

## **BUILDING INFORMATION MODELLING (BIM) IMPLEMENTATION AND REMOTE CONSTRUCTION PROJECTS: ISSUES, CHALLENGES, AND CRITIQUES**

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**ABSTRACT** *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. This paradigm shift is becoming more critical with remote construction projects, which reveals unique and even more complicated challenging problems in relation to communication and management due to the remoteness of the construction sites. On the other hand, Building Informational Modelling (BIM) is offered by some as the panacea to addressing the interdisciplinary inefficiencies in construction projects. Although in many cases the adoption of BIM has numerous potential benefits, it also raises interesting challenges with regards to how BIM integrates the business processes of individual practices.*

*This paper aims to show how BIM adoption for an architectural company helps to mitigate the management and communication problems in remote construction project. The paper adopts a case study methodology, which is a UK Knowledge Transfer Partnership (KTP) project of BIM adoption between the University of Salford, UK and John McCall Architects (JMA), in which the BIM use between the architectural company and the main contractor for a remote construction project is elaborated and justified. Research showed that the key management and communication problems such as poor quality of construction works, unavailability of materials, and ineffective planning and scheduling can largely be mitigated by adopting BIM at the design stage.*

**KEYWORDS:** *Building Information Modelling, Communication, Remote Construction Projects*

**REFERENCE:** *Yusuf Arayici, Charles Egbu, Paul Coates (2012) Building information modelling (BIM) implementation and remote construction projects: Issues, Challenges and Critiques, Journal of Information Technology in Construction (ITcon), Vol. 17, pg. 75 -92, <http://www.itcon.org/2012/5>*

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## **1. INTRODUCTION – REMOTE CONSTRUCTION PROJECTS-KEY CHALLENGES AND ISSUES**

Construction projects by their nature are fragmented, complicated, risky and uncertain. These challenges are, arguably, exacerbated in remote construction projects which have their unique problems, caused mainly by the remoteness of the project itself, resulting in the loss of control over communications and management, including lack of management skills, human resources and infrastructure (Sidawi, 2012). As a result, problems around communication, coordination and management occur especially in remote construction projects, in which stakeholders are all located in discrete locations or even in different countries. Sidawi (2012) and Yang et al, (2007) proposed Advanced Computer based Management Systems for effective information management and communication since conventional technologies are seen as not capable of meeting required processes and project improvements for the remote construction projects.

The extensive physical distance between stakeholders, who are all located in different regions or places is the primary cause of delays in decision making (Deng et al. 2001). The project team has to not only tackle traditional management problems but those that specifically occur as a result of the remote locations of these often environmentally sensitive sites (Kestle 2009; Kestle and London 2002, 2003; Sidawi, 2012). These sites are often far from logistic support and suffer a continuous shortage of materials and specialised labour (Kestle and London 2002, 2003).

Kestle (2009) highlighted that the lack of project pre-planning, uncertainty or lack of clarity concerning project process integration were also leading to misinterpretations and miscommunications of project results and needs issues. A centralised decision-making process and lack of delegated authority to field personnel often hindered progress and communications at critical emergency response and recovery stages (Sidawi, 2012).

This paper discusses BIM (Building Information Modelling) based design and construction processes for efficient and effective management of remote construction projects, such as the need for appropriate material management systems and design cost information, specifically in remote construction works. It employs a case study approach for BIM adoption and implementation in the design process and its subsequent impact on, and improvements for, an actual remote construction project. While section 2 elaborates Building Information Modelling as an evolving concept, section 3 explains the BIM adoption for an architectural company at organisational level. Following that, section 4 highlights the subsequent improvements in the project management and communication between the main contractor, sub-contractors, construction site team and the architectural company during the actual construction stage of a remote construction project.

## **2. BUILDING INFORMATION MODELLING FOR BUILDING LIFECYCLE MANAGEMENT**

While there are few definitions available for BIM in the literature, in this paper the authors propose a more comprehensive and operational definition, in order to give the reader a clear understanding behind the real agenda of BIM. Consideration is also given to the natural environment, user environment and owner satisfaction throughout the lifecycle within this definition.

BIM is defined as the use of ICT technologies to streamline the building lifecycle processes to provide a safer and more productive environment for its occupants, to assert the least possible environmental impact from its existence, and to be more operationally efficient for its owners throughout the building lifecycle (Arayici and Aouad, 2010).

BIM in most simple terms is the utilization of a database infrastructure to encapsulate built facilities with specific viewpoints of stakeholders. It is a methodology to integrate digital descriptions of all the building objects and their relationships to others in a precise manner, so that stakeholders can query, simulate and estimate activities and their effects on the building process as a lifecycle entity. Therefore, BIM can help with providing the required value judgments for creating a more sustainable infrastructure, which satisfy their owners and occupants.

BIM as a lifecycle evaluation concept seeks to integrate processes throughout the entire lifecycle of a construction project. The focus is to create and reuse consistent digital information by the stakeholders throughout the lifecycle (Figure 1). BIM incorporates a methodology based around the notion of collaboration between stakeholders using ICT to exchange valuable information throughout the lifecycle. Such collaboration is seen as the answer to the fragmentation that exists within the building industry, which has caused various inefficiencies. Although BIM is not the salvation of the construction industry, much effort has gone into addressing those issues that have remained unattended for far too long (Jordani, 2008).

