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 - Following the launch of the Government Construction Strategy in 2011, the UK construction sector has witnessed a significant increase in the awareness and adoption of Building Information Modelling (BIM). As recognised by the strategy, there are synergies between Lean Construction and BIM. BIM implementation demands changes in existing process and procedures for design and construction, representing a technology change but also a people and process change. Therefore, the implementation of BIM is a business decision that should be aligned with a business strategy in making the organisation leaner.

This paper presents a BIM implementation project through a Knowledge Transfer Partnership (KTP) between the University of Salford and Links, a design, manufacture and fit-out SME based in the UK. KTP is a government-funded initiative to support businesses improvements by accessing universities expertise. The project aims is to implement BIM as a catalyst for a lean transformation, streamlining process and operations. The research adopts a case study methodology on a BIM implementation for Design for Manufacture and Assembly (DfMA) at Links through an approach of reviewing the organisational business process and workflows followed by exploring and implementing appropriate technologies that then enable the people and process transformation.

The 30 months project is being delivered through 5 key stages. This paper presents the findings from the first two stages that have been completed to date of 1. Establishing and consolidating best practice knowledge in BIM; 2. Conducting a detailed review and analysis of the organisation's current situation, and the third, which is currently progressing, of 3. Developing a BIM-based collaborative strategy. The remaining stages will implement a BIM-based collaborative strategy for DfMA through a pilot project before conducting a project review and evaluation.

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

I. INTRODUCTION

Building Information Modelling (BIM) adoption and awareness is growing in the UK construction sector. The National BIM Report Survey [1] found that 95% of practitioners in the UK are current using or believe that they will be using BIM within the next 5 years. There has been significant influence of the "push-pull" Government Strategy for BIM that will mandate the adoption of BIM in all centrally public procured projects from 2016, and a 'feeling' of BIM being a new standard for project information, which is transforming the construction industry landscape. In addition, the UK construction industry is represented by 99.7% of SMEs who are therefore vitally important in the transformation of the whole UK sector.

BIM involves processes, people, technologies, and tools applied to generate and manage information about a building during its life-cycle [2, 3]. It utilises digital technology to design one or more accurate virtual models that represent a building before its construction, supporting the interaction of the different stakeholders around the models. Geometry and data to support construction,

fabrication, procurement and operations are included in the models, allowing a better analyses and control compared to manual processes [3].

In addition, BIM projects involve high levels of collaboration between players and integrated processes. Moreover, it demands changes in existing process and procedures for design and construction [4]. BIM also represents a technology change but also a process change [3], i.e. the reason why the application of Lean principles can benefit a BIM implementation.

Lean Principles are based on studies of the car manufacture Toyota, adapted over time to manufacture, construction and services by several authors. The core of lean is to deliver a product or service maximizing value (in the customer perspective) and minimizing waste. Lean is process oriented, and considers the use of technology only if it serves people and processes. Lean also offers sets of tools and techniques, however, Lean is not a set of tools, but a philosophy that is "shared throughout a value stream" [5, 6].

Technology alone will not make any significant change in a business; therefore an effective BIM implementation strategy must be aligned to the business strategy, based on a review of the organisation's business process and workflow, both internally and externally [4]. Technology should fit organisational infrastructure and reinforce business process. Furthermore, the emphasis should be in management and organisational changes to support the implementation of information technology, and not the converse in order for the company to succeed in realizing the full benefits of the implemented information technology [7, 8].

Lean Construction and Building Information Modelling are independent concepts that can be applied one without the other, although Sacks, Dave, Koskela & Owen [9] argue that there are synergies between them, while the full potential for improvement in construction projects had been achieved by the adoption of both concepts together.

Sack et al. [10] argue that any BIM implementation project should ensure that the process changes adopted are to make the organisational process leaner, stating that "*BIM could be an enabler or catalyst for lean transformation*".

II. METHODOLOGY

This paper presents a BIM implementation at Links, a UK based company that offers design, manufacture, supply and installation of quality fittings and furnishings for student accommodation.

The project is being delivered through a Knowledge Transfer Partnership (KTP) between the University of Salford and Links. KTP is a program partly funded by InnovateUK with the objective of supporting businesses that want to increment their performance and competitiveness with innovative solutions by accessing and transferring the knowledge and expertise of academia.

