University of Huddersfield Repository

Arayici, Y., Coates, P., Koskela, Lauri, Kagioglou, Mike, Usher, C. and O'Reilly, K.

BIM adoption and implementation for architectural practices

Original Citation

Arayici, Y., Coates, P., Koskela, Lauri, Kagioglou, Mike, Usher, C. and O'Reilly, K. (2011) BIM adoption and implementation for architectural practices. Structural Survey, 29 (1). pp. 7-25. ISSN 0263-080X

This version is available at https://eprints.hud.ac.uk/id/eprint/25832/

The University Repository is a digital collection of the research output of the University, available on Open Access. Copyright and Moral Rights for the items on this site are retained by the individual author and/or other copyright owners. Users may access full items free of charge; copies of full text items generally can be reproduced, displayed or performed and given to third parties in any format or medium for personal research or study, educational or not-for-profit purposes without prior permission or charge, provided:

- The authors, title and full bibliographic details is credited in any copy;
- A hyperlink and/or URL is included for the original metadata page; and
- The content is not changed in any way.

For more information, including our policy and submission procedure, please contact the Repository Team at: E.mailbox@hud.ac.uk.

http://eprints.hud.ac.uk/

BIM Adoption and Implementation for Architectural Practices

Y. Arayici, P. Coates, 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: Severe issues about data acquisition and management arise during the design creation and development due to complexity, uncertainty and ambiguity. BIM (Building Information Modelling) is a tool for a team based lean design approach towards improved architectural practice across the supply chain. However, moving from a CAD (Computer Aided Design) approach to BIM (Building Information Modelling) represents a fundamental change for individual disciplines and the construction industry as a whole. Although BIM has been implemented by large practices, it is not widely used by SMEs (Small and Medium Sized Enterprises).
Purpose: This paper aims to present a systematic approach for BIM implementation for Architectural SMEs at the organizational level
Design/Methodology/Approach: The research is undertaken through a KTP (Knowledge transfer Partnership) project between the University of Salford and John McCall Architects (JMA) a SME based in Liverpool. The overall aim of the KTP is to develop lean design practice through BIM adoption. The BIM implementation approach uses a socio-technical view which does not only consider the implementation of technology but also considers the socio-cultural environment that provides the context for its implementation. The action research oriented qualitative and quantitative research is used for discovery, comparison, and experimentation as it provides "learning by doing".
Findings: The strategic approach to BIM adoption incorporated people, process and technology equally and led to capacity building through the improvements in process, technological infrastructure and upskilling of JMA staff to attain efficiency gains and competitive advantages.
Originality/Value: This paper introduces a systematic approach for BIM adoption based on the action research philosophy and demonstrates a roadmap for BIM adoption at the operational level for SME companies.

Keywords: Building Information Modelling, Lean principles, Knowledge Database, Action research, Architectural practice

1. INTRODUCTION

The construction industry has been facing a paradigm shift to (i) increase: productivity, efficiency, infrastructure value, quality and sustainability, (ii) reduce: lifecycle costs, lead times and duplications, via effective collaboration and communication of stakeholders in construction projects (Nour, 2007). Building Information Modelling (BIM) seeks to integrate processes throughout the entire lifecycle (Aouad and Arayici, 2010).

There is some evidence to suggest that the architectural profession is beginning to come under pressure to adopt BIM. Although BIM has existed for over 20 years, it is only over the last few years that 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 insist that architects and other design professionals, construction managers and construction companies adopt BIM (Mihindu & Arayici, 2008). On the other hand, there are challenges in implementing BIM in UK construction practice such as:

- Overcoming the resistance to change, and getting people to understand the potential and the value of BIM over 2D drafting
- Adapting existing workflows to lean oriented processes
- Training people in BIM, or finding employees who understand BIM
- The understanding of the required high-end hardware resources and networking facilities to run BIM applications and tools efficiently
- The required collaboration, integration and interoperability between the structural and the MEP designers/ engineers
- Clear understanding of the responsibilities of different stakeholders in the new process by construction lawyers and insurers
  (Arayici et al, 2009a, Arayici et al, 2009b, Eastman et al, 2008)

Hence, implementing BIM effectively requires significant changes in the way construction businesses work at almost every level within the building process. That is to say, it does not only require learning new software applications, but also how to reinvent the workflow, how to train staff and assign responsibilities, and changing the way of modelling the construction (Bernstein and Pittman, 2004, Eastman et al, 2008). Thus, it appears that the industry could benefit from a clear set of guidelines outlining an effective strategy and methodology of implementing BIM at the organizational level (Bernstein and Pittman, 2004). Therefore, the aim of this paper is to introduce a best practice study of BIM adoption for an architectural company practising in social housing and to highlight the implications for the company workflows and identify efficiency gains. The paper then recommends the adopted approach of BIM implementation at the operational level for other SME architectural companies.

