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Implementing BIM to Streamline a Design, Manufacture, and Fitting Workflow:
A Case Study on A Fit-Out SME in the UK

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ABSTRACT

This paper presents a case study of BIM implementation for Design for Manufacture and Assembly (DfMA). The project is a Knowledge Transfer Partnership (KTP) between the University of Salford and Links FF&E, a design, manufacture and fit-out SME based in the UK. The project aims to implement BIM as a catalyst for a Lean transformation, streamlining process and operations. Initially, organisational process are reviewed, which is followed by implementing appropriate technologies to enable subsequent people and process transformation. The 30 month project is organized in 6 key stages. This paper presents findings from the first four stages that have been completed to date of 1. Establishing best practice knowledge in BIM; 2. Conducting a review and analysis of the organisation's current situation, 3. Developing a BIM-based collaborative strategy, and the fourth, which is currently progressing, 4. Pilot implementation of BIM collaborative strategy for DfMA. The remaining stages will conduct a project evaluation, before finally implementing an Enterprise Resource Planning (ERP) system.

KEYWORDS

Building Information Modelling Implementation, Knowledge Transfer Partnership, Lean Construction, Process Improvement

1. INTRODUCTION

Small and Medium Enterprises (SME) are predominant in most economy structures. In the United Kingdom (UK) construction industry SMEs represent 90% of the whole industry (Statistics, 2015). To respond to the competitive pressures from low cost international nations, increasing concerns with health and safety, and the sustainability agenda, the UK Government is encouraging innovation for SMEs (Adegoke, Gerard, & Andrew, 2007; Wolstenholme et al., 2009). While the focus tends to be more on product innovation than process innovation, several studies show that the use of business approaches, such as process improvements and knowledge management, can incrementally reduce costs and increase competiveness for SMEs (Hoffman, Parejo, Bessant, & Perren, 1998; McAdam, Moffett, Hazlett, & Shevlin, 2010).

Building Information Modelling (BIM) is one of the promising approaches to improving processes and efficiencies in the construction industry (Eastman, Teicholz, Sacks, & Liston, 2011). In 2011, the UK Government launched its Construction Strategy which mandated that by 2016, all centrally procured projects should be utilising BIM; driven by deriving full value from public sector construction and the failings to exploit the potential for public procurement of construction and infrastructure projects to drive growth.

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This paper presents a BIM implementation at Links FF&E, a UK based company that offers the design, manufacture, supply and installation of quality fittings and furnishings for student accommodation. The aim of the project is to ensure that the company has the expertise and capability needed to operate in a BIM environment and to comply with the BIM Level 2 mandate. The project is being delivered through a Knowledge Transfer Partnership (KTP) between the University of Salford and Links FF&E. The KTP is a program partly funded by InnovateUK (a UK government-funded initiative) with the objective of supporting businesses that want to incrementally improve their performance and competitiveness with innovative solutions by accessing and transferring the knowledge and expertise of academia. Through the project, Links FF&E expect that the implementation of BIM will streamline their processes and operations thereby facilitating the transformation of the organisation to becoming BIM-enabled through the development of a business wide BIM strategy, and ultimately improving their business performance.

2. LITERATURE REVIEW

2.1. Proposed Improvements in the UK Construction Industry

In proposing radical improvements in the UK construction industry, Egan (1998) stated that construction should learn from manufacturing and services industries and rethink the way of delivering projects to achieve better performance, better products and continuous improvement. Egan (1998) advocated the use of standardised components and processes, the implementation of performance measurements, the application of Lean thinking in construction, and the use of technology as a tool to support cultural and processes improvements.

In 2011, the UK Government Construction Strategy reinforced the need for supply chain integration in order to accomplish reliability and better value for money, encouraging the use of BIM to allow the full potential of technological improvements in the construction industry, reducing coordination errors and transaction costs. In addition, there is a vision for the use of BIM to allow design to feed directly into machines, connecting design and manufacture, and discarding unnecessary intermediaries (Cabinet Office & BIS, 2011).

Indicated as one of the most propitious developments in the industry, BIM involves the application of processes, people, technologies, and tools to generate and manage information about a built environment asset during its whole life (Eastman et al., 2011; Lee, Sacks, & Eastman, 2006). Moreover, BIM increases efficiency and productivity by utilising digital technology to design one or more accurate virtual models that represent an asset before its construction. This supports the interaction of the different stakeholders around the models that include geometrical and non-geometrical data of the built asset to enable better analysis and control of the design, construction and operations compared to manual processes (Sanchez, Hampson, & Vaux, 2016).

BIM adoption and awareness is growing globally but particularly in the UK construction sector following the Government's commitment. The NBS National BIM Report (2016) stated that 54% of organisations are currently using BIM, compared to just 13% in 2010 (Paterson, Machado, Platts, & Underwood, 2016). There has been the significant influence of the "push-pull" Government Strategy for BIM that has mandated the adoption of BIM in all public centrally procured projects from April 4th 2016, and encouraged a 'feeling' that BIM is a new standard for project information; this is transforming the construction industry landscape (Cabinet Office & BIS, 2011; NBS, 2015). Moreover, the majority of UK construction industry enterprises are SMEs and therefore the adoption of BIM within SMEs is vitally important for the transformation of the whole UK construction sector.

