (Coghlan and Brannick, 2001)

In the BIM implementation, it is critical to consider the process and people factors in addition to technology. Without considering the former, successful implementation of the latter is almost impossible for BIM adoption. Therefore, in each cycle of the implementation, these three key factors considered. However, emphasis on these factors was varied from cycle to cycle. For example, cycle 1 focused on technology while cycle and cycle 3 centred on the process and people factors respectively

The rest of the paper explains these cycles in an iterative manner.

3.1 Cycle 1: The Current Practice and the BIM Tool Selection

Stages of the action research in the BIM implementation is shown in Table 1 below. The main focus of Cycle 1 is to find out i) about the current work practice of the company, ii) which BIM tool is the most appropriate for JMA based on the company's specific features, priorities and iii) the efficiency gains required. The project had a steering group involving five key members. These were BIM and lean design experts from the university, a researcher based in the company, one company director and an experienced architect acting as a supervisor for the company.

Stages	Activities
Diagnosing	Explore the company's current work practice and BIM tools available and identify efficiency gains and potential competitive advantages
Action Planning	Development of cases and plans for the experimentation of the BIM tools
Action Taking	Piloting the tools on the case studies by the vendor representatives and JMA's staff
Evaluating	Comparative analysis of the BIM tools in both quantitative and qualitative manner,

Table 1 The Stages of Cycle 1 in the BIM implementation Process

3.1.1. Diagnosis in Cycle 1: Explore the Practice and BIM

Firstly the methods of communication in the organization were analyzed and flow diagrams produced. The main methodology for mapping the current process workflow was the contextual design technique (Beyer & Holtzblatt, 1998), which prescribes modelling techniques such as flow diagrams, sequence diagrams, artefact modelling, and physical environment modelling and culture modelling to understand and examine the current practice, needs and requirements for improvement via contextual inquiry (Aouad & Arayici, 2010). For example, the communication flow diagrams in pictorial nature were made easily legible and formed a good basis for discussions and interviews with the members of staff and obtained feedback from them.

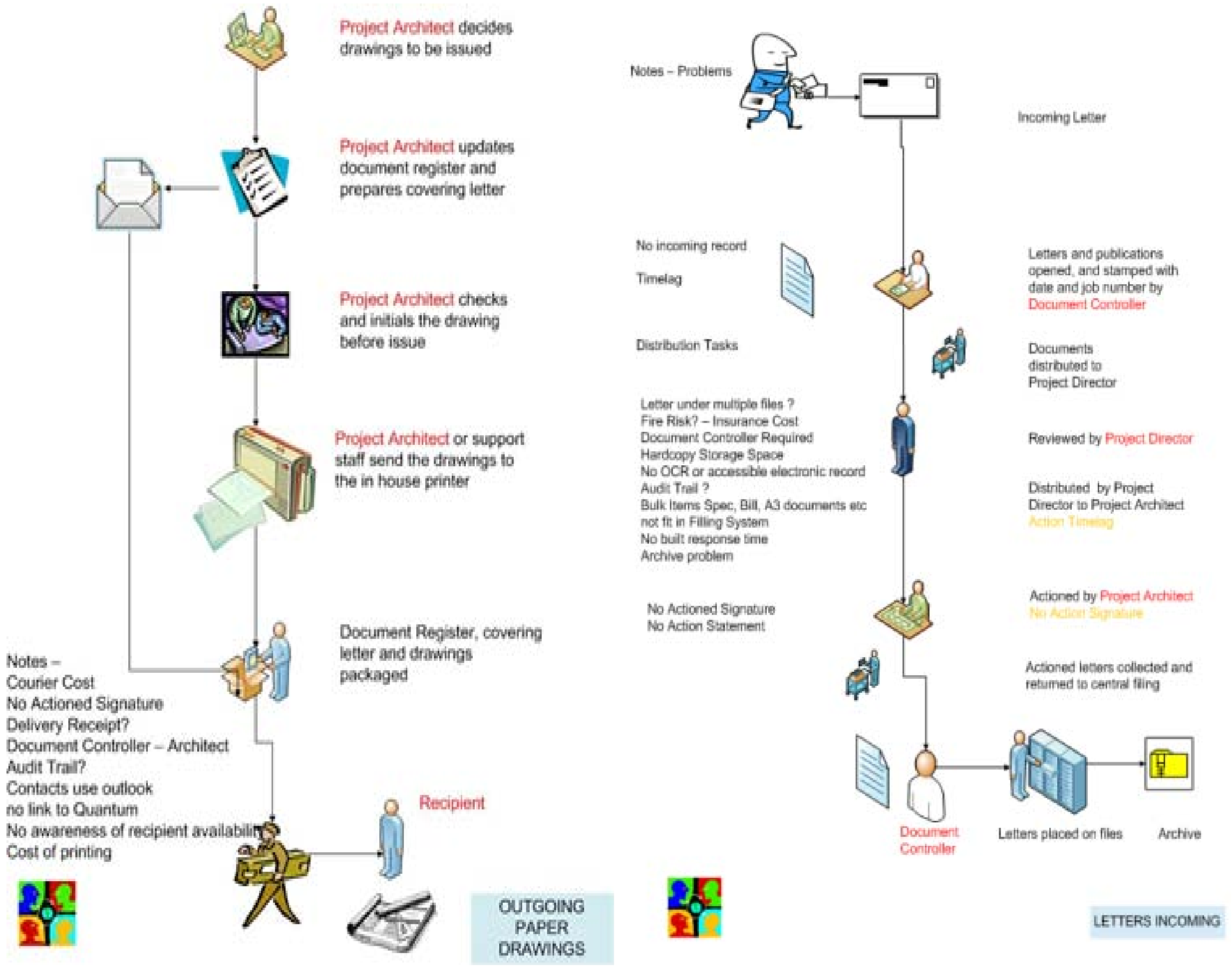

Figure 2: Communication Diagram Outgoing Paper Drawings and incoming letters

The IT System in JMA is integral with the production processes undertaken by the practice. The standard server PC (Personal Computer) model was adopted with intranet connections. The software adopted can be broken up by usage such as document production, presentation production and drawing and graphic production. Bespoke software is used for accounting and resource monitoring processes. All the different software result in a lot of duplication of data in different file formats. In some cases the data is fragmented such as reference files to allow multiple members of staff to contribute to one drawing or brochure.