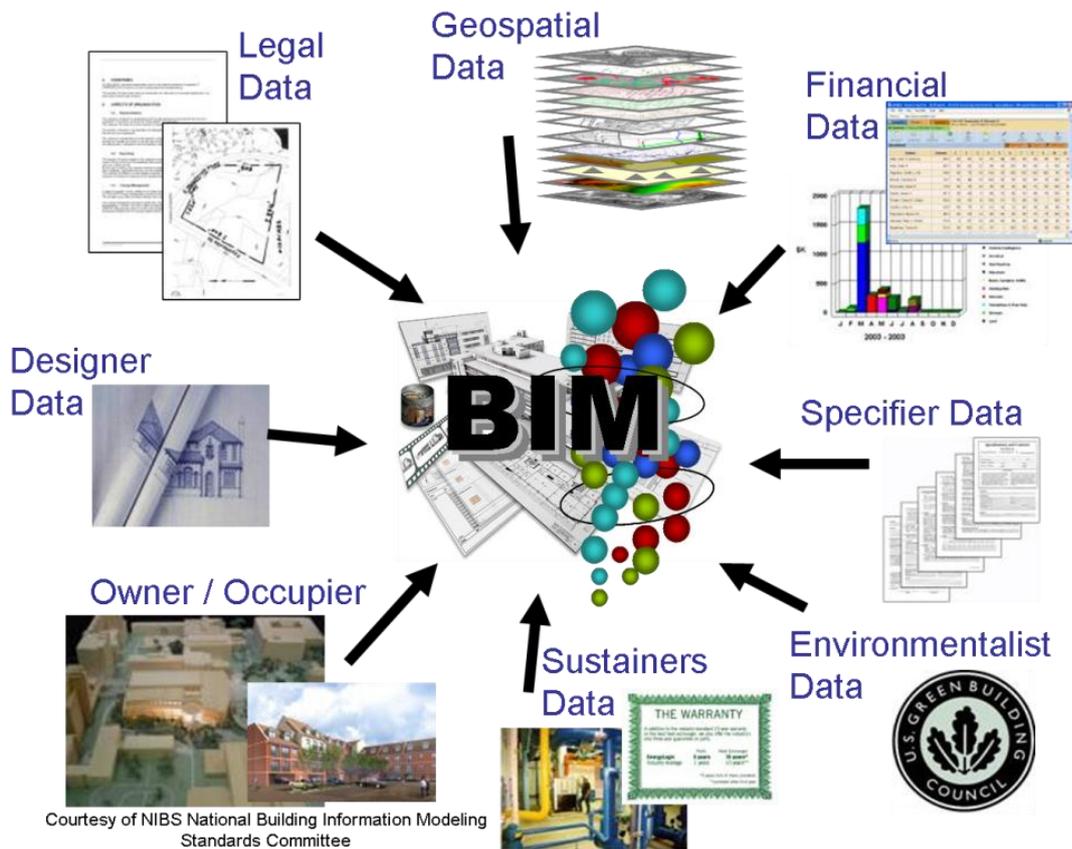


FIG 1: Communication, collaboration and Visualization with BIM model (NIBS, 2008)

Taking into consideration the design process solely within construction lifecycle process, in the majority of the construction procurement systems, design work needs to be completed in a multidisciplinary teamwork environment. The design process is by nature illusive and iterative within the same discipline, and between the other Architecture, Engineering and Construction (AEC) disciplines. During the design development, severe problems related to data acquisition and management, in addition to multi and inter disciplinary collaboration arise. Often, design team members including those from the same discipline, use different software tools and work in parallel (Arayici and Aouad, 2010). For example, a building can be divided into three different sections amongst three different architects to design. Architects can be using a different software tool, needing to incorporate their work at the end (Nour 2007). When considering the whole construction lifecycle, including the design process, the complexity, uncertainty and ambiguity will increase.

In recent years, many governments and authorities have openly accepted BIM within the construction industry to provide the required information exchange between stakeholders. An alternative methodology is not in the vicinity that could provide the required benefits. BIM technology can also provide a more streamlined business process, associated project and site management methodologies, including complete facilitation of construction knowledge during the full lifecycle of a building project (Arayici and Aouad, 2010). However, to gain these and other benefits, BIM stakeholders are required to go through a comprehensive change management process which

may require external assistance. The construction industry stakeholders currently operate with much inefficient processes and it has come to a point where change is now eminent (NBIMS, 2007). The following section introduces a change management process of BIM adoption and implementation for an architectural company and the subsequent impact of this implementation on a case study of a 'remote' construction project in Manchester, UK.

### **3. THE CASE STUDY OF BIM ADOPTION AND IMPLEMENTATION FOR JOHN MCCALL'S ARCHITECTS (JMA)**

This case study BIM adoption and implementation was undertaken under a UK Department of Trade and Industry (DTI) funded Knowledge Transfer Partnership (KTP) scheme. It aims not only to implement BIM and therefore assess the degree of the successful implementation, but rather to position this within the context of value-add offerings that can help the company place itself at the high-end knowledge-based terrain of the sector. Therefore, it adopts a socio-technical view of BIM implementation in that it does not only consider the implementation of technology but also considers the socio-cultural environment that provides the context for its implementation (Arayici, et al, 2011a).

#### **3.1. The Case Study Company: John McCall's Architects (JMA)**

The company was established in 1991 in Liverpool in the UK, and has been involved in architecture and construction for more than 17 years, designing buildings throughout the Northwest of England. Focusing primarily on social housing and regeneration, private housing and one off homes and large extensions, the company is known for good quality, economical, and environmentally sustainable design. JMA works with many stakeholders from the design through to building construction process, and the associated information is very fragmented. Projects in which JMA are involved are typically of 2½ years duration, involving many stakeholders and requiring considerable interoperability of documentation and dynamic information (Coates, et al, 2010).

By tradition, the company used a 2D CAD tool for the last two decades and it also has its own procedures, templates to optimize its practice. However, the current practice with this 2D CAD tool brings about some inefficiency such as timescales, deadline pressures, duplications, lead times, lack of continuity in the supply chain, over processing, reworking, overproduction, distractive parallel tasks, reliability of data and plan predictability, lack of rigorous design process, lack of effective design management and communication.

The company was, therefore, required 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.

### **4. BIM Implementation Approach**

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; Arayici et al, 2011b). 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 (Arayici et al, 2011b).

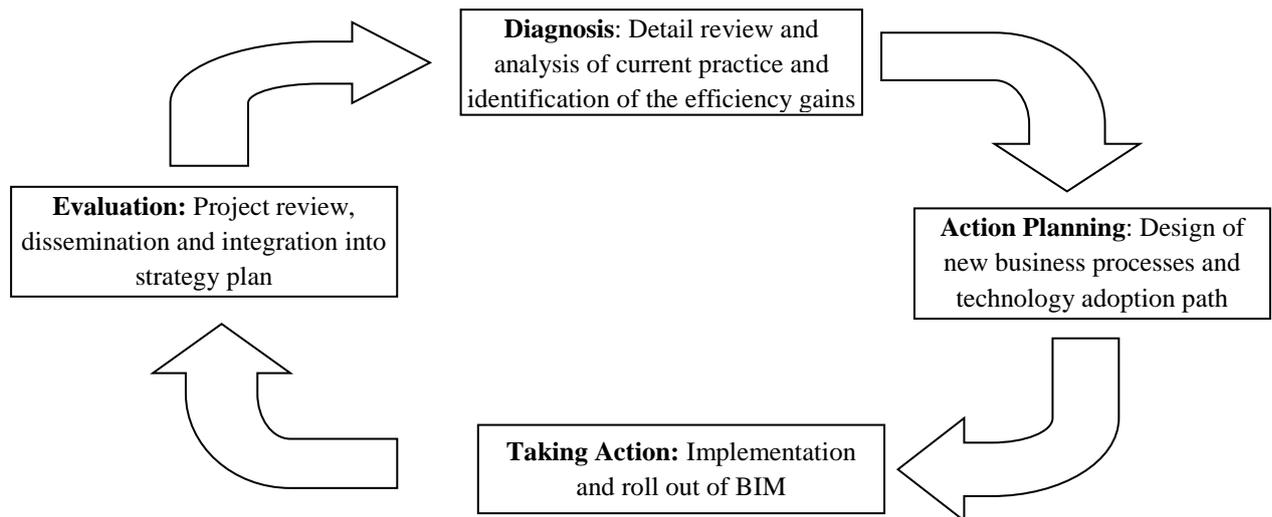


FIG 1: Action Research Process adopted (Arayici et al, 2011b)