2.2. BIM in SMEs

Small and medium companies are usually defined as companies with less than 250 employees. In the UK, 99.9% of the enterprises are SMEs, turning over 47% of the country's economy turnover

(White,2016). Although there is a significant increase in the uptake of BIM within the UK in recent years, the SME uptake of BIM is still slow. The international survey, Smart Market Report (2014), stated that 34% of the large contractors have more than five years' experience with BIM, which contrasts against just 16% of small firms. However, it is not clear how "large/small" firms were categorised in the survey. In the UK, the NBS National BIM survey (2014) compared the use of BIM in organisations through the number of employees; it reported that, whilst 61% of the companies with more than six employees were aware and using BIM, only 35% were aware and using it in organisations with one-to-five employees. Although one can argue about the representativeness of the survey (due to the small number of respondents), it provides confirmation that small organisations are lagging behind their larger counterparts in their engagement with BIM.

While the evidence regarding the slow adoption of BIM by SMEs in the UK is limited, the challenges and risks related to innovation within SMEs is well documented. Implementing innovation in SMEs is a complex and nonlinear process, with issues around the lack of/scarce resources (both financial and human), a lack of skills and capabilities, and the lack of systematic measurements, which can result in implementation failure and frustration for SME managers (McAdam et al., 2010). Moreover, SMEs tend to be slow on the adoption of disruptive technologies, preferring well tested technologies that pose lower risks for the investment by the organisation in change (Poirier, Staub-French, & Forgues, 2015).

Although SMEs are more agile in incorporating changes in comparison with larger organisations, SMEs tend to innovate to survive in business (Carrier, 1994). For example, when working collaboratively with other companies in projects that adopt innovative technologies, SMEs usually adopt the approach of learning by doing (the job), missing a strategic vision for implementing innovation (Poirier et al., 2015). However, Harty (2015) argues that the benefits for SMEs are higher when not just embracing the technology, but by embedding technologies within the business processes and workflows, which poses strategic changes for the whole organisation. Such an approach to technology implementation is aligned with Lean Principles.

2.3. Synergies of Lean and BIM

BIM projects involve high levels of collaboration between stakeholders and integrated processes. Smith and Tardif (2009) argue that the most effective BIM implementation strategy must be aligned to the business strategy, based on a review of the organisation's internal and external business processes and workflows. Moreover, it demands changes in existing processes and procedures for design and construction. BIM represents a technology change but also a people and process change. It is acknowledged that technology alone will not make any significant change to a business (Love, Matthews, Simpson, Hill, & Olatunji, 2014). Furthermore, technology should fit the organisational infrastructure and reinforce the business process, with emphasis on management and organisational changes that are supported by the implementation of information technology, and not the converse, in order for the company to succeed in realising the full benefits of the implemented technology (Koskela & Kazi, 2003; Rafael Sacks, Koskela, Dave, & Owen, 2010). The concept of implementing BIM, with emphasis on streamlining company processeses and workflows, are aligned with Lean Thinking, and recommended by such government and industry initiatives as those detailed by Simon (1944), Latham (1994), Egan (1998), and Wolstenholme (2009).

Lean Principles are derived from studies into the car manufacturer Toyota; these have been adapted by several authors and applied over time to other manufacturing sectors (Liker, 2004), the construction industry (Arbulu & Zabelle, 2006; Ballard, Kim, Jang, & Liu, 2007) and service industries (Womack, 1996). The core principle of Lean is to deliver a product or service, while maximising value (from the perspective of the customer) and minimising waste (Womack, 1996). Lean is process-oriented and considers the use of technology only if it serves people and processes (Liker, 2004). While Lean also offers sets of tools and techniques, it is more than simply a set of tools. It is a philosophy that is shared throughout a value stream (Ballard et al., 2007; Diekmann, Krewedl, Balonick, Stewart, & Won, 2004).

Lean Construction and BIM are independent concepts, each of which can be applied without the other; however, Sacks, Dave, Koskela & Owen (2009) argue that there are synergies between them, while the full potential for improvement in construction projects has been achieved by the adoption of both concepts together. Sack et al. (2010) argue that any BIM implementation project should ensure that the process changes adopted aim to make the organisational process leaner, stating that BIM enables, or is the catalyst for, the organisational lean transformation.

To enable the vision of the UK Construction Strategy 2011, in linking design through to fabrication with the use of BIM, a closer analysis of the process from design to construction is needed. Kieran (2003) suggests a review of the architectural design process, and the use of technology to manage information about the building through the whole supply chain. Moreover, it explains how complex manufacturing projects, such as airplanes, ships and cars, have changed over the years, focusing on the process of design and manufacturing parts or components that are further assembled together. The construction industry can learn from these industries in streamlining processes of design and construction, which can thereby reduce the time and cost of projects, while creating value for the client.