An important part of the success of the project has been the buy-in by senior member of staff. However, the BIM implementation would affect both internal and external stakeholders. Using contextual design techniques how the existing stakeholders interact with the present process was observed. An area of particular interest was how internal stakeholders maintain the consistency of the drawing set. An area where BIM could make considerable saving in maintaining the dimensional consistency of between representations (drawings) was noted.

The company was using Microstation as a drafting tool and intended to upgrade it to Bentley Architecture as it was provided by the same vendor. Continuous exploration of BIM tools took place for a period of three months. Software vendors ArchiCAD, Revit, Allplan, Vectorworks and Bentley Architecture visited the office to give presentations or webinars to discuss the benefits of their particular software platform. This has proved to be an effective way to generate interest and awareness in the office to BIM and its terminology and associated ways of working. It was also a good way to reduce the reservations in the company against any BIM system as the company simply upgrade itself from Microstation to Bentley Architecture. The more exposure members of staff become more knowledge about it, the easier the transition would be.

As a background for the BIM implementation project, a SWOT (Strength, Weaknesses, Opportunities, and Threats) analysis was undertaken to realize the potential efficiency gains and ultimate competitive advantages for JMA. Through the SWOT analysis, both internal and external positions of JMA at the current time and in the future have been examined; looking into the company's strengths, weaknesses, opportunities and threats. The analysis included looking at emerging technology and changing methods of procurement. By understanding the strengths of the company it is possible to understand those factors that are important for JMA to maintain competitive market share. By looking at the companies weaknesses and undertaking a review against lean principles (Koskela, 2003) it was possible to reveal areas of waste.

By envisioning the future trends, it was possible to better predict how BIM would be used in the company. It is also possible to predict for what type of project the BIM process would be used. The competitive advantages in the SWOT report were identified as cost leadership, differentiation, cost focus, differential focus and collaboration. BIM has the potential to provide advantages in all of these areas. By reducing both the time and the effort to generate architectural information, BIM could give John McCall Architects or its team the opportunity to offer the most competitive bids for projects. By avoiding errors and reducing the need for information requests from site John McCall Architects has the potential to differentiate itself by providing a better service by using BIM.

The SWOT analysis also demonstrated how saving could be made through the adoption of Lean principles (Koskela & Ballard, 2006). Initial seminars have been given in the office on "quality" and "lean principles". The discussion about lean principles; avoiding waste and focusing on value adding processes has provided a good counter balance to the ISO 14000 principles which are also been reviewed by the practice. Meetings have also been setup to discuss how the adoption of BIM can assist in the drive for sustainable design projects. On the other hand, members of staff need to be trained how to use the BIM system and guideline and procedures needed to be developed. But the important thing is to engender the staff with the attitude of looking for better ways of working and the team mentality of discussing new ideas as an ongoing process development and improvement.

The main characteristics of BIM implementation strategy and the subsequent efficiency gains are clarified at the completion of the diagnostic activities, which are listed below.

- Improvement of the operational and IT processes and broaden the knowledge of existing staff and stakeholders up and down the supply chain
- Significant competitive edge over similar sized practices potentially resulting in increased turnover
- Improved management of the client/contractor/consultant relationships, essential to support the sales growth, leading to enhanced partnering/framework options.
- Better co-ordination, better quality data production and information exchange across the wide spectrum of information sources utilised and exported to others, including the building model, technical drawings, schedules and specifications.
- Enhanced design solutions developed at an earlier stage due to more time and effort being available to the design team. Improvements in dealing with design changes and change control enabling the practice to react efficiently and proactively to changing client aspirations throughout the design stages.
- Savings through improved internal efficiencies and better service delivery to clients enabling JMA to position itself at the forefront of international trends in the sector.
- Development of staff to increase the visible expertise and reputation of the company. Increased technical staff job satisfaction by the removal of inefficient and repetitive tasks which detract from the core task of the design process.

3.1.2 Action Planning in Cycle 1: Development of Cases and Plans for Experimentation

As a result of the diagnostic review, a good level of presentational output from the BIM system was expected. Additional rendering engines were required. The way multiple users interact with a single model was also important. The methods of sharing outputs and interaction with other consultants within the team were also critical. How models can be recombined and clash and warning mechanisms were also important. The level of support and training provided by the software vendor also needs to be considered. The other question is whether to adopt a BIM system that runs on top of 2D software or to purely adopt a BIM system. Another consideration is the level of bidirectional interoperability. External stakeholders may demand intelligent or non intelligent outputs from the BIM system. In this sense there should be a flexibility of output, but this does not degrade the output to the stakeholders compared with the output from the existing CAD systems. The primary need of the external stakeholders is to facilitate the built objective. Though the multifaceted forms of output and analysis from the BIM model should be possible, new and more appropriate artefacts should be tailored to the building design process. These are only some of the 40 key criteria identified from diagnostic stage for the selection of the right BIM tool.