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

TABLE 1: Detailed activities in the action research stages

Stages	Activities	Implementation Strategy
<b>Stage 1:</b> Detail Review and Analysis of Current Practice and Identification of Efficiency gains from BIM implementation	1.1. Production of Current Process Flowcharts 1.2. Review of overall ICT systems in the company 1.3. Stakeholder Review and Analysis 1.4. Identification of competitive advantages from BIM implementation 1.5. Review of BIM tools for the company 1.6. Efficiency gains from BIM adoption	<ul style="list-style-type: none"> <li>• Soft System Methodology</li> <li>• Process Innovation</li> </ul>
<b>Stage 2:</b> Design of new business processes and technology adoption path	2.1. Production of detail strategies 2.2. Documentation of Lean Process and Procedures 2.3. Development of the Knowledge Management system 2.4. Documentation of BIM implementation plan	<ul style="list-style-type: none"> <li>• Soft System Methodology</li> <li>• Process Innovation</li> <li>• Information Engineering</li> </ul>
<b>Stage 3:</b> Implementation & roll-out of BIM	3.1. Piloting BIM on three different projects (past, current, and future) 3.2. Training the JMA staff and stakeholders 3.3. Devising and improving companywide capabilities 3.4. Documentation and integration of process and procedures	<ul style="list-style-type: none"> <li>• Soft System Methodology</li> <li>• Process Innovation</li> </ul>
<b>Stage 4:</b> Project review, dissemination and integration into strategy plan	4.1. Sustaining new products and processing offerings 4.2. Evaluation and dissemination of the project	<ul style="list-style-type: none"> <li>• Process Innovation</li> </ul>

#### 4.1. Diagnosis: The Current Practice Review, Technology Selection and Efficiency Gains

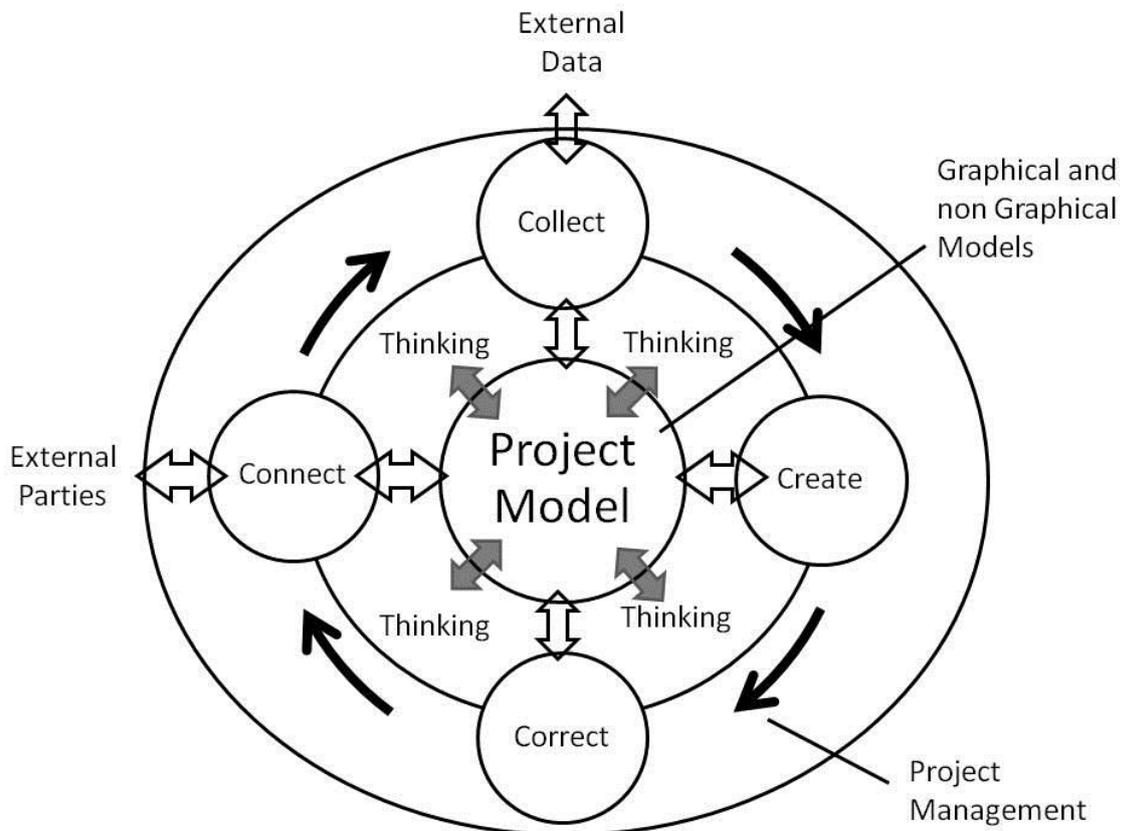
The diagnosis stage (stage 1) of the action research for BIM implementation is shown in Table 1. The main focus was to find out i) about the current work practice of the company including issues, challenges, problems and inefficiencies in the practice, ii) which BIM technology was the most appropriate for the company's specific features, priorities and iii) the lean efficiency gains required for improvement.

The project had a steering group involving five key members. These were knowledge-based supervisors in BIM and lean design from the university, a researcher located in the company, one company director and an experienced architect acting as a company supervisor on behalf of the company.