2.4. Digital Design and Manufacturing

The process of design and manufacturing involves three major components: digital interactive design tools using a computer aided design (CAD) system, a computer aided manufacturing (CAM) system to specify how the digital design model is actually manufactured, and a computer numerical control (CNC) machine to fabrication (Schodek, 2005). Combining Design for Manufacture (DFM) and Design for Assembly (DFA) concepts, Design for Manufacture and Assembly (DfMA) is a product design tool that aids manufacture and assembly. Assembly can be categorised as fitting or assembly; fitting often requires power tools and skilled work and is considered a secondary manufacturing activity that allows product functionality, while assembling involves the manipulation of finished parts, transforming it into a meaningful object (Redford, 1994). DfMA is often neglected by designers who prioritise activities that are apparent to the client, like conceptual and functional design. However, the application of DfMA can shorten the time to the conclusion of the finished product and consequently reduce the overall product cost (Boothroyd, Dewhurst, & Knight, 2002; Kuo, Huang, & Zhang, 2001).

Collaboration between the design and delivery team is essential for the use of DfMA (O'Rourke, 2013) and BIM supports this co-ordination to facilitate DfMA. 3D BIM models for fabrication need to be populated with data sets and attributes for manufacturing (Fereday & Potter, 2013), requiring parameters for design and close co-ordination (Irizarry, Karan, & Jalaei, 2013). Once designed, 3D models can be archived as BIM libraries for further reproduction and fabrication. BIM libraries allow customisation with control of the parameters for fabrication.

Being relatively mature in terms of their BIM capabilities, major contractors in the UK are expanding the use of DfMA in construction. Such organisations have programs to increase off-site fabrication by up to 70% on all projects. These programs incentivise innovation and emphasise that, in a competitive industry, those organisations that can deliver innovative, integrated solutions most cost effectively are more successful (O'Rourke, 2013). However, one consideration to be made is the challenges identified for pre-fabrication relating to the cost of projects. On low cost projects there is less space for product and service innovation, while high end projects can be highly customised, using more reliable and state-of-the-art technology, which can see the creation of higher quality products (Thomas & Thomas, 2012).

Although it is possible that the use of BIM could enable the use of digital fabrication tools, such as CNC machines to improve the construction performance and the quality of products, there is a need to integrate the design and manufacturing processes to manage the production system and the supply chain, which is majorly composed of SMEs (Gann, 1996). Lean principles and tools adopted by other industries, have proved to increase the effectiveness and reliability of projects, and the integration of the supply chain around the design to manufacturing process (Ariaratnam & Rojas, 2009). Furthermore, collaborative BIM projects, could provide mechanisms to control processes and communication around the supply chain (Irizarry et al., 2013). Therefore, the adoption of Lean together with BIM can reduce the gap between design to manufacture. However, there is a need to address the slow uptake of BIM by SMEs to achieve integration across the whole supply chain.

3. RESEARCH METHODOLOGY

The research is currently being undertaken through a Knowledge Transfer Partnership (KTP) between the University of Salford and Links FF&E. The KTP's aim is to ensure the company has the expertise needed to operate in a BIM environment from design through to assembly, while filling the gaps between design to manufacture, streamlining processes, reducing duplication of information, ensuring control, and increasing projects' efficiencies.

Dealing with real-world issues, the research adopts a pragmatic philosophic position, considering that a proposition is valid if it works satisfactorily, dealing with practical consequences of accepting the proposition, and rejecting unpractical ideas (Mounce, 1992). It is an action research initiative with the purpose of studying a system (Links FF&E culture and process), diagnosing the current situation, exploring alternatives, proposing changes towards a desirable direction, and measuring the results (French, 1999). Due to the nature of the project, the research focuses on a single case study and applies qualitative and quantitative methods. Data collection was conducted through interviews, document analyses and observations by the researcher during the time of collaboration with Links employees.

The 30-month project comprises five key stages: 1. establishing and consolidating best practice knowledge in BIM; 2. conducting a detailed review and analysis of the organisation's current situation; 3. developing a BIM-based collaborative strategy; 4. piloting an implementation of the BIM-based collaborative strategy for DfMA (which is currently in progress, following on from the previous two completed stages); and 5. conducting a project review and evaluation, to further disseminate the results. Table 1 outlines the project stages' main objectives and outputs.

4. CASE STUDY ORGANISATION

The case study company, Links FF&E, operates with three core areas: design, project management and support services; manufacturing provided by a sister company based in Lithuania; and fitting and installation, with teams based on sites across the UK. This KTP project concentrates on the design service and its relationship with the manufacturing and fitting.

In 2014, in response to market demands, Links started offering full design services for bedrooms, kitchens and common areas of student accommodation. Initially, all drawings were outsourced, therefore the department is currently developing its capabilities and trying to address the lack of standardised processes, lack of internal capabilities and lack of applied technology. The company is addressing this challenge through the implementation of BIM with the support of the University of Salford though the KTP. Moreover, as the industry begins to embark on the challenge set down by the Government Construction Strategy/BIM Task Group, this project also aims to demonstrate an SME's organisational transformation in meeting this challenge.