While the diagnosis helped increase the understanding about current practice of the company and the off-the-shelf BIM tools, JMA’s initial intention towards Bentley Architecture was neutralised. Further hands-on experimental studies were planned. Initially, trial versions of all the considered BIM tools were obtained for hands-on experimentation. Many members of the staff were given the opportunity to try these BIM tools on simple designs. It was observed that different members of the staff had a distinct preference for a particular BIM tool.

Although the BIM tools evaluated were similar in many ways, certain tools such as the ArchiCAD seemed intuitive to some staff. Some members of the staff viewed the tools as design tools; some others considered them as tools for production information. The JMA staff developed basic skills using the BIM tools but did not reach a level of proficiency. Thus, one month trials were not sufficient to make decisions on the selection of a BIM tool.

In order to address the issue of lack of experience in the use of various BIM tools, it was the time to plan rigorous experimentation. A clear action plan and scenario from a past project was developed for the experimentation of the BIM tools. Previously identified criteria derived from the potential efficiency gains refined as the checklist for the experimentation. The plan included alpha tests conducted by the vendors' demonstrators and the beta test undertaken by the selected JMA staff.

3.1.3 Action Taking in Cycle 1: Piloting Exercise by the Vendors and the JMA Staff

Initially the vendors performed their proprietary BIM tools and the JMA staff observed and assessed the performances against the test checklist. The experimentations for each BIM tool were undertaken in two sessions of one and a half hour periods. Throughout the experimentations, the level of details in the test case was increased and changes in the design were requested. This was to test the flexibility of the tools. What seemed easy in one tool looked particularly difficult in another one. This was a critical exercise to understand how a BIM tool aligns itself to specific company requirements. As a result of this initial experimentation, the JMA staff filtered three BIM systems for the second phase of experimentation. These are ArchiCAD, Revit and Allplan, while they had a preference towards ArchiCAD tool as seen intuitive and straightforward in the following efficiency gains

- The quality, speed and cost of the services JMA 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
- Information sharing
- Greater flexibility to satisfy customers
- Better financial control
- Simultaneous work by multiple disciplines

However, it was not sufficient to make the final decision. Therefore, the test records were kept against the specifically designed checklist of 40 criteria. It was now time for the second phase experimentation by the JMA staff. Three remaining BIM tools were tested by the three selected JMA staff on other past projects. The test results were logged into the checklist document by the three testers individually to form the basis of the quantitative assessment. This provided the opportunity to compare three BIM tool with each other. The test results were logged into the checklist document by the three JMA staff individually to form the basis of the quantitative assessment.

3.1.4 Evaluation and Outputs from Cycle 1

Each criterion in the checklist was then given a score of 1 to 5 depending on how well each BIM tool met the corresponding criterion by each staff separately. All three separate analysis showed that ArchiCAD was the leading tool in the results. Following that, the 40 criteria in the checklist were weighted by JMA's senior management based on their priorities. The three separate test results were aggregated according to JMA's priority weightings and specific requirements. This helped to produce cumulative scores for each BIM tool. As a result, ArchiCAD tool was favoured selection for JMA use as shown in table 2 below.

Facet	**Weight**	**ArchiCAD**					**Revit**					**Allplan**				
		J	K	P	T	TW	J	K	P	T	TW	J	K	P	T	TW
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
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
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
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
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
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
Market Share	0.95	4	4	3	11	10.45	5	5	5	15	14.25	3	2	1	6	5.70
3D pdf capability	0.95	5	5	5	15	14.25	1	2	2	5	4.75	5	5	3	13	12.35
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
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
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
Print management	0.90	5	5	4	14	12.60	1	3	3	7	6.30	4	5	4	13	11.70
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
Virtual reality engine	0.90	5	5	5	15	13.50	2	3	3	8	7.20	2	3	3	8	7.20
Drawing issue management	0.85	5	5	4	14	11.90	2	2	4	8	6.80	4	4	4	12	10.20
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
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
Eco Linking	0.85	5	5	4	14	11.90	3	3	4	10	8.50	4	3	3	10	8.50
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
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
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
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
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
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
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
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
Support	0.75	5	3	4	12	9.00	3	3	4	10	7.50	3	3	3	9	6.75
Training Arrangements	0.72	5	5	4	14	10.08	4	5	4	13	9.36	3	4	2	9	6.48
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
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
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
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
Clash Detection	0.60	3	3	1	7	4.20	4	5	4	13	7.80	2	2	1	5	3.00
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
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
New material input	0.50	5	5	4	14	7.00	4	5	4	13	6.50	5	5	4	14	7.00
Revision control management	0.50	5	5	2	12	6.00	3	3	4	10	5.00	4	3	2	9	4.50
Cost of Licience	0.50	4	4	4	12	6.00	3	3	3	9	4.50	2	2	2	6	3.00
Service Cost	0.50	4	4	4	12	6.00	4	4	4	12	6.00	3	3	3	9	4.50
Design Options	0.50	3	1	3	7	3.50	4	3	5	12	6.00	4	1	3	8	4.00
Demonstrate rendered image quality	0.40	5	5	4	14	5.60	5	5	5	15	6.00	4	4	3	11	4.40
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
Network capabilities	0.25	5	5	5	15	3.75	4	4	4	12	3.00	4	4	4	12	3.00
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**

Table 2: matrix analysis of the BIM tool experimentations

3.2 Cycle 2: Lean Process Improvements and Knowledge Management (KM)

Increased understanding and awareness of BIM led to further diagnosis towards lean design process in cycle 2. For example, lean improvements were needed in the marketing, administration, finance, contractual related project support information, which are directly related to one or many projects yet cannot be modelled with BIM. However, efficient handling those project support information certainly has impact on the actual design project information modelled in BIM. Therefore, lean improvements should not only be considered at project level via BIM but also at organisational level via Knowledge Management. While cycle 2 also considered technology, people and process aspects, the main emphasis was on the process factor in this round.