Experimentation of different BIM tools was a critical exercise to understand how a BIM tool aligns itself to specific company requirements. While observing and measuring capabilities of different BIM tools, these experimentations also helped to build up in-depth understanding about BIM as a new way of working methodology and reduce resistance against the change. The company was using Microstation tool since it was established. However, as a result of both qualitative and quantitative experimentations, ArchiCAD tool was selected as the BIM authoring tool since it was considered most appropriate in relation to the company needs and requirements and found as intuitive and straightforward in realising the following efficiency gains (further information can be found in Arayici et al, 2011a):

- The quality, speed and cost of the services JMA provides
- Automatic low-level corrections when changes are made to the design through the use of parametric relationship between objects
- Generate accurate and consistent 2D drawings throughout the design
- Visualizations to allow checking against design intent
- Discovering design errors before construction
- Information sharing
- Greater flexibility to satisfy customers
- Better financial control
- Simultaneous work by multiple disciplines

An architectural practice is a business that takes the needs and requirements of a client and translates those predilections and concepts into a holistic buildable form. Services of providing construction information and site administration may also form part of the architectural duties. The scope of architectural responsibility and level of development of deliverable is defined by contractual agreements. To achieve the scope of the architectural practice requires the processes of communication, creation and management. The actions required are illustrated in Figure 2.



*FIG 2: The Scope of the architectural practice*

The activities in the architectural business process can be defined into five themes. These domains are thinking, collecting (relevant data, information and knowledge), creating (abstractions, models, concepts and artefacts), correcting (reviewing, refining, verifying and validating) and connecting (transferring an understanding of the output to others) as illustrated in Figure 2. In the diagnosis stage, expected efficiency gains via BIM adoption are elaborated under these five themes below.

#### **4.1.1. Thinking as Part of the Architectural Process**

Thinking is an integral activity in the collecting, creating, correcting and connecting activities. These activities can have the added bonus of facilitating thinking by doing in the development of architecture. Thinking may take place individually or as a collaborative process. Technology has developed to allow collaborative interaction as part of the BIM systems. For example, the Teamworks™ server used as part of ArchiCad 14™ is an example collaborative tool embedded into the BIM authoring tool.

The architectural practice has complexity in itself and requires the use of technology and processes for the management of this complexity. However, Johnson (2000) noted that it is necessary to be cautious in distinguishing between thinking differently for better and efficient work and thinking differently to use a tool. While the former is admirable, the latter is the sign of a faulty tool. Thus, tools should help architects focus on what is important.

Developing a successful architecture needs correct thinking processes at the right time. There are many different methods of thinking: proprioceptive thinking, forming patterns, empathizing, role playing, modelling, transforming, synaesthesia and synosia, dimensional thinking, synthesizing, analogizing, observing, imaging, abstracting and pattern generation (Coates et al, 2010). For BIM to be effective it should allow and enhance this range of thinking methods and act as a decision support system and the machine readable model forms of BIM may align themselves with some thinking methods but not all.

#### **4.1.2. Collecting as Part of the Architectural Process**

Contemporarily, there is an ever increasing number of interests, technologies and factors that impinge on the architectural process. Considering the effectiveness of BIM is not possible without considering the informational requirements of building projects. Information and knowledge is required for bringing the building into existence and for the whole building lifecycle. It is the latter for which BIM provides information. For example, the acronym of BIM is used for both Building Information Modelling and Building Information Management to address the latter, not the former. In either case, the collection of information and knowledge remains an intrinsic and critical part of the architectural process.

The collection process and the timely application of knowledge into the creation process are profoundly important. Koskela (2004) addresses that making do (progressing with inadequate information) results in a considerable “was” in the preconstruction and construction process. Architectural projects often encompass unique requirements. Therefore, collecting of new knowledge is essential for successful and efficient conduit of architectural projects. For example, Figure 3 illustrates the potential sources of information and knowledge attainment in the architectural practice.

Knowledge and information may be provided in many forms, which include stories and storyboards, proverbs, scenarios, content inventories, analytics, user surveys, concept maps, process flows, style guides and design patterns. Technology can assist in the collecting process in several ways. For example, it can provide a framework for storing knowledge being collected or it can facilitate the collection of information via the use of the internet. Furthermore, technology can assist in the automated collection of information by the use of agents.

However, these tools have not been integrated with BIM and thus BIM reveals limitations in the collecting process. On the other hand, BIM facilitates the process of documenting and organising predefined design alternative. However, BIM needs to be developed further to address the limitations in the information gathering process because effective and efficient design is dependent on the effective collection and distillation of user requirements and needs.

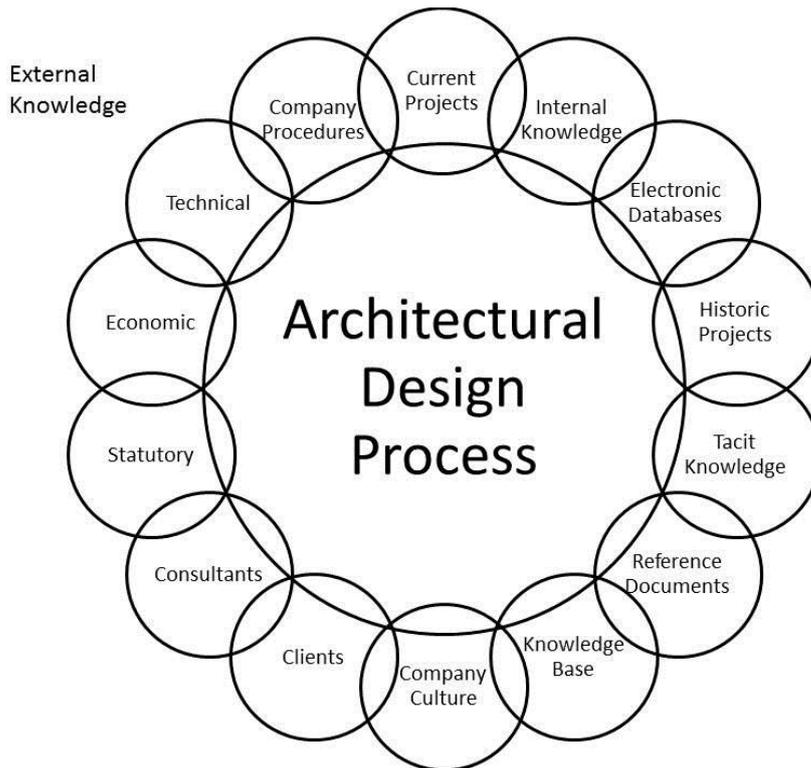


FIG 3: Sources of knowledge in Architectural Practice

#### 4.1.3. Creating as Part of the Architectural Process

BIM offers the double-edged promise of displacing abstraction with simulations, which is significant for architects to bring concepts into reality. Hatchuel and Weil (2002) propose a set of dualities of concept and knowledge iterations that occur in the development of design in which design alternatives are iterated through a process of testing scenarios from anchored objects. User feedback is obtained and the anchored objects are modified and improved accordingly. Therefore, BIM need to facilitate this iterative cycle.