The core challenge posed for the KTP is in changing current work practices, and processes, and adopting a culture that a BIM approach brings in terms of Links FF&E at an organisational level and in enabling even more effective collaborative engagement with their supply chain in a move towards whole-life thinking. BIM requires shifting from an innate traditional 'fragmented' culture, currently embedded within the industry, towards operating in a collaborative working environment, whereby project teams use standardised protocols and agreed standards, methods, and procedures, to ensure the same form and quality of information is managed and produced, enabling it to be used and reused without change or interpretation. This shift towards 'true collaboration' requires people, systems, processes and practices to be collaboratively aligned whereby project partners share a common 'project-focused' goal.

Table 1. BIM implementation approach at links

Project Stage	Outputs
Stage 1: Establish and consolidate best practice knowledge in BIM	State-of-the-art best practice knowledge in BIM and for collaborative DfMA report and presentation (Output 1A)
Stage 2: Detailed review and analysis of the organisation's current situation	Detailed and validated current process maps and information flows (Output 2A) IT systems, file formats, information exchanges review and recommendations (Output 2B)
Stage 3: Develop BIM-based collaborative strategy	Improvement gains analysis (Output 3A) BIM-enabled processes and practices mapped and documented (Output 3B) IT systems and information requirements documented (Output 3C) Training plan formulated (Output 3D) Organisational BIM implementation strategy (Output 3E) DfMA BIM implementation strategy plan formulated (Output 3F)
Stage 4: Pilot implementation of BIM-based collaborative strategy for DfMA	Pilot implementation DfMA project identified (Output 4A) IT system(s) selected, procured and integrated (Output 4B) Component libraries developed and implemented (Output 4C) Training plan implemented rolled out in Links UK&Lithuania (Output 4D) New processes and practices embedded (Output 4E)
Stage 5: Project review, evaluation, and dissemination	Implementation project impact assessment (Output 5A) Project review and evaluation (Output 5B) Academic and industry dissemination (Output 5C)

5. PROJECT STAGES DESCRIPTION AND FINDINGS

To date, the project has completed the first three key stages and is currently finalising the fourth stage of the project to develop BIM libraries and embed the new processes and procedures through a pilot implementation. The results of the first three stages are discussed below.

5.1. Project Stage 1: Establish and Consolidate Best Practice Knowledge in BIM

The main objective of Stage 1 is to establish and consolidate best practice knowledge in BIM and collaborative process for collaborative DfMA. The initial stage of the implementation aimed to benchmark the best practice of BIM in the UK. Based on a state-of-the-art literature review, the final report at this stage gave a brief overview of BIM implementation, an outline of the UK Government BIM Strategy, an overview of BIM protocols and data formats, relevant results from recent surveys about BIM, and the main concepts of BIM for DfMA. Next, based on primary data collected from semi-structured interviews with industry key players, a report established the state-of-the-art BIM implementations in the UK covering the key aspects that shape BIM implementation, namely: main drivers, steps for implementation, and challenges related to people and SMEs. A content analysis of the data collected through both the literature review and interviews led to a discussion of the challenges related to protocols, the development of component libraries, and the opportunities of BIM for SMEs as outlined below.

Based on the experiences of 'BIM mature' companies in the UK, the study found that Links' complex business process, which involves design, manufacturing and fitting, could benefit from BIM, especially regarding information exchange, integration with the supply chain and DfMA (Eastman et al., 2011). However, in order to implement BIM successfully, a change management plan was recommended to deal with risks related to the resistance of people to change and the amount of investment in training and technology (Arayici et al., 2009).

Results from the interviews indicated that dealing with the resistance of people to change is one of the main challenges experienced in implementing BIM irrespective of the company size or activity.

The way in which the KTP team overcame this challenge was to demonstrate the value of BIM to the organisation through awareness and training sessions across the organisation, in order to thereby gain 'buy-in' from those affected by the change. For example, regular lunchtime seminars are held to increase the awareness of BIM and of the project across the organisation. During these seminars, the KTP Associate presents an update on the results of the project, information regarding BIM in the UK and on process improvement, and other relevant aspects to ensure that the whole of the organisation is engaged in its transformation through the project and the adoption of BIM. To date, the seminars have proved to have had a positive impact on people's understanding and engagement with BIM and also on the project, thus creating the right mindset for the success of the BIM implementation. Further formal evaluation is planned to be rolled out during Stage 5 in order to establish their effectiveness in increasing the awareness and engagement of the organisation with BIM.

5.2. Project Stage 2: Detailed Review and Analysis of the Organisation's Current Situation

The main objective of Stage 2 was to produce a detailed review and analysis of the company's current situation. The paradigm of BIM comprises people, process, information and technologies. Following the approach proposed by Smith & Tardif (2009), which involved reviewing the organisation's business processes and workflows, and exploiting the enabling technology, Stage 2 aimed to explore Links FF&E's processes and understand their business through mapping their current business processes, ICT systems and infrastructure, file formats and information exchange. Therefore, this meant identifying, through an improvement gain analyses, the areas where BIM processes and technologies could support the organisation to achieve its strategic objectives.