Stages	**Activities**
Diagnosing	Lean thinking exercise for process improvements and subsequent requirements engineering for the organisational KM System
Action Planning	identifying three different current design projects of JMA for ArchiCAD piloting and design of KM system
Taking Action	piloting the AchiCAD tool on the identified current design projects and the development of the project support information database
Evaluating	assess the performance against the efficiency gains (lean efficiency gains achieved by now)

Table 2: Action Research Stages of Cycle 2 in BIM Implementation

3.2.1 Diagnosis in Cycle 2: Lean Thinking and KM at Organisational Level

It was necessary to understand the organizational inputs, outputs, and the desired outcomes in relation 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). Using the diagnostic material from cycle 1, the following attributes are sought for the definition of KPIs:

- Does the KPI motivate the right behavior?
- 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 the company?
- Is the KPI meaningful?

This led to identification of the following KPIs for the evaluation of the business improvement in JMA and subsequently the assessment and measures the extent of the success of BIM adoption.

a) Man hours spent per project
b) Speed of Development
c) Revenue per head
d) IT investment per unit of revenue
e) Cash Flow
f) Better Architecture
g) A better product

h) Reduced costs, travel, printing, document shipping
i) Bids won or win percentage
j) Client satisfaction and retention
k) Employee skills and knowledge development

Unlike on an assembly line where lean principles were initially developed by Toyota, in architectural practice, it is not so much about assembling parts but applying knowledge. Therefore, development and documentation of lean process and procedures highlights how, data, information and knowledge could be handled better at JMA via creative processes.

The main approach used for lean process improvements in the project is A3 method, which is a proven to be a key tool in Toyota's successful move towards organisational efficiency and effectiveness and improvement (Durward and Sobek, 2008), (Koskela, 2003). The A3 management process is used to solve problems, gain agreement, mentor and lead (Shook, 2008) to identify and resolve i) waste of overproduction, ii) waste of waiting, iii) waste of transportation, iv) waste of inappropriate processing, v) waste of unnecessary inventory, vi) waste of unnecessary movement, vii) waste of defects and ix) other wastes. It was used not only to simulate changes at project level but also at organisational level including finance, administration and marketing. For example, it was used for i) Improvements via BIM based product information documentation at project level, ii) improvements via knowledge management system at organisational level. The figures 3 and 4 below show these two examples of lean process improvements.

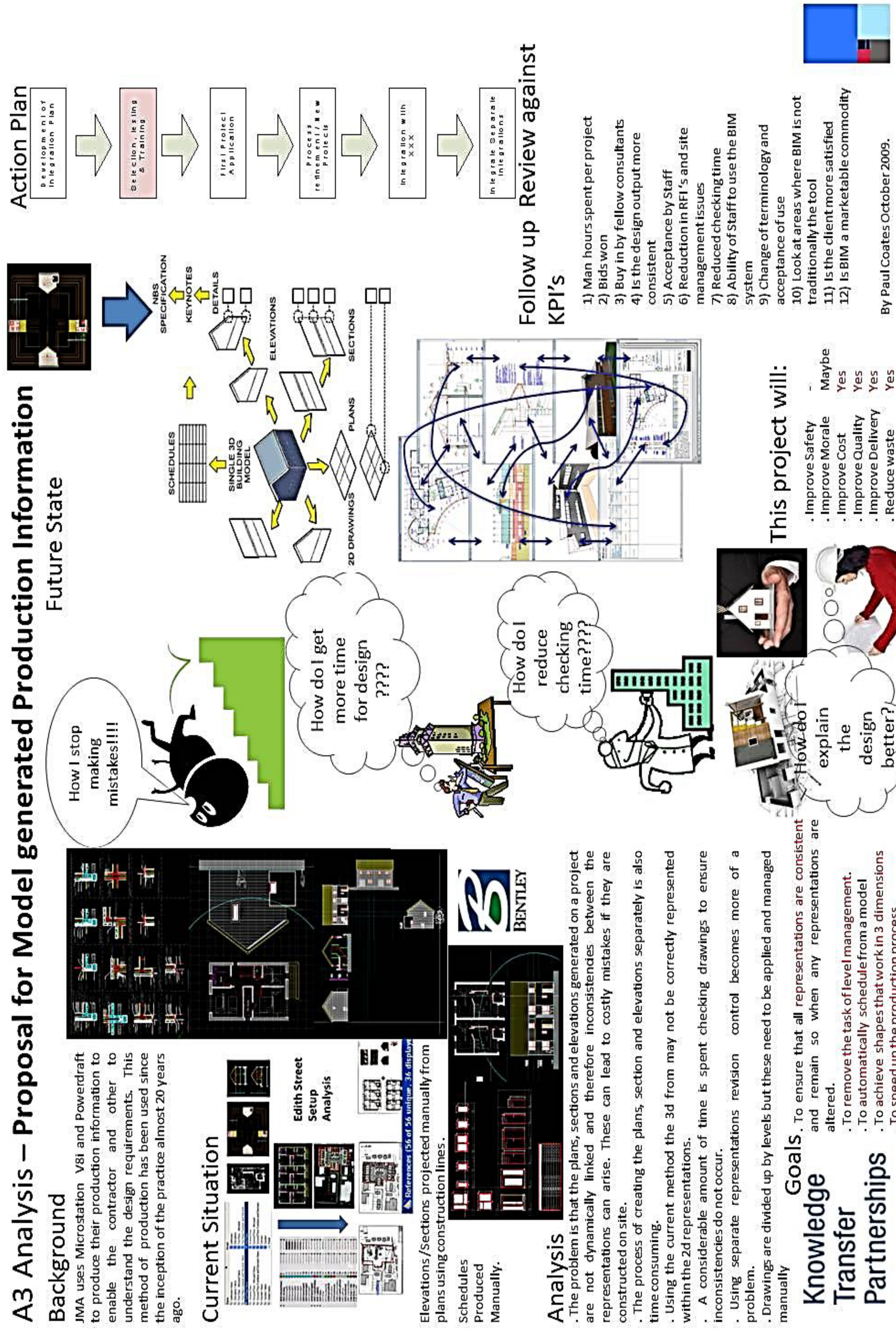

Figure 3: Improvements via BIM based product information documentation at project level