2. THE CASE STUDY COMPANY: JOHN MCCALL'S ARCHITECTS (JMA)

John McCall Architects in Liverpool focuses 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 has used a 2D CAD tool for two decades. The company also has its own procedures and templates to optimize its practice. However, the current practice with this 2D CAD tool brings about some inefficiencies such as timescales, deadline pressures, duplications, lengthy lead times, lack of continuity in the supply chain, over processing,

reworking, overproduction, distractive parallel tasks, lack of 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.

At the strategic level, lean principles (Liker, 2003, Koskela, 2003) which are: i) eliminate waste, ii) increase feedback, iii) delay decision, iv) deliver fast, v) build-in integrity, vi) empower the team, vii) see the whole have been utilized and they formed the seven pillars of the BIM implementation strategy. There was no practical understanding and awareness of BIM in the company at the beginning of the project. Yet, senior managers of the company had some visionary understanding of BIM for investment to attain competitive advantage and better position in market place and provide sustainable green design solutions in the future. The next section explains the research methodology of the paper.

3. RESEARCH METHODOLOGY

The aim of the paper is to demonstrate a BIM adoption process for mapping and re-engineering the strategic and operational processes of the company at the organisational level of SMEs. It adopts a socio-technical view of BIM implementation in that it not only considers the implementation of technology but also considers the socio-cultural environment that provides the context for its implementation.

An action research oriented qualitative and quantitative approach for discovery, comparison, and experimentation has been employed in the research. This is because, the KTP project with JMA also provided an environment for "learning by doing" (Boshyk and Dilworth, 2009).

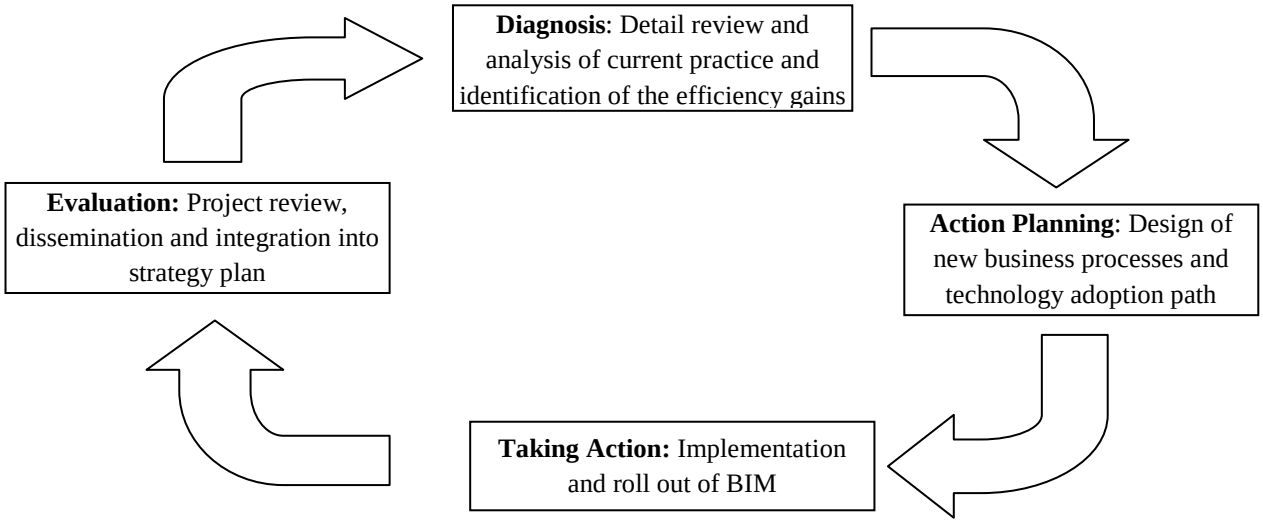

Figure 1: Action Research Process adopted

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 are JMA's staff, in changing the system towards a desirable direction. Accomplishing these twin goals 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). Furthermore, primarily, its focus is on turning the people 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.

In accordance with the action research philosophy, the BIM implementation process is planned through four stages as illustrated in figure 1. These stages further detailed in table 1 below.

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. Review of BIM tools for the company
	1.6. Identification of competitive advantages from BIM implementation
Stage 2: Design of new business processes and technology adoption path	2.1. Identification of Lean Efficiency Gains
	2.2. Production of detail strategies
	2.3. Documentation of Lean Process and Procedures
	2.4. Development of the Knowledge Management Database
	2.5. Documentation of BIM implementation plan
Stage 3: Implementation & roll-out of BIM	3.1. Piloting BIM on different projects (past, current, and future)
	3.2. Training the JMA staff and stakeholders
	3.3. Devising, improving and documenting companywide capabilities and processes
Stage 4: Project review, dissemination	4.1. Sustaining new products and processing offerings
	4.2. Evaluation and dissemination of the project

Table 1: detailed activities in the action research stages

The remainder of the paper elaborates the activities above and highlights the outcomes.