Links FF&E processes, which had previously been documented for attaining their Quality Management System ISO 9001, were found to be out of date and the company was operating with processes that have not been previously documented. Therefore, through the KTP project the organisation began mapping their processes, which, while an extremely time consuming exercise, brought several benefits of standardising the organisation's processes and operation (Indulska, Green, Recker, & Rosemann, 2009).

The technique adopted to map their current processes was a series of interviews with each department of the organisation in order to capture the information about their current activities and workflows. Based on the interviews' data, a series of process maps were designed and subsequently validated with the interviewees and amended where required.

Several different notations can be used map business processes. The key to choosing the notation for adoption is to consider who is going to use the process maps produced (Harmon, 2003). For this project, the Business Process Modelling Notation (BPMN) was adopted as it is considered to be user friendly and produces diagrams that are easy for business managers to understand and analyse their business processes (Harmon, 2003). Moreover, the BPMN notation was recommended for use on BIM projects by the National BIM Standards United States (Eastman, Jeong, Sacks, & Kaner, 2010).

The resulting "As-Is" process maps represented how Links FF&E currently operate and immediately, some discrepancies of process and procedures adopted from different employers in the same function were highlighted. In addition, the discussion around the processes was important to promote process standardisation, which is aligned with the Lean principle stated by Liker (2004): "standardised tasks are the foundation for continuous improvement and employee empowerment."

Furthermore, a workshop to identify areas for improvement, involving the key stakeholders of the project (head of departments, academic team and company directors) took place and clarified the vision as to how the company could increase efficiency with the same resource through the re-engineering of their existing processes. The workshop promoted a great debate between employees from different business functions of the company, promoting a better understanding of Links business processes from end-to-end. Therefore, the company agreed actions needed to be taken in order to reduce waste and increase profitability and the processes that could benefit from the use of technology for automation or to reduce cycle times.

The relevant process for the BIM implementation is the design to manufacture. Figure 1 illustrates a summary of the current Design process including interfaces with Customer and Manufacturer. In the current process, after the client has signed the contract, the *Design Preparation* starts, when the designer's ideas for the space are sketched by hand on paper. Next, the *Concept Design takes place, when* specification sheets are produced and 2D layouts and elevations are drawn using AutoCAD software, and 3D visualizations (CGIs) in 3DMax. The project is then presented to the client. Once the client approves the design, the design outputs are sent to their manufacturer sister company in *Project Planning & Procurement.* During the *Furniture Detail Design,* the manufacturer develops detailed furniture drawings in 2D AutoCAD, which are then sent back to Links FF&E for approval. Next, Links sign off the drawings and the manufacturer sister company produces the *3D Models* of the furniture including all manufacturer information to be input into their CNC machines. Finally, all the project furniture is manufactured and sent to site for Fitting/Installation. During the process, all information is shared in pdf, i.e. non-editable files.

5.3. Process Analysis

Bicheno & Holweg (2009) propose a set of tools to apply Lean Principles to services, redefining the types of waste initially described in the Toyota Production System to support service operations to eliminate waste in their value stream in order to produce more value for the customer. Based on these principles, Links' design processes were analysed to identify waste in their current processes as follows:

5.3.1. Over-Production/Duplication of Information

This relates to the copying of the same information in multiple file formats which are not interoperable, with a lack of the "single version of the truth" in design projects. Duplication of information is considered a waste, which can cause errors and an excess of inventory.

5.3.2. Motion/Waiting

This relates to unnecessary information movement between departments due to the lack of skills and technology. When information is moved from one department to another, if not well planned, the process can be delayed by the availability of the next department, and further waiting occurs.

5.3.3. Over Processing/Defects

This relates to unclear communications and the lack of systematic procedures to capture client requirements can cause misunderstandings, and projects can be developed that do not conform to a client's requirements, ultimately causing re-work.

5.3.4. Skills

This relates to the lack of knowledge transfer throughout the organisation. For example, Links FF&E has specialists in product development, manufacturing process, and fitting; however, those skills and knowledge are not transferred to the design department.

A final consideration is the lack of a clear design freeze moment in the project. The client must have a clear understanding of when the design needs to freeze because the root cause of many problems during procurement and installation is the client not making decisions during design on time and the provision of inadequate drawings (Bildsten & Guan, 2011). To enable manufacturing, the client has to acknowledge that the design has to freeze earlier for the benefit of all concerned (Gibb & Isack, 2003). However, considering the Lean Project Delivery System, it is also important to consider several design alternatives and find the last responsible moment to freeze the design (Ballard et al., 2007).

Findings from this stage of the project highlighted that mappings of the business process and workflows serve to clarify the steps that are necessary for the organisation to produce its products. Moreover, it clarifies the relationship between stakeholders, helping to establish roles and integrate the company departments towards the final company objective, which is to deliver the product to the client while maximising its value. By reviewing the process mappings, it is possible to identify inefficiencies in the current processes. Furthermore, shifting the discussion from managing people to managing process enables employees to engage in proposing process improvements that can both benefit the organisation and their clients along with empowering the employees.