The aim of the project is to implement BIM within Links ensuring the company has the expertise needed to operate in a BIM environment and comply with the BIM Level 2 mandate. Links expect that BIM will streamline their processes and operations; thereby consequently increasing profits The project will enable the transformation of the organisation towards being BIM-enabled through the development of a business wide BIM strategy, which will be initially rolled out for Design for Manufacture & Assembly (DfMA) through the proposed project.

Due to the nature of the project, the research adopts a case study methodology. The 30-month project is comprised of the following 5 key stages and associated objectives and outputs:

Stage 1*: Establish and consolidate best practice knowledge in BIM*

- State-of-the-art best practice knowledge in BIM and for collaborative DfMA

Stage 2: *Detailed review and analysis of the organisation's current situation*

- Detailed and validated current process maps and information flows
- IT systems, file formats, information exchanges review and recommendations

Stage 3*: Develop BIM-based collaborative strategy*

- Mapped BIM-enabled processes and practices
- Improvement gains analysis
- IT systems and information requirements
- Developed training plan
- Organisational BIM implementation strategy
- DfMA BIM implementation strategy plan

Stage 4: *Pilot implementation of BIM-based collaborative strategy for DfMA*

- Pilot implementation DfMA project identified
- IT system(s) selected, procured and integrated
- Component libraries developed and implemented
- Training plan implemented and rolled out
- New processes and practices embedded

Stage 5: *Project review, evaluation, and dissemination*

- Implementation project impact assessment
- Project review and evaluation
- Academic and industry dissemination

III. CASE STUDY PRESENTATION

Links, the case study company, operates with 3 core areas: design, project management and support

services; manufacturing – provided by a sister company based in Lithuania; and the fitting and installation – with teams based on sites across the UK. This paper concentrates on the design service and its relation with manufacturing and installation.

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 standardized processes, lack of internal capabilities and lack of technology to improve processes. The company is addressing this challenge through the implementation of BIM with support of the University of Salford.

IV. Results of Stage 1: Establish and Consolidate Best Practice Knowledge in BIM

To date the project has completed the first three key stages and is currently engaged in the fourth stage of the project, preparing the company to run a pilot project with BIM. The results of the first three stages are discussed below.

The initial stage of the implementation was to benchmark the best practice of BIM in the UK. Based on a state-of-the-art review of literature, the final report of this stage gives 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 main concepts of BIM for DfMA. Next, based on primary data collected from semi-structured interviews with industry key players, the report established the state-of-the-art of BIM implementation in the UK covering the key aspects to shape a BIM implementation: main drivers, steps for implementation, challenges related to people and SMEs, and measurements. A final discussion emphasizes challenges related to protocols, the development of component libraries, and the opportunities of BIM for SMEs.

a) Challenges

Based on the experience of BIM mature companies in the UK, the study found that Links' complex business process, which involves design, manufacturing and installation, could benefit from BIM, especially regarding information exchange, integration with the supply chain and Design for Manufacture and Assembly. 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.

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 the KTP team has found to overcome this challenge was to demonstrate the value of BIM through awareness and training sessions. For example, regular lunchtime seminars are held to raise the awareness of BIM and the project within the organisation. During these seminars, the KTP Associate presents the results of the project, information about BIM in the UK, information about process improvement and much more. The seminars have had a positive impact on people's engagement with BIM and the project, creating the right mindset for the BIM implementation.

V. Results of Stage 2: Detailed review and analysis of the organisation's current situation

The paradigm of BIM comprises people, process, information and technologies. Following the approach of reviewing the organisation's business processes and workflows, and then exploiting the enabling technology, the aim of Stage 2 was to explore Links processes and understand their business through mapping its business process, IT systems and infrastructure, file formats and information exchange, which would inform the decisions of the enabling technology in the next stage of the implementation.

Links processes, which had previously been documented for purpose of attaining their Quality Management System ISO 9001, were out of date and the company was operating with processes that have not previously been documented. Through the KTP project the organisation began mapping their processes from scratch, which while an extremely time consuming exercise, has several benefits on stabilising and standardising the organisation's processes and operation.