3.1.Diagnosis: Detail Review of Current Practice and Identification of Efficiency gains

3.1.1. Production of the Current Design Process Flowcharts

To make lean process improvements it is necessary to understand the existing practices used at JMA. Firstly the methods of communication in the organization were analyzed and flow diagrams produced. The main methodology for mapping the current process workflow is the contextual design technique (Beyer & Holtzblatt, 1998), which prescribes work modelling techniques such as communication flow modelling, sequence modelling, artefact modelling, physical environment modelling and culture modelling to understand and examine the current practice, needs and requirements for improvement via contextual inquiry.

For example, the communication flow diagrams formed a good basis for discussion with the members of staff and feedback was obtained from them (Arayici et al, 2009a). Following this, face to face interviews were undertaken to understand and examine the artefacts used in

the current process. The findings from the interviews around the communication flow diagrams were brought together to create the artefact models that are tangible and intangible aspects used in the workflow.

The overall flow chart was produced by mapping out a typical project undertaken by JMA. This was divided up into the RIBA (Royal Institute of British Architects) stages of work and by taking into consideration the other disciplines involved in the design project who collaborated with JMA as external partners. The artefacts at each activity stage were identified and reviewed - see Arayici et al (2009a) for details.

3.1.2. Soft System Analysis

Soft systems methodology (SSM) is a systemic approach for tackling real-world problem situations (Checkland & Poulter, 2006). It sets out to build a model of what a Human Activity System must do if it is to achieve the purposes defined. This was achieved through these four steps: i) an initial appreciation and expression at JMA was developed using rich picturing, ii) the human activity systems thought to be relevant to the situation of concerns were defined, iii) Activity models were produced with their dependencies, iv) these models were then presented to the JMA stakeholders and staff to gain further insight into the work activity at JMA. For example, the storyboarding technique was adopted to find out how the members of staff carried out their activities at JMA and to identify the correct needs and user requirements through contextual inquiry. This was undertaken by a series of interviews with members of staff in their working situation where possible examples and demonstrations were asked for.

3.1.3. Review of IT Systems and the BIM Tool Selection

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

Packaging and transmission of information represented a time consuming activity for many of the staff, who are generally proficient software users. The IT system was overseen by the computer manager and CAD management was devolved to the team members. The IT system was on a rolling programme of upgrade and subsequently staff skills were upgraded while hardware and software were upgraded. The underlying observation from the review was that the data used by the company was very fragmented. The inefficiencies are mainly because the software tools used do not have bidirectional interoperability.

Most of JMA's work is within the housing sector and therefore certain criteria will be required by the BIM system chosen. Multiple house types should be inserted into a single site model. Ease of creating site terrain is also important. Also the ease of working with brick dimensions would be a real advantage. In evaluating the appropriateness of the BIM tools to be adopted, it is important to understand the present skill set of the staff. Also high quality presentational output from the BIM system will be expected. Additional rendering engines may be used. The way multiple users interact with a single model is also important. The methods of sharing outputs and interaction with other consultants within the building team are also critical. How models can be recombined and clash and warning mechanisms are 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 the BIM software has.

An evaluation of alternative BIM systems took place for a period of three months. Software vendors visited to give presentations or webinars to discuss the benefits of their particular software platform. Furthermore, software vendors demonstrated their tools through a given project scenario by JMA in front of the staff. This has proved to be an effective way to generate interest and awareness about BIM and its terminology and associated ways of working. It was also a good way to reduce the reservations of many staff in the office to the adoption of BIM.

Although these activities helped to short-list three potential tools (ArchiCAD, Revit and AllPlan), they were not sufficient to determine which BIM authoring tool should be best suited to JMA's priorities and the intended competitive advantages to be gained through the BIM adoption. Thus, it was also necessary to conduct comparative evaluation of the potential BIM tools in a quantitative manner. Thus, a list of 40 criteria was produced via brainstorming sessions for the matrix analysis of the potential BIM authoring tools. It was now time for the JMA staff to test and experiment with the three remaining BIM tools on past projects of JMA. This provided the opportunity to compare the three BIM tool with each other. The test results were logged into the checklist document by the three testers individually to form the basis of the quantitative assessment.

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 tester separately. All three analyses showed that ArchiCAD was the leading tool in the results. Following that, the 40 criteria in the checklist were weighted by JMA's top management based on the priorities of these criteria. The three separate test results were averaged and weighted collectively according to JMA's priorities and specific requirements and cumulative scores were generated for each BIM tool. As a result the ArchiCAD tool was the 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: Comparative analysis of the BIM tools under consideration against the checklist

3.1.4. Stakeholder Review and Analysis

An important part of the project has been the buy-in by the senior members of staff. Since the BIM implementation will affect both internal and external stakeholders, contextual design technique was used to see how the existing stakeholders interact with the present process. An area of particular interest was how internal stakeholders maintain the consistency of the drawing set. An area where BIM could make considerable savings is in maintaining the dimensional consistency between representations (drawings) was noted.

External stakeholders may demand intelligent or non intelligent outputs from the BIM system. In this sense there should be a flexibility of outputting, 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 is possible, new and more appropriate artefacts can be created and tailored to the building design process.