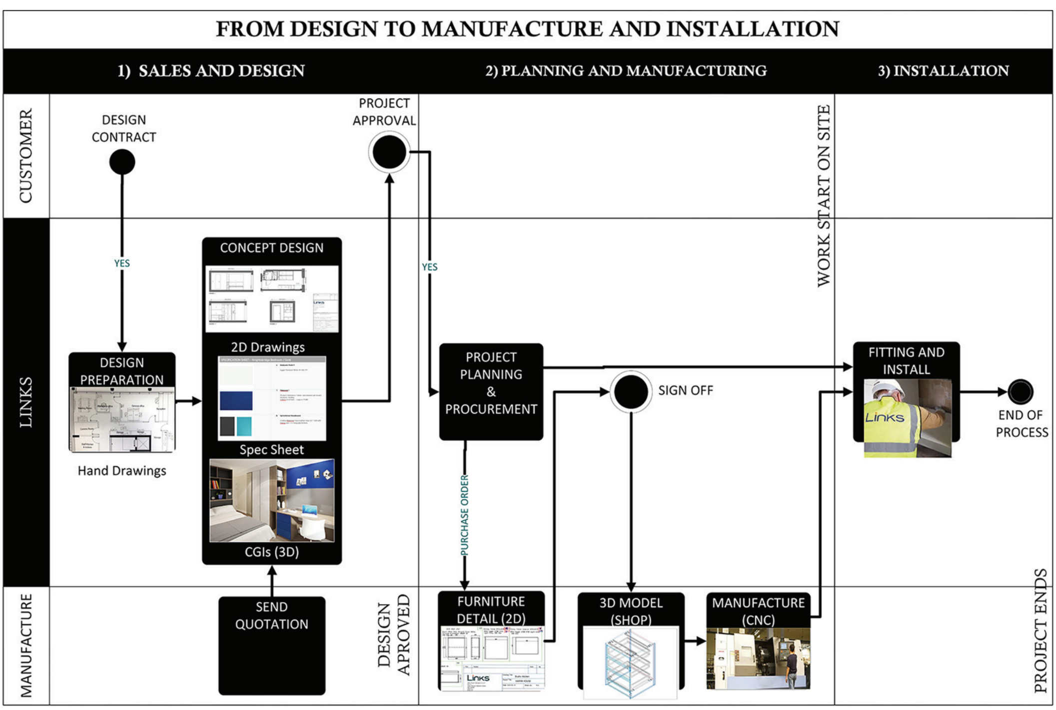
5.4. Project Stage 3: Develop BIM-Based Collaborative Strategy

During this stage, the strategy to implement BIM-based collaborative DfMA was developed by establishing the areas of improvement gain followed by the process, procedures, systems, practices and people capabilities to facilitate these improvements, including an improvement gains analysis and the development of a training plan. The state-of-the-art review and the organisation's vision/business strategy was brought together through focus group meetings with the key stakeholder group in order to establish and review the areas of potential improvement gain of a BIM-enabled approach across the business, along with identifying the potential risks. Based on the vision of how to improve the current design process, a "To-be" target process was established.

5.4.1. Target Process

The development of a long term BIM strategy for DfMA, enabled by appropriate technology and consideration of the interoperability of the different software utilised in design into manufacture, would eliminate the current information duplication. In addition, part of the BIM implementation is concerned with the development of standard component libraries with parametric models that will

Figure 1. Design to manufacture and fitting current process



be used in concept design and sent direct to manufacture after design approval (Kolarevic, 2005). As outlined below, it is expected that the use of such component-based design will speed up the design process, reduce errors, and increase manufacture efficiency (Gann, 1996).

Based on the data captured in the first stages and the technology chosen for the organisation, Table 2 compares the current process with the target process in relation to the estimated time savings. The left-side of the table has the 23 steps that Links FF&E currently takes from design to manufacture. The right-side of the table has the target process, and marked in red are actions that incorporate the suggested changes with BIM. Comparing the two tables the initial steps (1 and 2), that are related to design preparation, remain the same, but in step 3 the development of a 3D BIM model enables plans and elevations to be extracted (step 4) and to use the model as a base to produce CGI (step 5). This avoids duplication of the information and unnecessary motion, thereby saving time, while improving information consistency. The use of BIM can also speed up the handover to the estimators, as all the furniture quantities can be extracted automatically from the model. Finally, at the bottom of the table are the activities performed by the manufacturer's sister company. In the target process, it is proposed to incorporate 3D component libraries at the design stages that are compliant with the manufacturer's requirements; therefore, the BIM model could potentially diminish or eliminate the necessity of re-design for manufacturing purposes and thereby enable a seamless flow of information through to the CNC machines. Furthermore, the full BIM process can save time and increase efficiencies in the overall design process. However, for the development of the 3D component libraries, there is the need to build up designers' knowledge about the manufacturing drawings requirements, which can increase the collaboration between design and manufacture.

At this stage, the organisation also decided on the ICT requirements for software selection and procurement by considering the workflow improvements proposed above. In addition, a training plan has been formulated, including technical skills (software), design to manufacture skills to improve the integration of these areas of the organisation, and change management skills to support the transition to the next stage of the project.