The methodology adopted was a series of interviews with each department of the organisation in order to capture the information about their current workflows. From the interview information the KTP team then developed a series of process maps using Business Process Modelling Notation (BPMN) as recommended to be used by NBIMS [11] on BIM projects. Finally, the process maps were validated through workshops involving Links departments and management teams.

The process of mapping how Links currently operate has served to identify areas for improvement. Furthermore, it clarified the vision on how the company could increase efficiency with the same resource through the re-engineering of their existing processes. Therefore the company have realised

what actions need to be taken in order to increase profit and turnover.

a) Current Process

Focusing on the Design to Manufacture and Installation process, Figure 1 represents the Design process including interfaces with Customer and Manufacture. Process steps are described below:

- Design Preparation: ideas for the space sketched by hand.
- Concept Design: 2D layouts and elevations using (dwg), specification sheet (doc), and 3D visualizations (CGIs) on 3DMax.
- Project Planning & Procurement: Once the client approves design, design outputs are sent to their manufacturer sister company.
- Furniture detail Design: the manufacture develop detail furniture drawings (dwg), which are sent back to Links for approval.
- 3D Models: Following drawings sign off, 3D models (CAD) with all manufacture information are developed (by the manufacturer sister company) to be input into their CNC machines for production. Information is shared in pdf, non-editable files.
- Furniture is manufactured and send to site for fitting/installation.

b) Process Analysis

Analysis of Links' design processes has identified various types of waste as follows:

- *Over-production/duplication of information:* 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 excess of inventory.
- *Motion/waiting:* unnecessary information movement between departments due to the lack of skills and technology. When information is moved from one department to others, if not well planned, the process can be delayed by the availability of the next department, and waiting is a further.
- *Over processing/defects:* unclear communication and the lack of systematic procedures to capture client requirements can cause misunderstandings, and projects can be developed that do not conform to client's requirements, ultimately causing re-work.
- *Skills:* the lack of knowledge transfer throughout the company. For example, Links 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 on when the design needs to freeze because the root causes of many problems during procurement and installation are the client not making decisions from design on time and inadequate drawings[12]. To enable manufacturing, the client have to acknowledge that the design has to freeze earlier for the benefit of all concerned [13]. 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 [5].