In creating building designs, consideration should be given to what is functional, sustainable, practical and affordable. Architects manage not only information about the building but also about the user organization. Therefore, information systems for architectural design ideally should be able to handle both building and organizational data (Ekholm, 2001). Different design facets will be evaluated at different stages of the design. Ideally the system used to develop architectural design should be able to enhance the facets of architecture under consideration in order to contribute to the design development dialogue. For example, some designers prefer to design creation from the inside out whilst others prefer to do it from the outside in. Currently BIM tools do not allow for these personal nuances in the design process. However, only few BIM tools can accommodate the ambiguities of early design. To accommodate these ideas, the concept of architectural informational modelling should be developed as a precursor to BIM in the design practice (Pauwels et al. 2009).

However, BIM moves the focus away from the needs of the end users by focusing on the construction objects as opposed to elements of architecture. In other words, BIM concentrates rather too much on providing means of representing the final form of the design whereas designers also need a continual stream of abstractions, advice and information to facilitate the process from information to the knowledge distillation.

#### 4.1.4. Correcting as Part of the Architectural Process

Correcting brings the concept of errors or mistakes to the mind since it is important that non conforming design product is identified and rectified. However, correction here is as much about evolutionary design development of the product as it is about error correction. Correcting as part of the design process can enable better design solutions too (Austin & Devin 2003).

With the automation features built into many BIM, certain historical problems are less likely to occur. First of all, consistency between the plans, elevations and schedules can be attained if these are generated from a single BIM model. 3D geometric errors are less likely to occur because 3D buildings are constructed as 3D models not 2D representations of 3D forms. Specification errors are less likely to occur if the specification is directly linked to the BIM model. Clash detection has the ability to assist in interdisciplinary coordination issues. Where the BIM systems use constraints, dimension driven design and automated code compliance are also possible. An example of this would be the knowledge based design integration using blue think applications (Opdahl and Olsen, 2009; and Love, 2010).

#### **4.1.5. Connecting as Part of the Architectural Process**

BIM has capabilities to transfer richer data than the CAD systems. There are two facets in the connecting process. First, information from the architectural process needs to be transferred accurately: information exchange and sharing can be achieved via the use of IFC at the varying levels of success (Kiviniemi, 2010), which will of course improve. However, such information transfers may need subsequent editing, filtering and manipulation to make comprehensible and usable by the recipient. The second facet of connecting is to make information supplied fit for purpose in line with the recipients' requirements.

Communication of architectural concepts is necessary with other disciplines such as planners, building control officers, end users, clients and contractors. The precise format and content that is required by each of these parties is different. Also the level of understanding of each of the parties varies. This means that semiotic issues come into play.

While 2D representations remain as the baseline method for informational delivery even from 3D models, consistency in information exchange still remain as an issue. In this respect, a major advantage of BIM is the 3D printing, automated creation of animations and virtual environments for efficient connecting between stakeholders.

It became ascertained that the managing and maintaining knowledge efficiently across the company requires an appropriate Knowledge Management strategy for discovering, collating and sharing knowledge together with BIM implementation in order to gain efficiencies not only from projects but also in other parts of the company. Therefore, the Action Planning Stage (stage 2) concentrated on lean process improvements via defining detailed strategies, documenting new business process procedures and development of Knowledge Management system and the BIM implementation plan.

## **4.2. Action Planning Stage: Design of New Processes and Technology Adoption Path**

Increased understanding and awareness of BIM and Knowledge Management led to further diagnosis towards lean design process at this stage. For example, lean improvements were needed in the marketing, administration, finance, contractual related project support information, which were directly related to one or many projects, which as yet, cannot be modelled with BIM. However, efficient handling of those project support information certainly had impact on the actual design project information modelled in BIM. Therefore, lean improvements should not only be considered at the project level via BIM but also at the organisational level via Knowledge Management and BIM together.

The main approach used for lean process improvements in the project was A3 method, which was proven to be a key tool in Toyota's successful move towards organisational efficiency, effectiveness and improvement (Durward and Sobek, 2008; Koskela, 2003). It was used to solve problems, gain agreement, mentor (Shook, 2008); and led to the identification and resolution of i) waste of overproduction, ii) waste of waiting, iii) waste of transportation, iv) waste of inappropriate processing, v) waste of unnecessary inventory, vi) waste of unnecessary movement, vii) waste of defects and ix) other wastes. It was used not only to simulate changes at project level but also at organisational level, including finance, administration and marketing.

The A3 exercise in figure 4 showed that there was a need for development of a KM System that would pool all the project support information for all projects and facilitate lean improvements by eliminating wastes due to ad hoc management of those activities, and also help to generate value as it would have impact on the actual design project via BIM.

# A3 Analysis – Change to Database

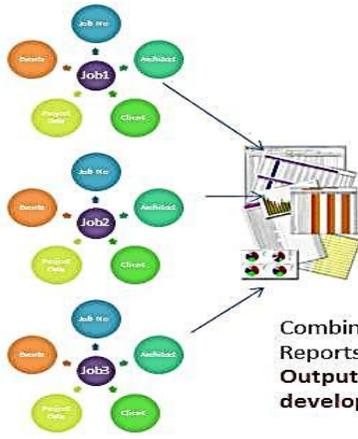
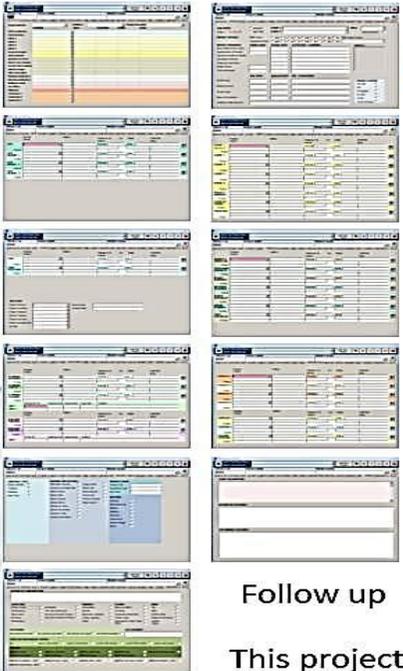
## Background

- . Items of Data are distributed through many none connected files
- . Items of data maybe difficult to locate
- . Data many not be consistent across files
- . Review of data from multiple projects is difficult
- . Time is wasted searching for information

## Current Situation



## Future State



Combined Reports Outputs to be developed

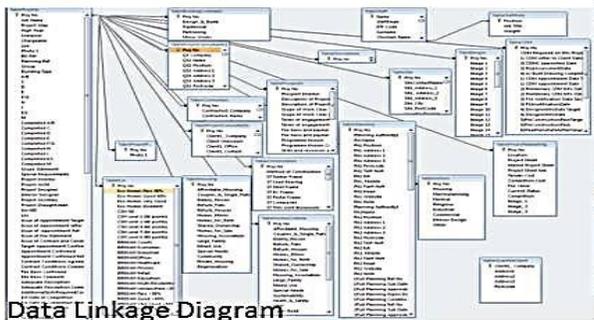
- Job Number
- Job Name
- Project Architect
- Email Address
- Project Location
- Project Start Dates
- Project Description
- Project Costings
- Project Sectors

Some of the common items of data.