5.4.2. ICT System(s)

In addition to the shift from 2D drawings to 3D models using BIM enabled technologies, the ICT choice for Links considered the integration between a computer-aided design (CAD) system, a computer-aided manufacturing software (CAM), and a computer numerically controlled machine (CNC) for production (Schodek, 2005). Links FF&E currently utilises several pieces of software in their workflow. The aim of the new BIM enabled technology is to provide information integration, thus avoiding error prone duplication of information. It was important to identify a software solution that could integrate technical drawings, 3D renderings for visualisation, shop drawings and extract information from the drawings for different purposes. The employees also considered the availability of training and support in the UK.

The approach to technology selection was to compare systems against a list of requirements produced in collaboration with the employees involved in the project. The team considered: ImosCAD, which is software specifically for furniture design and manufacturing, utilised by the manufacturer sister company; Solidworks, which is software currently in use by company furniture designers; and the chosen system was Autodesk Inventor, part of a software package called Factory Design Suite that includes AutoCAD, 3DMax and Navisworks. The list of requirements for the design software is listed in Table 3. Autodesk Revit and Graphisoft ArchiCAD, two of the most used BIM authoring tools, were reviewed, but due to the nature of the company's work, i.e. furniture design, neither of these software tools would support the level of detail and customisation that could facilitate the design to manufacturing process integration. The decision for the selected ICT system was aligned with the BIM strategy of adopting technology that could streamline business processes. The systematic approach to collaborative decision making also reinforced the awareness of BIM around the organisation's employees, thereby facilitating the change process from the current "as is" process, to the BIM enabled target process.

Table 2. Current process (left) compared to target process (right)

Title: Design to Manufacture (As-Is Process) — Date: 20/11/14

	Step	Flow	Time (min)	Operation	Move	Delay	Store	Inspect
1	Request Suppliers Quotation and Samples	●	2 days					
2	Spec Sheet Development	●	1 day					
3	Send Information to CAD/3D Visualizers	➡	0,5 days					
4	Wait until CAD/3D Visualizers can allocate design	◗	up to 7 days					
5	Prepare Layout and Elevations	●	2 days					
6	Prepare CGIs	●	5 days					
7	Prepare Mood Boards	●	2 days					
8	Recieve and Review CGIs and 2D Drawings	■	0,5 days					
9	Finalize Spec Sheet	●	0,5 days					
10	Amend CGI	●	1 day					
11	Handover to estimators	➡	2 days					
12	Wait until estimators allocate design	◗	up to 3 days					
13	Send drawings for quotation	➡	1 hour					
14	Wait until Nordic can allocate quotation request	◗	up to 4 days					
15	Receive and review Cost plan	■	1 hour					
16	Prepare final presentation	●	0,5 days					
	Total		17 days 2h	14d	2.5d 1 h	14d		0.5 d 1 h
	Process at Nordic (manufacture)							
17	Send Quotation	●	1 day					
18	Receive Purchase orders	●	1 hour					
19	Produce furniture drawings for approval	●	2 days					
20	Send drawings for approval	➡	1 hour					
21	Review and sign Drawings (Links)	■	0,5 day					
22	Wait for drawings sign off	◗	up to 7 days					
23	Design for manufacture	●	3 days					
	Total		6 days 1h	6d 1h	1h	7d		0,5d

Title: Design to Manufacture - (Target Process) — Date: 06/05/15

	Step	Flow	Time (min)	Operation	Move	Delay	Store	Inspect
1	Request Suppliers Quotation and Samples	●	2 days					
2	Spec Sheet Development	●	1 day					
3	Using BIM Libraries, design model in 3D	●	3 days					
4	Export and format Layout and Elevations	●	1 day					
5	Export and include light and finishes to final CGIs	●	3 days					
6	Prepare Mood Boards	●	2 days					
7	Review CGIs and 2D Drawings	■	0,5 days					
8	Finalize Spec Sheet (paralel to CGI developement)	●	0,5 days					
9	Handover to estimators with quantities	⇨	1 days					
10	Wait until estimators allocate design	◗	up to 3 days					
11	Send drawings for quotation	➡	1 hour					
12	Wait until Nordic can allocate quotation request	◗	up to 4 days					
13	Receive and review Cost plan	■	1 hour					
14	Prepare final presentation	●	0,5 days					
	Total		14.5 days 2 h	13d	1d 1h	7d		0.5d 1h
	Process at Nordic (manufacture)							
15	Send Quotation	●	1 day					
16	Receive Purchase orders	●	1 hour					
17	Receive and Review Design for manufacture	●	2 days					
18	Send drawings for approval (Links)	⇨	1 hour					
19	Review and sign Furniture Detail Drawings	■	0,5 day					
20	Wait for drawings sign off	◗	up to 7 days					
	Total		3.5 days 1 h	3d 1h	1h	7d		0.5d

5.5. The Way Forward

The BIM Implementation at Links is currently on Stage 4 of the project, namely the Pilot implementation of a BIM-based collaborative strategy for DfMA. The component library is being developed using the chosen software package, in parallel with the deployment of a BIM pilot project that puts in practice the new processes and procedures that will enable Links to operate in a BIM Level 2 Environment. By the end of the project, the Links FF&E component library, which consists of 40 typical furniture components, will have its design completed, including shop drawings attached to each furniture item and the capability of exporting the data into BIM exchangeable file formats. Further internal training will be scheduled, and the full shift to BIM-enabled processes and practices will be established.