The stakeholder review and analysis involved presentation, survey based questionnaire and discussions with clients, consultants, surveyors and contractors. It was recognized that the full benefits of the project can only be realized if the BIM process is integrated and utilized by the other disciplines in the building process.

3.1.5. Identification of Competitive Advantages from BIM Implementation

SWOT analysis was undertaken to assess the competitive advantages for JMA. 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 emerging technology and changing methods of procurement. By understanding the strengths of the company it was possible to understand those factors that were important for JMA to maintain competitive market share. By looking at the company's weaknesses and a review against lean principles, it was possible to reveal areas of waste.

The competitive advantages via SWOT 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 may give JMA the opportunity to offer the most competitive bids for projects. By avoiding errors and reducing the need for information requests from site, JMA has the potential to differentiate itself by providing a better service with BIM.

Cost focus competitive advantage is gained by carrying out specific parts of the process cheaper than competitors. Sustainability issues are becoming more and more important for housing design. By adopting BIM, JMA can analyse environmental factors at a lower cost. BIM offers several potential areas for differential focus. The BIM system has a major potential for use in facilities management and life cycle management. The major advantage of BIM is by providing a central focus on the collaboration between the building team and through integration and alignment of all the participants within the building process, savings will be made on cost, quality and time.

One of the potential gains coming out of the SWOT analysis is the use of BIM models for rapid prototyping via 3D printers. This has the potential to give yet another understanding of a scheme as it develops.

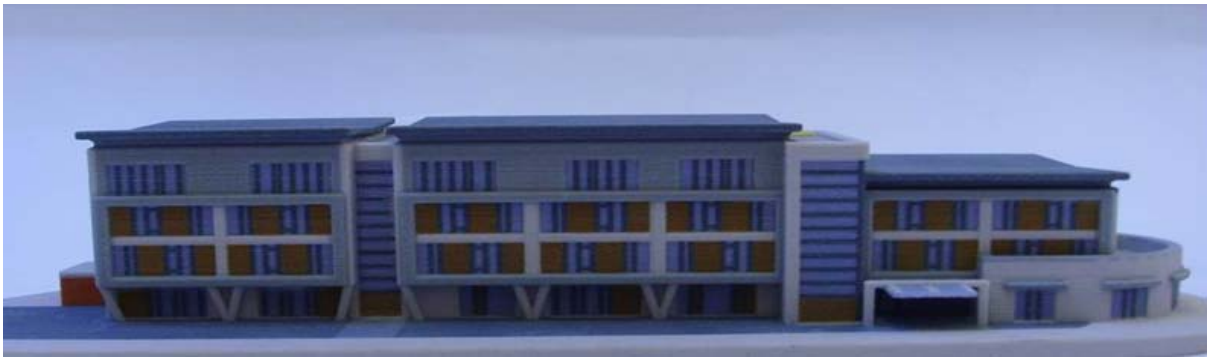

Figure 2: Rapid prototyping exercise with BIM Modelling

The SWOT analysis also demonstrated how saving could be made through the adoption of Lean principles. Seminars were 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.

3.2. Action Planning Stage: Design of New Processes and Technology Adoption Path

3.2.1. Identification of Lean Efficiency Gains

Findings from the SWOT analysis helped to identify the efficiency gains that are treated as Key Performance Indicators (KPIs) to undertake quantitative and qualitative assessment. These KPIs are identified at the organizational level and project level (details can be found in Coates et al, 2010). These KPIs briefly are:

- Man hours spent per project
- Speed of Development
- Revenue per head
- IT investment per unit of revenue
- Cash Flow
- Better Architecture
- A better product
- Reduced costs, travel, printing, document shipping
- Bids won or win percentage
- Client satisfaction and retention
- Employee skills and knowledge development

3.2.2. Development and Documentation of Lean Process and Procedures

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 the A3 method, which has 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 has been used to simulate the proposed changes to JMA's practice. For example, it has been used for i) Improvements via BIM based product information documentation, ii) improvements via knowledge database. Tables 3 and 4 below show these two examples of lean process improvements.

1.Background
JMA uses Microstation V8i and Powerdraft to produce their production information to enable the contractor and the stakeholders to understand their design requirements. This method of production has been used since the inception of the practice almost 20 years ago. 2D representations are created to illustrate 3D forms.
2. Situation before the BIM tool Adoption
Elevations/Sections projected manually from plans using construction lines. Schedules produced manually.
3. 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 form may not be correctly represented within the 2D representations. A considerable amount of time is spent checking drawings to ensure inconsistencies do not occur. Using separate representations revision control becomes more of a problem. Drawings are divided up by levels but these need to be applied and managed manually.
4. Goals
• To ensure that all representations are consistent and remain consistent and accurate when any representations are altered. • To remove the task of level management. • To automatically generate schedules from the BIM model. • To achieve shapes that work in 3 dimensions. • To speed up the production process.
5. Situation after the BIM tool Adoption and the Lean Efficiency Gains Achieved
Using BIM software to create 3D models from which 2D representations and schedules can be generated automatically. Furthermore, construction planning, costing, energy and thermal analysis, daylight and acoustic analysis can be carried out in a fast and accurate manner to ensure sustainable design outputs. Efficiency gains are: 1) the consistent and better quality design outputs, 2) reduction in RFI (Requests For Information) and site management issues 3) reduced checking time 4) ability of staff to use the BIM system and capacity improvement 5) pinpointing other areas where BIM is not traditionally the tool for improvement but still requires improvement, 6) reduced costs, travel, printing and document shipping.