- . Multiple files and file type containing common data
- . Simultaneous searches of multiple projects is not possible.
- . Projects are delayed from archive because important data would be more difficult to find.
- . Time is spent searching for historic information for future Marketing and submissions.

## Analysis

. The primary key that links the different data together is the project number.



## Knowledge Transfer Partnerships

## Data Linkage Diagram Goals

- . To make data more consistent
- . To make data easier to find, save time and money
- . To make multiple project review possible
- . To flag up error and omissions in data
- . To keep critical project data available even after the project is archived

## Jobs in the Database

## Examples of Database Input Screens



## Follow up

- . Program Test – Debug Bug
- . Report Design
- . Possible future Development.

## This project will:

- . Improve Safety
- . Improve Morale
- . Improve Cost
- . Improve Quality
- . Improve Delivery
- . Reduce waste

- Yes
- Maybe
- Yes
- Yes
- Yes
- Yes



By Paul Coates October 2009.



FIG 4: Improvements via knowledge Management system at organisational level

Therefore, requirements engineering studies were carried out, which were then translated into the system architecture for the KM system. Evolutionary prototyping approach was decided for its development to enable symbiotic user communication. For example, the first early release of the KM system was demonstrated to the staff. It was then gradually and continuously improved based on the feedback from the staff and subsequently used by the staff.

The major advantage of BIM was to input into a single information model and the multiple representations and extraction from this single information model. However, there are areas of knowledge such as finance, marketing, administration that does not go into BIM model but has certain impact on the BIM modelling of a design project. Therefore, it was decided to apply these principles for the management and sustainable maintenance of these organisational knowledge and information residing outside of the BIM graphical model such as client names, address, and dates. For this purpose, the critical data that is commonly duplicated in spreadsheets, word documents and emails was reviewed and developed into a knowledge management system used by all members of staff in the company. That provided a platform for recording, sharing and interrogating the organisational knowledge and information internally across the company. This is illustrated in figure 5.

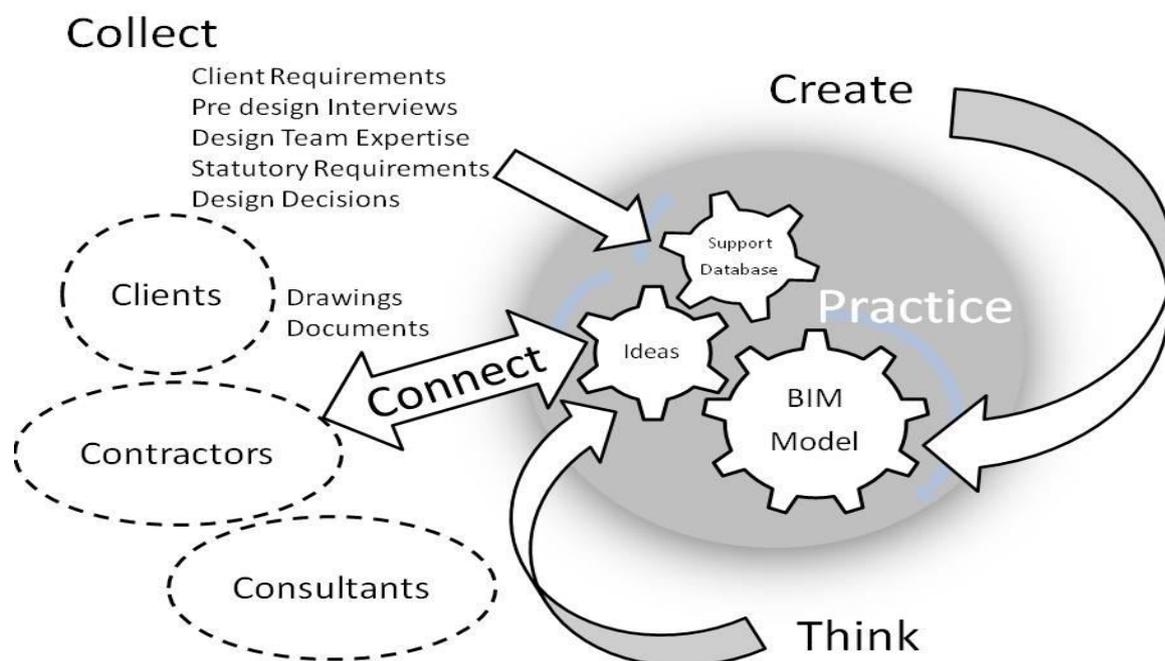


FIG 5: Shows the architectural practice with the design information encapsulated in BIM and the project support information encapsulated in the support database (Arayici et al, 2011b)

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

The Knowledge Management strategy involved actively managing knowledge. In this case, individuals strive to explicitly encode their knowledge into a shared knowledge repository, such as a database, and retrieving knowledge needed, which is provided to the repository by other individuals. Merging the architectural practice databases into an integrated multidimensional knowledge base helped JMA support the competitive intelligence and organisational memory. Furthermore, the centralized knowledge repository also enabled the optimisation of information collection, organization, retrieval and knowledge enriching features to support the seamless interoperability and flow of information and knowledge. These features included the incorporation of video and audio clips, links to external authoritative sources, content qualifiers in the form of source or reference metadata, and annotation capabilities to capture tacit knowledge. Figure 6 shows the structure of the database.