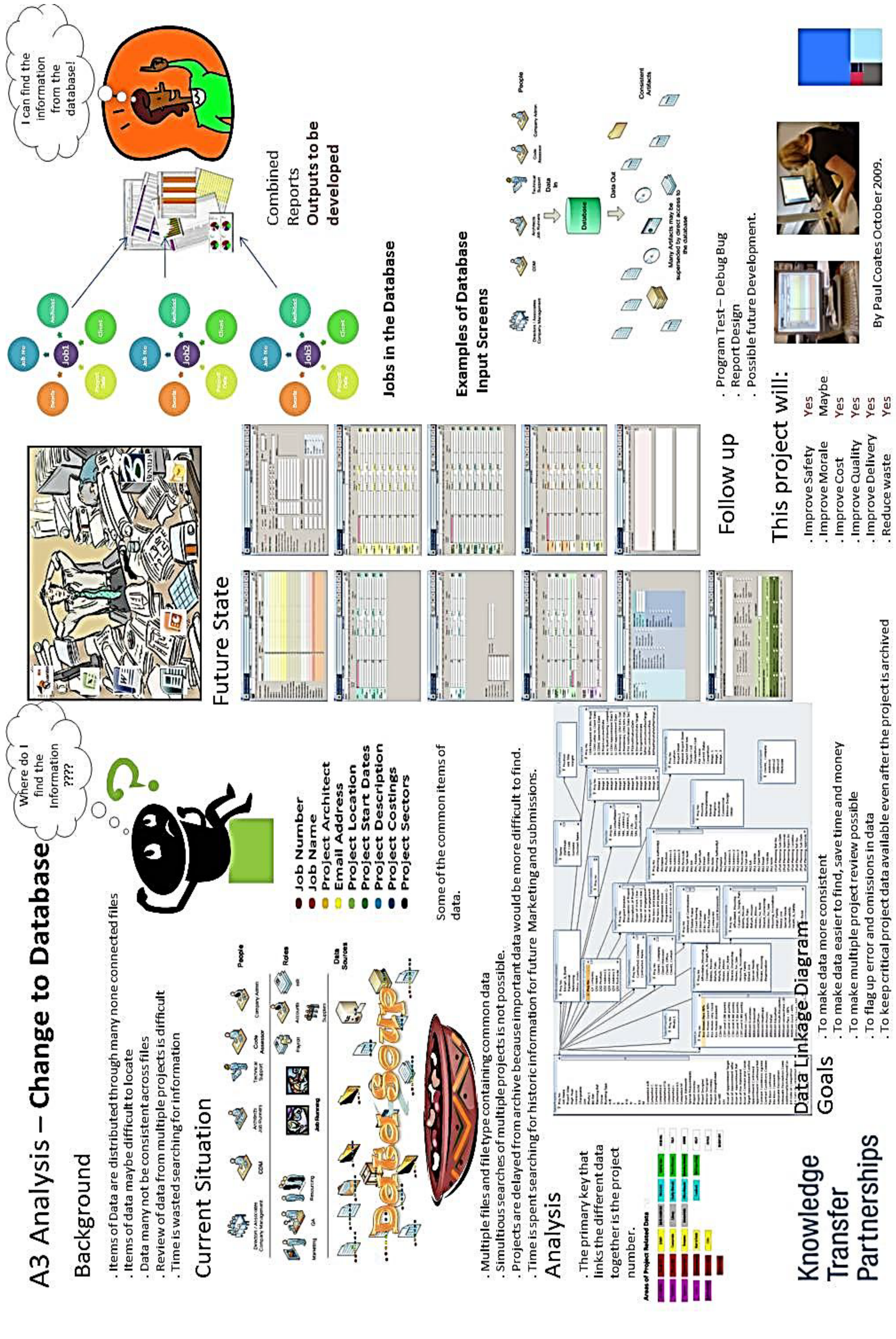

Figure 4: Improvements via knowledge Management system at organisational level.

3.2.2 Action Planning in Cycle 2: Selection of Current Design Projects in JMA and the Design for the KM System

The A3 exercise above showed that, there was a need for development of a KM System that would pool all the project support information for all projects and facilitate lean improvements by eliminating wastes due to ad hoc management of those activities and generate value as it would have impact on the actual design project via BIM. Therefore, requirements engineering studies were carried out, which was then translated into the system architecture for the KM system. Evolutionary prototyping approach was decided for its development to enable symbiotic user communication. For example, the first early release for the KM system was demonstrated to the staff use and it was then gradually improved based on the feedback from the staff continuously.

The preparation and planning of the actual BIM tool adoption was primarily prescribed by three factors; i) the financial restrictions on the speed with which the BIM tool could be purchased, ii) finding appropriate projects on which to use the BIM orientated approach and iii) the speed with which members of staff could be trained to use the BIM authoring software. Particular consideration in the planning process was given to when and how the BIM object libraries and also office BIM standards were to be developed.