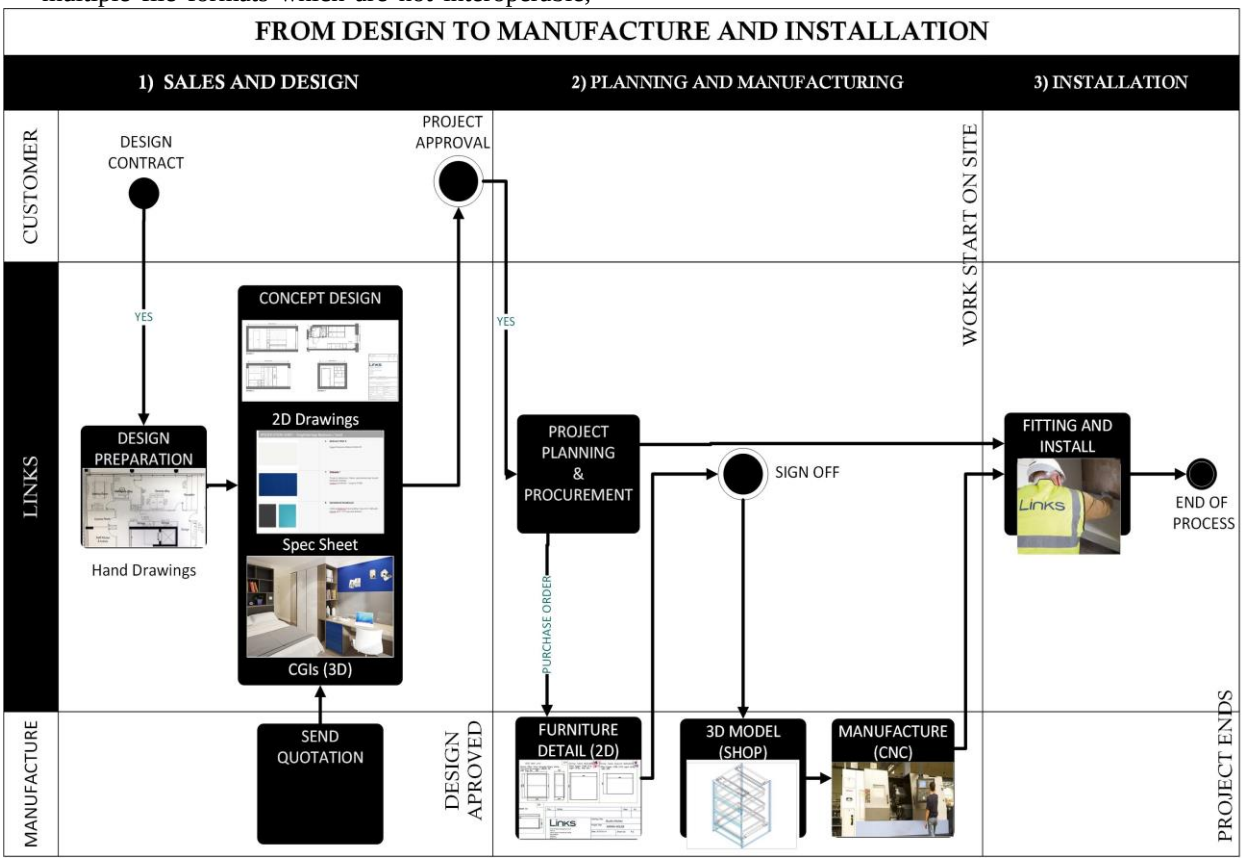

Fig. 1: Design to Manufacture and Installation current process

Process	Common Issue	Waste	Vision	Action
General	• Design need to freeze in a certain point to avoid defects			Management
	• Lack of knowledge of fabrication process and fitting process to be able to develop new products	Skills	Integration of company departments knowledge though workshops	DfMA Training
	• Lack of training on software	Skills		BIM Training
Concept Design	• Areas of improvement: Information about the products better organized to speed up design and specification process	Over processing	BIM: Design Software, Component Library with Links products, Researchable database of suppliers	BIM Software
	• Cost of Design is calculated at the end of the design concept process, by other department	Motion Re-work	Implement a BIM 5D tool to have the capability of cost in early design stages	BIM Software
	• Small amendments asked by the client after the amendment period make the project finish difficult to be establish	Unclear communication	Clarify on contract the kind of amendments that are included or not in the proposal.	Management
	• Duplication of information in multiple formats • Lack of a "single version of the truth"	Overproduction Duplication	BIM: Design Software interoperable with CNC	BIM Software
Design Handover	• No formal handover to project management teams, lack of information for manufacture	Unclear communication	BIM: Common Data Environment for a better Information Management	BIM Software Process change

Table 1: Improvement gain analyses

VI. Stage 3: Develop BIM-Based Collaborative Strategy

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 also identifying the potential risks. Table 1 presents a summary of the findings.

Based on the issues that the project identified, a set of KPI's were proposed. The KPI's were established by applying the Balanced Score Card (BSC) methodology, which cover 4 areas of every organisation: Customer, Internal Process, Financial, and Learning and Growth [14]. The KPIs are to measure more than the processes but to assess that the company is moving towards its strategic objectives. Furthermore, such systematic measurements serve to also stimulate and embed a process of continuous improvement within the organisation.

To get a comparison of the results of the BIM implementation, a baseline project is going to be initially measured followed by KPIs being captured on a BIM Pilot Project. Table 2 describes the KPIs, their objectives and proposed metrics.

a) Target Process

The development of long term BIM Strategy for DfMA, enabled by appropriate software along with considering the interoperability of the different software utilized in design into manufacture would eliminate the information duplication. In addition, part of the BIM implementation is the development of standard component libraries with parametric models that will be used in concept design and send direct to manufacture after design approval. It is expected that the use of such component-based design will speed up the design process, reduce errors and increase manufacture efficiency.

Based on the data captured in the first stages and the software chosen for the organisation, Table 3 compares the current process with the target process in relation to estimating the time savings. The left table has the 23 steps that Links currently does from design to manufacture. The right table has the target process, marked in red are actions that incorporate the suggested changes with BIM.