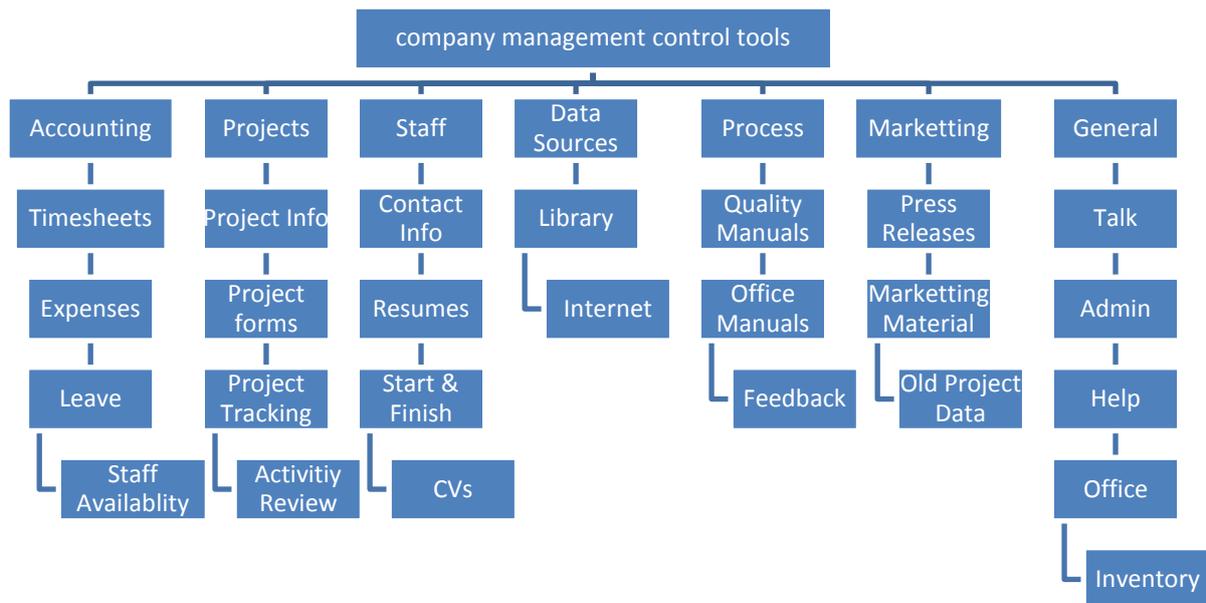


FIG 6: Categorisation of data in JMA's Practice and subsequent Data Structure of Knowledge database

The Action Planning Stage was also the preparation and planning of the actual implementation of the new BIM systems 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. In addition, training and up skilling staff is also planned at this stage. The preparation and planning of the actual BIM implementation is primarily prescribed by three factors; i) the financial restrictions on the speed with which the BIM software could be purchased, ii) finding appropriate projects on which to use the BIM orientated approach and iii) the speed with which members of staff could be trained to use the BIM authoring software. Particular consideration in the planning process was given to when and how the BIM object libraries and also office BIM standards were to be developed.

### 4.3. Action Taking Stage: Piloting BIM on a Real Remote Construction Project

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. Although the concepts of the design solutions were complex, the resultant form of the proposed building was relatively simple. This initial 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 (Arayici et al, 2011b).

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

A 2D set of CAD drawings had already been developed for these projects and BIM models with associated plans sections and elevations were rapidly produced. Objects were built from scratch on these projects. 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.

In particular, the Broom lane project was exemplified and focused on in this section because it represents an example of a remote construction project. While the architects were based in Liverpool, the main contracting company was located in Cheshire. Sub-contractors were all at discrete regions and the construction site was in Manchester. As opposed to the many remote construction projects undertaken in a traditional way, this project employed the use of BIM, which led to an effective way of management and communication between those discrete stakeholders. Figure 7 shows an example of the piloting projects with the BIM tool.

JMA, the architectural company shared a lightweight version of the BIM model with the main contractor, who also shared this model with the relevant sub-contractors and the remote site management team. This lightweight version of the BIM model can be run in windows browser easily without requiring any proprietary tool. In addition to the BIM model, a list of building schedules and quantities, which was automatically generated from the BIM model, was also shared with the main contractor.

The main contractor used the model together with the quantity take-offs to coordinate the remote site project activities and successful communication and shared understanding between all the aforementioned stakeholders.



*Fig 7: Shows a scene from the BIM model of the Broom Lane project*

For example, the images in Figure 8 below shows an example of communication style between the procurement manager of the main contractor, the site team and the sub-contractor in relation to the procurement and installation of the different window frames.

In the meantime, the piloting projects helped in developing an understanding of what was needed for BIM modelling, which subsequently led to improvements in how to sequence the steps in efficient BIM modelling. Furthermore, this increased understanding brought about a systematic approach of how to effectively use reference BIM objects, which could prove particularly efficient in generating design solutions with multiple similar units. This systematic approach was initially experimented for the use of object assembles such as kitchens and bathrooms. The major benefit noted at this cycle was the increased awareness of the design through rapid generation of 2D and 3D representations (Arayici et al, 2011b).

Rather working on 2D drawings, working on the 3D model which embeds semantic information of building objects was a significant experience for all the stakeholders at discrete locations in avoiding misunderstanding and lack of understanding in communication, ordering the correct building material at the right size, managing site activities remotely, monitoring site progress in relation to planning and safety by the site team. In other words, this experience became an eye opening and convincing exercise for all the stakeholders to mitigate the inefficiencies in their practice via BIM while this experience was recorded into JMA's knowledge database for future references as a company asset and lessons learnt.