3.2.3 Action Taking in Cycle 2: Piloting ArchiCAD on the selected projects and Development of the KM System

For the gradual increase in the use of the ArchiCAD tool in JMA, it was used on three different ongoing JMA project by the staff. While this would give the opportunity for training of the staff and increase their skills to proficiency, it also provided the chance to observe how much efficiency can be achieved via the BIM tool. The projects selected were i) Leathers Lane Adult Centre ii) Millachip Court Phase 3 and iii) Broomlane Autistic Centre. These projects were monitored closely to distil the lessons learnt. Figure below shows an example of the piloting project with the BIM tool.

Figure 5: Part of the BIM model belonging to the Millachip piloting project

The major advantage of BIM was to input into a single information model and the multiple representations and extraction from this single information model. However, there are areas of information such as finance, marketing, administration that does not go into BIM model but has certain impact on the BIM modeling of a design project. Therefore, it was decided to apply these principles for the project support information residing outside of the BIM graphical model such as client names, address, dates etc. For this purpose, the critical data that is commonly duplicated in spreadsheets, word documents and emails was reviewed and developed into a relational database used by all members of staff in the company. This provided a platform to record, share and interrogates project support information internally across the company. This is illustrated in figure 6 below.

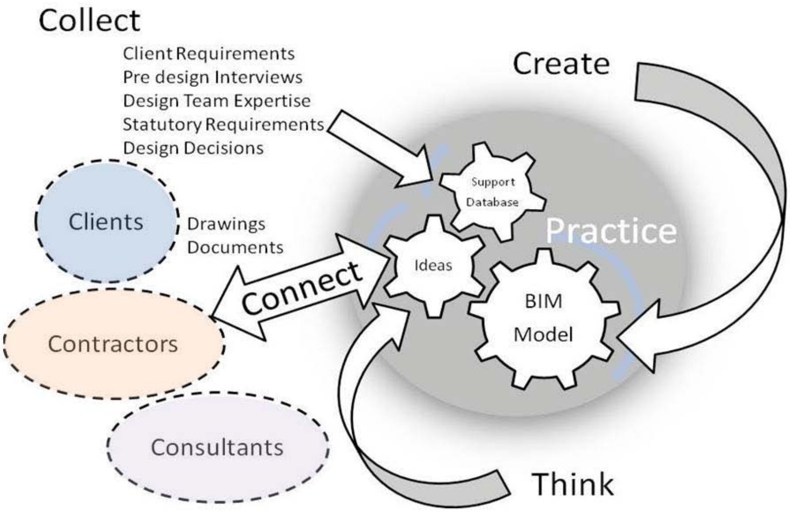

Figure 6: Knowledge Management Perspective integrating BIM with the rest of the architectural practice.

3.2.4 Evaluation in Cycle 2

The piloting projects helped to develop an understanding of what is needed for BIM modeling, which subsequently led to improvements in how to sequence the steps in efficient BIM modelling. Furthermore, this increased understanding brought about a systematic approach of how to effectively use reference BIM objects, which could provide particularly efficient in generating design solutions with multiple similar units. This systematic approach was initially experimented for the use of object assembles such as kitchens and bathrooms. The major benefit noted at this cycle that the increased awareness of the design through rapid generation of 2D and 3D representations

The particular benefits of KM system were that information was retained in the same database even when projects are archived. Experiences from past projects are maintained as the company's knowledge asset. Also the database has become particularly useful for marketing purposes. The resultant schema that is being worked towards is as to capture knowledge and experiences from past projects and from experienced staff via this knowledge database in the future.

Continuous improvement was a facet built into JMA's quality system. However, with a radical change via BIM adoption, it was critical to continually review and benchmark the new process. BIM opened the door to many possibilities. For example, working with 3D models facilitates the generation of 3D visuals, 3D printing and linking with virtual environments. Part of improving the companywide capabilities was maintaining the BIM dialogue so BIM knowledge and best practice was disseminated around the practice.

3.3 Cycle 3: Staff Upskilling in Conjunction with Further Technological and Process Improvements

Through the action research cycles, learning was increased tremendously and better shared understanding about BIM was established, particularly after witnessing the benefits through the piloting activities in cycle 1 and 2, forward lean thinking led to how further efficiencies could be gained, which had particular focus on people factor of BIM implementation while considering the technology and process factors.

Stages	**Activities**
Diagnosing	Identify needs for further improvement and up skilling across the company and beyond
Action Planning	Planning activities in i) training and dissemination within JMA and beyond, ii) Design of object library structure and iii) documenting process and procedures of the BIM system use in conjunction with the KM system,
Action Taking	Conduct Training programmes, object library and catalogues development specific to social housing, documentation and testing of the new process and procedures on JMA's current housing design projects
Evaluation	Measure and assess the performance improvement and impacts on the overall performance of the company, internal and external dissemination of the findings

3.3.1 Diagnosis in Cycle 3: Requirements Engineering For Improvements and Upskilling

Although some efficiency gains were achieved in Cycle 2, it was agreed that they could be increased by expanding the use of the BIM enabled new lean process across the company by conducting regular but intensive training and lecture sessions for the staff and the presentations for the external partners of JMA. In addition, these training and lecture sessions could enable interaction with the staff to explore and capture the tacit requirements and needs, which could help for further efficiency gains and improvements via BIM while increasing their knowledge and skills in BIM.

For example, social housing has its own types, standards and regulations. Even if BIM authoring tool was used, there would still be some repetitions, overworking due to similar requirements of social housing projects. Therefore, a leaner process of BIM modelling could be achieved by developing a BIM object library and catalogues specific to social housing and regeneration. Use of these objects in a collaborative environment, enabled with the internal BIM server technology, in the design projects could tremendously improve the process in cost, time and workforce. However, to assure that this BIM object library was used effectively, it was also required to produce a guide for the BIM enabled lean process and procedures in social housing projects.