Table 3. Design software requirements decision making matrix

	Facet	Weight	Autodesk Factory Design Suite	Solidworks + 3DMax	ImosCAD + 3D Max
			AutoCAD Invertor 3DMax Showcase Naviswork		
Design (layouts, elevations, specification sheets)	Ability to input data with accurate dimensions		5	5	3
	Ability to use customize libraries		5	5	3
	Ease of setting up standards and templates		4	5	5
	Speed to design a simple room		5	3	5
	Revision control management		5	4	1
	Accuracy of relation of plans & elevations		5	5	5
	Ease of use furniture libraries		5	5	5
	Ease of development of 3D Models for CGIs (export-import models)		5	4	4
	Facility to find compatible 3d models from furniture suppliers		5	3	5
	Ease of development of shop drawing from the layouts & elevations		5	5	4
	Flexibility to design bespoke shapes and bespoke furniture for common rooms		5	5	3
	Metric measurement system		5	5	5
	Speed to get design visualization for project development purpose		5	4	5
CGI	Ability to produce Photorealistic images				
	Ease to input bespoke materials for CGI				
	Facility to find object libraries for interiors				
	Ability to save backups that can be opened in older versions of the same software				
	Ease to detail furniture for photorealistic images (bold edges, etc.)				
Shop Drawings	Ease of input design drawings into production		4	4	5
	Interoperability with CAD/CAM system of Manufacturer (including Nordic - Imos)		5	4	5
Internal Information exchange	Interoperability between layout, CGI and production systems		5	5	4
	Ability to connect objects with data base of prices		5	5	4
	Ability to link objects with data base of manuals		5	5	5
	Ability to extract schedule of quantities of furniture		5	5	5
	Ability to produce estimating from the 3D models		5	5	5
External Information exchange	Interoperability with architects/contractors systems		4	3	3
	Ability to extract COBie data (spreadsheet)		2	3	2
	Ability to export IFC		3	4	1
	Interoperability with coordination software (e.g. Solibri and Naviswork)		5	4	3
Cost	Cost of Licence		4	3	4
	Cost of Training		4	4	4
	Year maintenance cost		4	4	5
Total			124	116	108
	Score				
	1-Doesn't meet criteria				
	2-Below Average				
	3-Average (e.g. requires advanced setting to meet criteria)				
	4- Good				
	5-Excellent (100% meet criteria)				

The change management process is gradual and follows a process of cultural change that has occurred since the project began. The change from 2D project design to the use of 3D BIM models requires time and effort from employees to develop their capabilities. Furthermore, the design to manufacture and installation knowledge has to be matured alongside the project. All these changes are currently ongoing and expect to be finalised at the end of this project.

6. CONCLUSION

The launch of the UK Government Construction Strategy in 2011 has witnessed a build-up of momentum within the construction industry with a significant increase in the awareness and adoption of BIM following the mandate for the use of collaborative BIM on all centrally procured public projects by 2016. In addition, the large majority of enterprises in the UK construction industry are SMEs; therefore SMEs are vitally important in the whole UK sector's approach to BIM and in transforming the industry. Moreover, the use of business approaches, such as process improvements and knowledge management, can incrementally reduce costs and increase competiveness for SMEs.

This paper has presented the findings to date of a 30 month KTP project in support of BIM implementation within a design, manufacture and fitting SME based in the UK. The project is being delivered through five key stages. The paper has presented the findings of the first three stages that have been completed to date and the fourth, which is currently in progress. The first stage was focused on establishing and consolidating best practice knowledge in BIM prior to stage 2, which mapped the current business processes, and various associated waste in the process was identified through their analysis. Stage 3 then established and reviewed the areas of potential improvement gain of a BIM-enabled approach across the business together with the potential risks. Stage 4 is currently implementing the developed BIM-based collaborative strategy for DfMA through an identified pilot project. The remaining stages will conduct a project review and evaluation along with further dissemination of the results.

In conclusion, the findings from the work to date suggest that the proposed BIM workflow from design through to manufacture and fitting within Links could reduce cycle times in design from concept to shop drawings, saving time and increasing profits. BIM can address issues commonly found in the design to manufacture and fitting, supporting a better integration between the organisation's business functions, increasing predictability and reducing the overproduction of drawings.

However, for the company to incorporate the streamlined BIM workflow there is a need to manage the change and get their employees engaged with BIM. As highlighted by the results of stage 1 of the project, there are challenges in managing the changes that are common for SMEs. Although very enthusiastic with the potential improvements proposed by the project, issues in dealing with the resistance of people to change, allocation of financial resources and people's time and effort, have impacted on the BIM implementation project so far. Culturally, changes have been embedded and the organisation is progressing towards its strategic objectives and continuous improvement. However, to conclude the project successfully, the implementation of BIM should focus on change management, process standardisation, training and metrics, thereby creating the right environment for continuous improvement in a learning organisation.

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