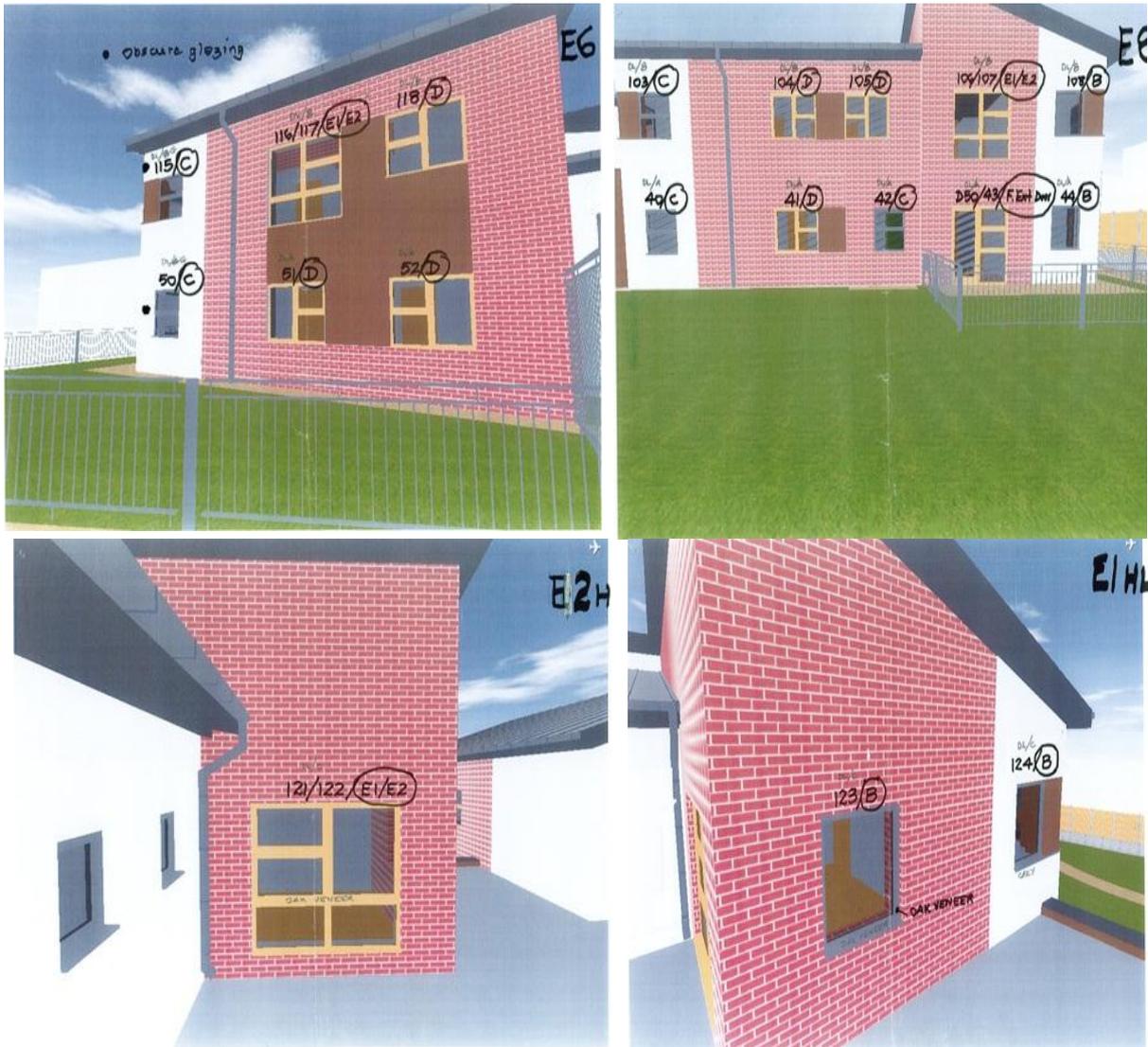


Figure 8: Shows the coded communication between the procurement manager, sub-contractor and the site manager for the procurement and installation of the window frames

Through the action research stages, learning was increased tremendously and better shared understanding about BIM was established. After witnessing the benefits through the piloting activities, forward lean thinking led to how further efficiencies could be gained, which had particular focus on people factor of BIM implementation while considering the technology and process factors. Therefore, in order to increase staff skills, training programmes were undertaken in parallel with the piloting projects, which include 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. 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. However, in all cases there was an effort to relate the learning, back to the specific type of projects undertaken at JMA

#### 4.4. Evaluation Stage: Project Review and Key Findings

It became obvious that BIM can open 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 were documented as a guide for the JMA staff on how best to use the BIM authoring tool, BIM object library addressing building types and components and the knowledge database.

Based on the interaction in the KTP projects, the following key findings were observed from the Broom Lane project as a result of BIM implementation for an architectural company and the subsequent impact of it on the management and communication of the remote construction projects:

- Effective reuse of information via knowledge database as it stores information centrally such as house types, materials used, code for sustainable home rating, and clients.
- Storing lessons learnt and experiences from the past projects as company asset
- Consistent information exchange internally and externally with the aforementioned stakeholders for successful communication and collaboration
- Enabling comparison, interrogation and correction of information shared between the stakeholders involved in the remote construction project
- Automation via BIM 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 for procuring the site material at the right time
- Effective design and technical review of the projects to avoid potential problems arising from mistakes in the future such as changes to specifications, specified materials, effective planning and scheduling
- Leading to streamlined 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.

However, it is clear that in the project further benefits and efficiency gains can 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.

## **5. Conclusion**

In the paper, BIM adoption and implementation within a remote construction project context has been presented and discussed. In doing so, it helped to raise an awareness of the remote construction projects and related key challenges faced by stakeholders situated in different locations. The study reported in the paper adopted an action research approach for the BIM adoption process. Architectural practice, in the paper has been explained comprehensively under five themes (thinking, creating, collecting, connecting, correcting). The paper has also critically elaborated on how BIM is covering those themes within architectural practice. This was the articulation of knowledge acquired via learning by doing during the diagnosis stage of the action research process, where a number of diagnostic activities were carried out. That showed that BIM can influence any of the themes differently. For example, it can have limited impact on thinking and creating themes, while it can have substantial influence on collecting, connecting and correcting themes of architectural practices at varying levels and subsequently it also impacts on external stakeholders such as contractors, client and construction site team due to the nature of those themes. The paper provided some evidence of how BIM can help to mitigate some of the key challenges of remote construction projects such as effective communication, procurement management, accurate building scheduling and quantity take-off, and establishing shared understanding between the stakeholders located at discrete locations but involved in the same remote construction project.

In addition, as a result of improved understanding and learning in the action research process of BIM implementation, knowledge management was also considered as a complementary initiative to BIM in order to help with streamlining the processes not only at the project level but also at the organisational level with regards to information management in the conduct of those five themes of architectural practice.

It is evident from the KTP project that BIM implementation serves as a useful alternative to addressing key construction sector issues, and offer solutions to these in order to increase productivity, efficiency, quality;

reduce costs, lead times and duplications, via effective collaboration and communication of stakeholders in remote construction projects. These key findings, in terms of challenges, also lend support to the classification of the key challenges noted by (Sidawi, 2012) for construction project management in remote construction projects, such as human resources, cost, time, scope, and quality management; procurement and risk management, and infrastructure and communication. The paper concludes by noting that many of the key challenges can be addressed via the adoption of BIM strategically for remote construction projects while it proposes an action research approach for BIM adoption to be successful, considering technology, process and people factors. In the case study example in this paper, BIM implementation was initiated by the architectural company. However, if BIM implementation is initiated by the main contracting company, the key benefits of BIM implementation in resolving the key challenges of the remote construction projects can be taking forward to benefit other aspects of construction activities such as health and safety, labour training, communication on site, construction planning and monitoring.

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