3.3.2 Action Planning in Cycle 3: Planning Training and Further Lean Improvements

Overall, four areas of training are organised and conducted. These are: 1) Basic Operation Skills, 2) JMA modelling standards, 3) JMA methodology of model construction, 4) How to work with external parties. To develop basic operational skills hands on training was given. This consisted of three two hour sessions. The members of staff were asked to produce in BIM projects they had already undertaken in CAD. To instil the modelling standards, methodology and the ability to work with others into the company demonstrations are reference material was developed.

Library objects were identified and developed. Firstly furniture libraries were developed with the clear zones required around the furniture marked. While the furniture objects were developed to comply the design solutions with the Housing Quality Index standards (HQI, 2008), which applies to social housing in the UK, the wall types were developed to comply the design solutions with part E of the UK building regulations and robust and enhanced details. A coding system was also developed to more accurately understand the wall types through the naming convention used. Although there was a time saving by using these components, the major benefit was in knowing preapproved wall types were being used, which would have great impact on the approval process of the proposed design solutions by JMA. Furthermore, composite floor slabs and roof types were also be developed.

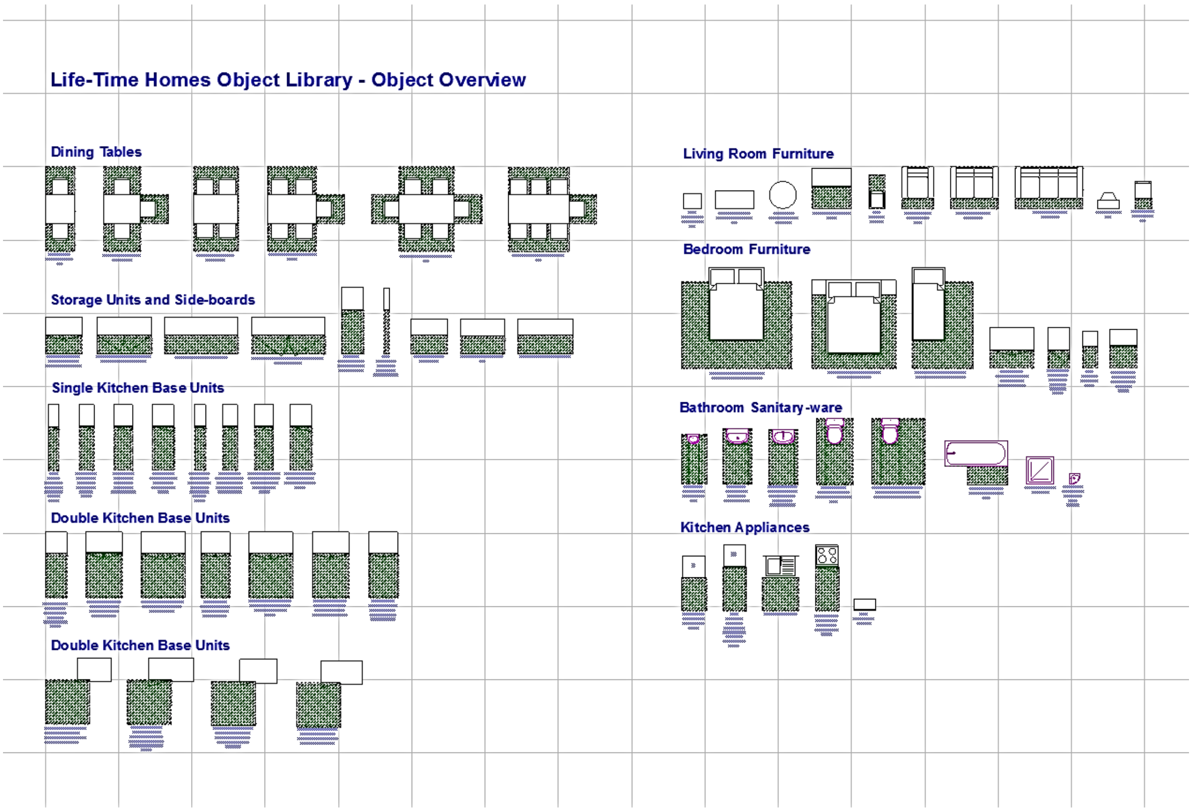

Figure 7: Example of Life Time Homes object library

To provide guidance for staff moving to BIM it was decided to write a guidance manual. The manual covered software concepts, project types, the working environment, filing structures, preliminary and scheme design methods, building control, planning and as built drawings. Although the manual was developed as a word file it is hoped to integrate this on the office intranet and possibly make it available from directly inside the BIM software.

3.3.3 Action Taking in Cycle 3: Conduct Training, Object Library development and Lean Process Documentation

Along with all staff receiving hands on training, presentations were made on specific topics. Either one or two presentations were given per week over a three month period. The lunchtimes were used to give these presentations. These were often followed by piloting projects using the BIM software. Usually about a third of the office attended these presentations. Listed below are some of the topics covered by these presentations:

1. How to create roofs 2. Eco considerations 3. How to make efficient models 4. Use of Libraries 5. Designing stairs 6. General Issues 7. Software Add-Ons	8. File Formats 9. Object Types 10. Template Files 11. New features in the software 12. Use of Guide Lines 13. Plot versus Print 14. Cursor Forms 15. Complex Profiles	16. Collaboration 17. Display Control 18. Schedules 19. Terrain Modelling 20. Virtual Legends 21. Wall and Slab Junctions 22. Using the BIM Server 23. GDL

Table 4: List of Training Topics given in Cycle 3

For the implementation and refinement of the object libraries, more piloting projects were used by the JMA staff. Since these piloting projects were carried out according to the process and procedures documented in the previous step, this documentation of the process and procedures were also rectified and improved. As a result of the training and piloting projects in the company helped to improve knowledge and skills of JMA staff.