Table 3: A3 exercise for process improvements via BIM tool adoption

1. Background
• Items of information that are distributed through many non-connected files • Items of information that are difficult to locate • Some information is not consistent across the files in the company • Review of data from multiple projects is difficult • Time is wasted searching for information scattered across the company
2. Situation before the knowledge database development

• Duplications and multiple files with different file types but containing common data • Simultaneous searches of multiple projects are 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 is painful and lengthy • Knowledge and experience from past projects remains only with the individuals not as company knowledge and experience
3. Analysis
Some primary project support information has been identified as commonly reoccurring such as project number, project name, project architect, email address, project start dates, project description, project castings, and project sectors. The database structure was developed around these fields. The scope to be covered by the database came out of interviews with most of the staff in the company and discussion on how different stages of the projects are addressed at John McCall Architects. Tasks that currently cause the difficulty in practice were identified and the structure and the front-end of the database were designed to address these deficiencies in the current system.
4. Goals
• To make project support information more consistent • To make data easier to find, save time and money • To make multiple project review possible and obtain lessons learnt from past projects • To flag up error and omissions in data • To keep critical project data available even after the project is archived
5. Situation after the knowledge database development and lean efficiency gains achieved
Database can be accessible to all JMA staff to input and obtain project related information. JMA staff can also refer to past projects of similar kinds to learn and apply to their current and future projects. In addition, lean efficiency gains obtained are 1) reduced waiting time, 2) improved quality in dealing with project support information and external stakeholders, 3) facilitating audit and reviews, 4) improved quality of service to JMA partners and clients, and 5) allows archiving and learning from past projects 6) retaining key knowledge and experience from projects for the company not only with individual JMA staff.

Table 4: A3 exercise for process improvement via the development of the Knowledge Database

3.2.3. Development of Knowledge Management Database

The major advantage of BIM is to input to a single information model and the multiple representations and extraction of that single information model. It was decided to apply these principles for the project support information residing outside the BIM model and residing in many non structured formats such as emails, letters, spreadsheets and PDFs and located in several stand alone databases. This meant that it was unlikely that JMA staff would know where to look for definitive information or know when the information was discovered whether it was the latest or not. Therefore, critical data that is commonly duplicated in spreadsheets, word documents and emails have been reviewed and populated into a relational database that has been developed for the use of JMA's staff.

It was recognised that standard elements of data exist across letters, spreadsheets and drawings etc. A list of over 500 of these data elements was created. These data fields were then normalized into a proposed data structure. This has provided an integrated knowledge database platform to record, share and interrogate project support information internally across the company. The particular benefits of this knowledge database are that information is retained in the same database even when projects are archived. This database is centrally accessible to all staff for the operations at JMA. However, it will also be integrated with the BIM project databases to enable bilateral information feeding between design information encapsulated in BIM and the project support information encapsulated in the knowledge

database. The resultant schema that is being worked towards is to capture knowledge and experiences from past projects and from experienced staff via this knowledge database in the future as illustrated in figure 3. This also proves the importance of linkage between BIM and Knowledge Management.

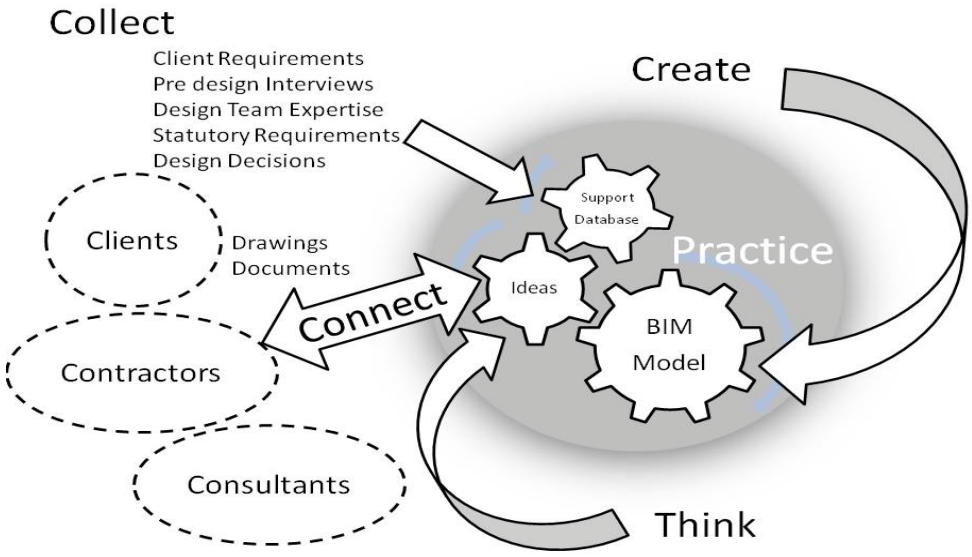

Figure 3: Combined model of architectural practice with the design information encapsulated in BIM and the project support information encapsulated in the knowledge database