Comparing the two tables it is possible to notice that the initial steps (1,2) related to design preparation remain the same, but in step 3 the development of a 3D BIM Model make possible to extract plans, elevations (step 4) and to use the model as a base to produce CGI (step 5). That avoid duplication

of the information and unnecessary motion, possibly saving time and improving information consistency. The use of BIM also can also speed up the handover to estimators, as all the furniture quantities can be extracted automatic from the model. Finally, in the bottom of the table are the activities performed by the manufacture sister company. In the target process, the idea is to incorporate on design stages 3D component libraries that are compliant with the manufacture requirements, therefore the BIM Model could potentially diminish or eliminate the necessity of re-design for manufacture purposes using CNC machines. Furthermore, the full BIM process could 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 designer's knowledge about the manufacturing drawings requirements, which can increase the collaboration between design and manufacture.

At this stage, the company have decided on IT requirements for software selection and procurement considering the workflow improvements proposed.

A training plan was formulated, including technical skills (software), design to manufacture skills to improve the integration of these areas of the company and change management skills to support the transition to the next stage of the project.

	Objectives	KPI	Measures	Targets
Satisfy Shareholders	Increase Customers numbers		Number of Customers	% increase
	Increase Design Turnover		Average Sale	% increase
	Increase Conversion rate	Percentage calculated by Projects proposal/ projects		
Delight Customers	Increase Customer Satisfaction	Questionnaire for Client Satisfaction Overall including service, specification, timely and accurate provision of information and personnel Compare before and after BIM	Customer Satisfaction	% increase
Effective Processes	Reduce Cycle or Lead Time	Capture time from baseline project and measure against pilot BIM Project	Cycle Time	% reduction
	Reduce Changes	Requirements captured (EIR) Capture Number of changes to measure how accurate EIR are	Number of Changes	% reduction
	Reduce changes after amendment period	Changes out of amendments period to be measured in separate	Number of changes	% reduction
	Increase Quality of information on internal handover	Provisional of Information Overall How satisfied the internal client was with the timely and accurate provision of information by design team	Internal client satisfaction	% increase
Motivated & Prepared	Increase Core Skills	Measure employee satisfaction before and after training	Training	% increase

Table 2: KPIs for BIM Implementation aligned with company strategy

Title: Design to Manufacture (As-Is Process)			Date: 20/11/14				
			Chart Symbol				
	Step	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 2 h**	**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 1 h**	**6d 1h**	**1h**	**7d**		**0,5d**

Title: Design to Manufacture - (Target Process)			Date: 06/05/15				
			Chart Symbol				
	Step	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**

Table 3: Current Process and Target Process Comparison

VII. CONCLUSION

The launch of the UK Government Construction Strategy in 2011 has witnessed a momentum build 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. The UK construction industry is represented by 99.7% of SMEs; therefore, SMEs and the manufacturing community are vitally important in the whole UK sector's approach to BIM. 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 a BIM implementation within a design, manufacture and fit-out SME based in the UK. A KTP is a program partly funded by InnovateUK aimed at supporting businesses in increasing their performance and competitiveness with innovative solutions by accessing and transferring the knowledge and expertise of academia through to the organisation.

The project is being delivered through 5 key stages. The paper has presented the findings to date of the first three stages that have been completed of establishing and consolidating best practice knowledge in BIM followed by conducting a detailed review and analysis of the organisation's current situation, and the third stage, which developed a BIM-based collaborative strategy. Stage 2 mapped the current business processes and various waste in the process was identified through their

analysis. Stage 3 established and reviewed the areas of potential improvement gain of a BIM-enabled approach across the business together with the potential risks. In addition, KPIs have been established for systematically assessing the company moving towards its strategic objectives and in embedding a process of continuous improvement within the company. Following the completion of the third stage, the remaining stages will implement the developed BIM-based collaborative strategy for DfMA through an identified pilot project before conducting a project review and evaluation long with further dissemination of the results.

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

However, for the company to incorporate the streamlined BIM workflow there is a need to manage the change and get the employees involved with BIM. As highlighted by the results of the stage 1 of this research, dealing with the resistance of people to change is crucial for the success of a BIM Implementation. Therefore, the research recommends the implementation of BIM focuses on change management, process standardisation, training and metrics; thereby creating the right environment for continuous improvement in a learning organisation.

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