Figure 8: The Broomlane Prototype Project

Furthermore, it was this stage that BIM server facility was embedded and experimented in the piloting projects initially internally within the company to collaboratively produce solution in a faster, accurate and cost efficient manner.

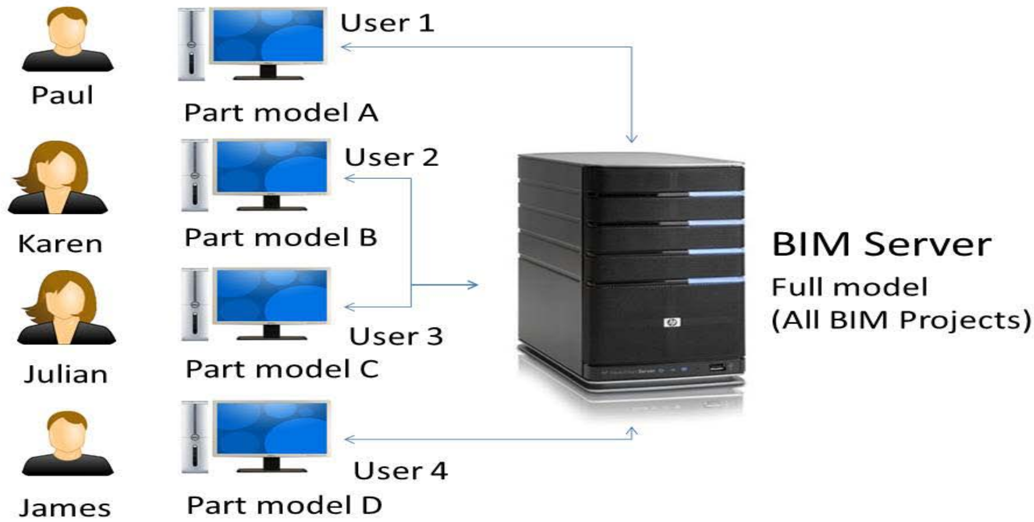

Figure 9: BIM server enabled collaborative environment

Furthermore, piloting ensured that all new objects within the library comply with the relevant building regulations. Using the objects in production projects also established how the objects export and print in other formats.

3.3.4 Diagnosis in Cycle 3: Assessment of the Performance Improvement and Dissemination

Assessment and discussions toot place as findings and efficiency gains that were observed in cycle 3 simultaneously in a collaborative manner. Lean is an ongoing journey that JMA can more effectively undertake through the experimentation of lean practices. BIM adoption in JMA had internally big impact to gain efficiencies and effectiveness as the adoption established the required capacity internally as follows.

- Maintaining lessons learnt and experiences from the past projects as company asset
- Integrating the KM system to marketing, finance, administration and BIM based design projects
- Ability of top management for project progress monitoring
- Effective reuse of information via the KM system that centrally facilitates search such as house types, materials used code for sustainable home rating, client, etc.
- Consistent exchange of information within JMA
- Quality, time and cost efficiency via automation such as drawings, quantity take-off automatically, instant generation of VR models, discovering design errors and conflict

analysis, information sharing and exchange, greater flexibility to satisfy customers, simultaneous work by the staff in the company.

- Consistency across the drawing sets
- Automation of emails and finding consultant offices via the KM system that facilitates faster access time to useful information, automatically include project information in email, and links postcodes to maps.
- Integration with Energy Assessment tools for “Code for Sustainable Homes” standards such as IES
- Lean process of conceptual design and detailed design development via BIM modelling of the housing design projects
- Effective design and technical review of all the projects in order to avoid potential problems arising from mistakes in the future
- Leading to standardised lean design process across the company

However, what JMA needs to do is push to develop linkages with other BIM enabled organizations so the true benefits of BIM through the supply chain can be achieved too. JMA intends to be a market leader in the field of BIM. In this line, a vision development exercise has also been undertaken, which brings together BIM, Lean and the sustainable design context as complementary components to provide a future roadmap for continuous improvement towards sustainable design solutions.

In regard to sustaining new products and services, with the capacity built via the BIM adoption JMA can offer the post completion facility management of the projects. Finally, for the dissemination of the project, presentations in different conferences, events and workshops for industrialists and academics, and involving in exhibitions were also undertaken.

4. CONCLUSION

The KTP enabled JMA to establish itself as the vanguard of BIM application giving them a competitive edge because BIM enables 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 both for JMA and across the supply chain.

It provided a clearer vision and roadmap with detailed strategies, methods and techniques for successful BIM implementation. Furthermore, based on the current findings and optimistic behaviour and culture evolved during the project, it re-engineered the operational and IT processes and broadened the knowledge of existing staff up in the company while increasing the awareness of the external partners working with JMA in the supply chain. This is because the BIM adoption and implementation approach was as much about people and processes as it is about technology to i) engage people in the adoption, ii) ensure that people’s skills and understanding increases and companies building up their capacities, iii) to apply successful change management strategies, iv) to diminish any potential resistance to change.

Although the adoption process can be slower as it is inclusive and engaged with people, the impact of the BIM adoption on the company practice can be measured. The employed action research strategy has enabled the "learning by doing". For example, in the JMA case study, no one had any knowledge or experience of BIM prior to this BIM implementation project apart from the few forward thinking top management members. However, after the completion of the-two-year project, the company made significant progress in up skilling staff, technology infrastructure development and lean process improvements. This progress did not stop. The intention was to enable JMA to maintain the continuous improvement even after the project. Hence, the paper finally recommends the BIM implementation strategy in this study as a guide at operational level for SMEs that also aims BIM adoption.

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