3.2.4. Documentation of BIM Implementation Plan

This stage was the preparation and planning of the actual implementation of the new BIM system and the processes on to past, present and future projects. When developing the BIM implementation plan, it was specifically required to make it appropriate for JMA. Various factors were of significance such as

- usage of the BIM tools
- approach for BIM adoption, top-down or bottom up
- scale of the BIM adoption; the whole building process or maybe at specific stages addressing specific problems.
- BIM adoption at single disciplinary or multi-disciplinary levels
- Single model accessibility on single server or federated model accessibility on a multi-server system
- balance between BIM training and education; while training teaches staff how to do, education teaches people how to think.
- recruiting or training BIM Champion / BIM team
- rate of adoption – appropriate program: The appropriate rate of BIM adoption depends whether it is internal driven or market driven.
- areas of the production to be integrated
- changes in the business model
- Job-led or process-led BIM adoption
- BIM adoption as a single solution or part of a suite of solutions
- method of model analysis when BIM is adopted e.g, thermal and environmental analysis

- methods of data transfer and interoperability
- task and role allocation to staff

In addition, 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. The BIM implementation plan was then presented to all in the company.

3.3. Taking Action Stage: Implementation & roll-out of BIM

3.3.1. Piloting BIM on Past, Current and Future Projects

In the piloting exercise, it was important that the piloting projects were representative of typical projects undertaken by JMA. The past project selected was the Grow Home project. This was an award winning design that received recognition in the RIBA's Lifetime homes competition. Initially, the BIM authoring tool was used to recreate the Grow Home design. Although the concepts of the design solutions were complex, the resultant form of the proposed building was relatively simple. This exercise proved positive in some respects. For example, reproducing this project via BIM has highlighted the specific order of decisions that are required to produce BIM models and the requirements for accurate and complete information when developing BIM models.

Figure 4: BIM model of the Millachip project produced with ArchiCAD

Two pilots of current projects were undertaken. The first is the Millachip Phase 3 project; a series of sheltered housing bungalows. A 2D set of CAD drawings had already been developed for this project and BIM models with associated plans sections and elevations were rapidly produced. Objects were built from scratch on this project. This has helped to match the generated 2D drawings from the BIM model with the previously produced 2D drawings to observe the accuracy, consistency, speedy and timely maintenance of such

drawings and finally to establish good communications with the client. Figure 4 shows the BIM model of the Millachip project produced with ArchiCAD.

The other current project is the Leathers Lane project, which is a series of flats and communal accommodation for the infirm and those recovering from hospital treatment. Through the piloting in this project, the BIM object libraries have been developed and implemented for JMA in its practice in housing and regeneration. The BIM object libraries will be further developed and improved through the future projects. Figure 5 below shows the schematic structure of the object library under development.

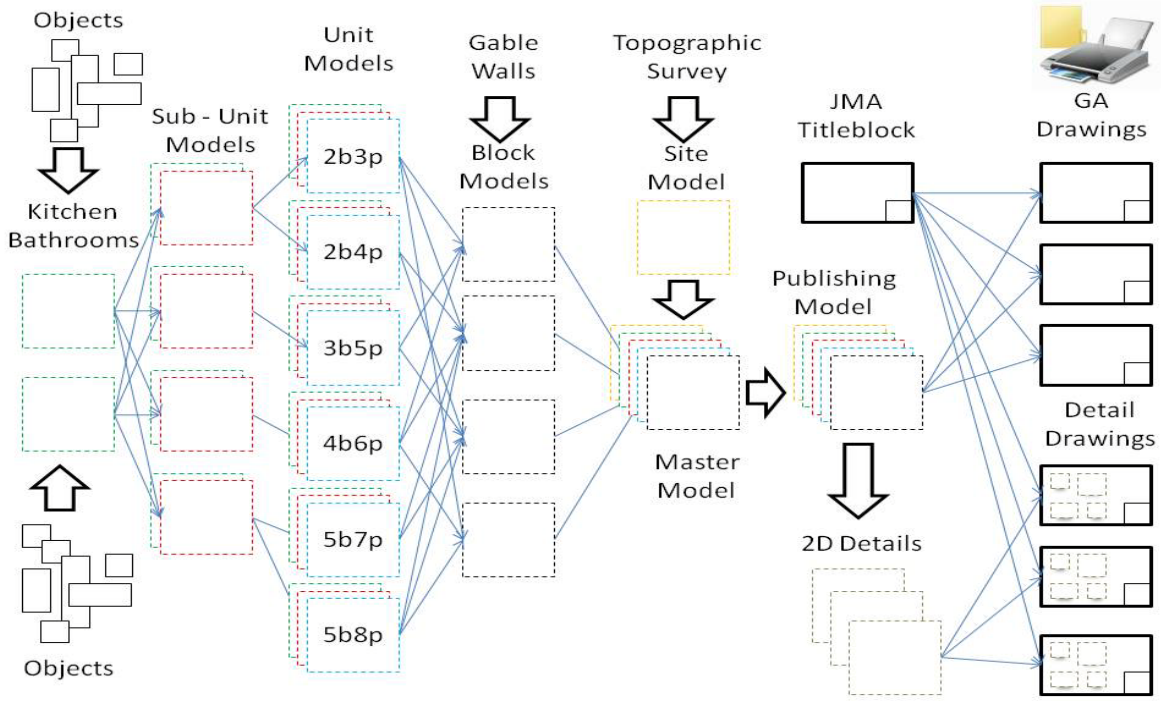

Figure 5: schematic structure of the BIM object library under development

However, the future projects will be identified later in the project once the initial core training for JMA staff has been completed via piloting. Furthermore, it will be determined on a project which can benefit from eco analysis in line with the sustainable design vision being developed as a result of new BIM led infrastructure.

3.3.2. Training of JMA Staff and Stakeholders

Successful change management requires i) training inside and outside the organization for JMA and its stakeholders, ii) informing the users about the improvements and changes in a timely manner via presentations, demonstrations and exhibitions. However, the training may vary depending on the party involved and the roles to be adopted. Overall, four areas of training were 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. The methods used to instill these different areas of BIM knowledge into the members of staff varied depending on the requirement. However, in all cases there was an effort to relate the learning, back to the specific type of projects undertaken at JMA.

3.3.3. Devising and Documentation of companywide improved capabilities

As the adoption of BIM and Lean thinking are at the core of the way JMA operates, it is important to continually review and benchmark the new process and procedures and to document them in accordance with JMA's ISO 9001 quality system. Several new quality procedures have been written due to the operational changes during the BIM adoption such as a revised incoming document handling and new email handling procedures.

BIM opens 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 is maintaining the BIM dialogue. Hence, BIM knowledge and best practice is disseminated around the practice. Currently the BIM enabled process and procedures are being documented. This will explain and guide the JMA staff how best to use the BIM authoring tool, BIM object library addressing building types and components and the knowledge database.

3.4. Evaluation Stage: Project review, dissemination and integration into strategy plan

Since stage 3 has not been completed yet, the evaluation stage has not been formally started according to the project plan yet, assessment and discussions have been taking place as findings and efficiency gains are realized through stage 3 activities simultaneously in a collaborative manner involving all parties in the KTP including JMA staff. Lean thinking is an ongoing journey that JMA can now more effectively undertake through the demonstration of Lean practices. The internal adoption of BIM at JMA is well underway. What JMA needs to do is push to develop linkages with other BIM enabled organizations so the true benefits of BIM can be realized. JMA intends to be a market leader in the field of BIM. To support this aspiration, 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.

It is envisaged that this adoption would enable JMA to provide faster and additional services such as i) the analysis of models to confirm compliance with the Code for Sustainable Homes, ii) the potential to provide models for post completion services and iii) output to virtual reality, iv) facilities management services. Furthermore, if the ArchiCad BIM tool is customised for JMA's practice, even more lean efficiency gains can be achieved towards a leaner design practice.

As part of the dissemination of the project, presentations at different conferences, events and workshops for industrialists and academics, and involvement in exhibitions have already been undertaken. However, some formal analysis and reviews such as cost benefit analysis have not been undertaken as the formal evaluation stage of the project has not been started yet according to the project plan. With respect to evaluation and dissemination of the project, a tangible benefits log has been maintained throughout the BIM implementation project (see section 3.4.1 for summary of the log). This will form the basis of an evaluation report that is to be written at the conclusion of the project.

3.4.1. Lean Efficiency Gains and Benefits Log Summary

While this benefits log will help to note the short term efficiency gains, it will also help to formulate the mid and long term efficiency gains by means of the KPIs listed in section 3.2.1 during the actual evaluation stage of the BIM implementation project. Some of the benefits are listed below.

- Linking project information to marketing via knowledge database
- Effective reuse of information via knowledge database as it stores information centrally and facilitates search via some criteria such as house types, materials used, code for sustainable home rating, client, etc
- Storing lessons learnt and experiences from the past projects as company asset via knowledge database
- Consistent information exchange through the existing company databases via knowledge database that provides linkages to these fragmented databases and allows comparison, interrogation and correction of information held on different databases
- Use of Automation via the adoption of the ArchiCAD tool brought about quality, time and cost efficient practice by generating i) drawings, quantity take-off automatically, ii) instant generation of VR models, iii) discovering design errors and conflict analysis, iv) information sharing and exchange, v) greater flexibility to satisfy customers, vi) simultaneous work by staff in the company
- Ability for checking drawings to ensure consistency and accuracy across the drawings
- Lean process of conceptual design and detailed design development via BIM modelling of the housing design projects
- Accurate and timely energy performance assessment for Code for Sustainable Homes via Integration with Energy Assessment tools for "Code for Sustainable Homes" standards such as IES
- Effective design and technical review of all the projects to avoid potential problems arising from mistakes in the future
- Leading to standardised lean design process across the company
- Effective information distribution to external stakeholders
- Automation of emails and finding consultant offices via the knowledge database that facilitates faster access time to useful information, automatically include project information in email, and links postcodes to maps.
- Better linkage will be established between the knowledge database and BIM

However, it is clear that in the project further benefits and lean efficiency gains will be logged such as effective resource monitoring, effective and accurate modelling with the JMA specific BIM object library, logical directory structure, provision of quantifiable building models, and linking drawings to specification.

4. CONCLUSION

The BIM adoption and implementation at JMA is well advanced and the project is moving from stage 3 to 4. The impact of the BIM adoption has already been realized during the project in that it has improved JMA's practice in eliminating the risk of duplication, misinterpretation of design, improving communication, streamlining processes, providing collaborative practice and, ensuring control and sharing of documentation. Thus, it is

believed that it will provide 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 can re-engineer the operational and IT processes and broaden the knowledge of existing staff and stakeholders up and down the supply chain. This is because the BIM adoption and implementation approach is actually 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 thus companies build 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 than envisaged, 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 "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 a few forward thinking top management members, which shows that top management support is also critical to the success of BIM adoption. However, after 18 months, the company has already made significant progress in up skilling staff, technology infrastructure development and lean process improvements. This progress has not been stopped. The intention is to ensure that the company has sufficient capacity to maintain the continuous improvement, even after the project, by establishing new service offerings such as facilities management. Finally, the paper recommends the BIM adoption approach based on this case study experimentation as a guide at an operational level for SMEs.

5. REFERENCE

Aouad, G., & Arayici, Y 2010, Requirements Engineering for Computer Integrated Environments in Construction, Wiley-Blackwell, Oxford, UK

Arayici, Y., Coates, P., Koskela, K., Kagioglou, M., Usher, C., O'Reilly, K., (2009a), "BIM Implementation for an Architectural Practice", Managing Construction for Tomorrow International Conference, October 2009, Istanbul Turkey

Arayici, Y., Khosrowshahi, F., Ponting, A.M., Mihindu, S., (2009b), "Towards Implementation of Building Information Modelling in the Construction Industry", Fifth International Conference on Construction in the 21st Century (CITC-V) "Collaboration and Integration in Engineering, Management and Technology" May 20-22, 2009, Istanbul, Turkey

Bernstein, P.G., Pittman, J.H. (2004). "Barriers to the adoption of building information modelling in the building industry", Autodesk Building Solutions, White paper

Beyer H, Holtzblatt K, (1998), "Contextual Design. Defining Customer-Centred Systems", Morgan Kaufmann Publishers, San Francisco

Boshyk, Y. and Dilworth, R.L. (Eds.) 2009, "Action Learning: History and Evolution", Basingstoke, U.K.: Palgrave Macmillan

Checkland, P., Poulter, J., (2010), “Systems Approaches to Managing Change: A Practical Guide”, Springer London, ISBN 978-1-84882-808-7, 2010-05-11

Coates, P., Arayici, Y., Koskela, L., Kagioglou, M., Usher, C., O’Reilly, K., (2010), “The key performance indicators of the BIM implementation process”, ICCBE 2010, Jun 30 2010, Nottingham

Coghlan, D., Brannick, T., (2001), “Doing Action Research In Your Own Organization”, London: Sage Publications

Durward K., Sobek, II, (2008), “Understanding A3 Thinking: A Critical Component of Toyota’s PDCA Management System”, Taylor & Francis Group, New York

Eastman, C., Teicholz, P., Sacks, R. & Liston, K. (2008), “BIM Handbook: A Guide to Building Information Modelling”, Canada: John Wiley & Sons

Koskela, L. J. (2003), 'Theory and Practice of Lean Construction: Achievements and Challenges', in: Proceedings of the 3rd Nordic Conference on Construction Economics & Organisation. Hansson, Bengt & Landin, Anne (eds). Lund University (2003)

Liker, J. E. (2003), “The Toyota Way”, McGraw-Hill, New York

Mihindu, S., Arayici, Y., (2008), “Digital construction through BIM systems will drive the re-engineering of construction business practices”, 2008 International Conference Visualisation, IEEE Computer Society, CA, ISBN 978-0-7695-3271-4, P29-34

Nour, M., (2007), “Manipulating IFC sub-models in Collaborative Teamwork Environments”, ITC Digital Library, http://itc.scix.net

O'Brien, R. (2001). An Overview of the Methodological Approach of Action Research, in Roberto Richardson (Ed.), Theory and Practice of Action Research, Available: http://www.web.ca/~robrien/papers/arfinal.html

Shook, J. (2008) Managing to Learn, Using the A3 management process to solve gain agreement, mentor and lead, The Lean Enterprise Institute, Inc. ISBN 978-1-934109-20-5