Cost Saving Benefits Derived through the Utilisation of Building Information Modeling (BIM) in the Design and Construction Process

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Abstract:
Design in construction has historically been conveyed by conventional 2D methods through the use of physical paper-based documentation either by hand by the architect and then engineer and other specialist designers, or later through the advent of computer aided design (CAD) technology prevalent in the 1990's. This 2D documentation, the result of both hand and CAD systems, has inherently been issued late due to the time to produce and uncoordinated due to the lack of integration with other design disciplines, and all this often in a very adversarial, contractual environment, often not taking into consideration the budget constraints and buildability issues and due to its 2D nature often does not address some of the 3D challenges posed by the project. There is also a very inefficient transfer of critical data during this process, particularly at the closure of a project at the development of the operation and maintenance manual and as built drawings.

BIM as a tool helps to manage the overall processes much more efficiently by enhancing the flow of project information. Starting with the 'end in mind,' a client is now able to define his requirement in the form of an Employers Information Plan (EIP), to define the outputs requirement at handover. True BIM has its roots in a 'three dimensional (3D) virtual model' that is automatically linked to standard 2D documentation all within the same software environment. Models can be combined into a 'federated' model that can coordinate the structure and services of the building. The system's information or data is transparent and available to all stakeholders throughout the duration of the project. The 3D nature of the model can be used as a tool to promote better collaboration between the stakeholders in a less adversarial environment. All parties benefit from the use of BIM from the Employer to the Design Team to the Contractor and his Sub-contractors. The designer benefits the most during the early design phase, whereas the contractor derives the most benefit during the construction phase. However, overall it is the Employer that benefits from the overall savings gained during the whole process if implementation correctly. Clients are increasingly requesting BIM services from construction managers, architects, and engineering firms as service to reduce schedule overruns, reduce cost overruns and success of company's capacity to finance virtual design and construction goals (VDC). Successful implementation of BIM can eliminate unnecessary cost and wastage due to design changes during the subsequent phases of construction process. BIM necessitates investment in software and training however returns on the investment (ROI) vary from project to project with right implementation strategy. Overall BIM ensures continuous performance and improvement by having effective and efficient collaboration amongst the stakeholders. Research has shown that there is a substantial cost saving impact through BIM implementation at all stages of the construction process (pre-construction, construction and operational stages).

Keywords: *Building Information Modeling (BIM), Return on Investment (ROI), Virtual Design & Construction (VDC), Cost Benefits*

1. Introduction

Every evolution in technology has been achieved due to advance in computer science. That each evolution has ability to supports humans with great information technology to achieve the goals and objectives easily. This new technology has impacted the Architectural, Engineering and Construction (AEC) industry. Design tools have changed and provided improvements in AEC industry within last 10 years. In 21st century, evolution of virtual design and construction (VDC) integrated with BIM has made a radically transform the designing and constructing process in AEC industry. (Eastman, 2011)

BIM is integrated process built on coordinated and reliable information. (PAS 1192-2, 2013) BIM has been seen as facilitating "collaboration" between all stake holders in the construction sector. Current AEC industry has adopted BIM concept as a collaborative way of working confirmed under digital technology. (Phillip G. Bernstein, 2012). BIM used for create coordinated, digital information and documentation, predict of performance appearance and cost and it also deliver the project faster, more economically and with reduced environmental impact. (PAS 1192-2, 2013) BIM is not only useful for "geometric modeling" but it also helps the management of project construction. Adopting BIM at an early stage in the project is very important to improve collaboration between owner, designer and contractor for demonstrate the waste from all sectors and save the cost of unnecessary variations and identifying the required design changes through clear visualization of building model for the satisfactory of project commencement. Eliminating the thousands of paper drawings and schedules, it can keep proper data base which is transparent among the stakeholders and can be referred for at any time. (Conradi D, 2009). BIM can avoid the difficulty of poor communication between the paper drawings since they are not well integrated and coordinated with each other and there is waste of communicating with lot of parties. (Dossick,2010).There are many challenges in the construction industry such as capturing design errors in early stage, integration with supply chain, resource planning, accurate estimate, avoiding re-work, quality control, realistic base line program, clash detection between structure and services and finally sustainability. (CIDB, 2007), (Sambasivan, 2007) And they are leading the project for cost and time overrun when there is management failure to face those challenges. (S Abdullah, 2009).BIM has been taken of major role of construction industry to reduce the cost and time by guiding to the management with its great technology. (Smith, 2003), (Eastman, 2008)

The aim of this paper is to identify the cost impact challenges of construction industry, how & when BIM can help to reduce the cost risks of those challenges and an assessment of the typical cost saving benefits that may be derived through the use of BIM during the design and construction process reviewing the Preconstruction and Construction phases of the project.

Methodology

This research begins with a historical review of literature regarding BIM and adoption to the construction industry to evaluate the present condition of integration of BIM and commercial benefits for the construction industry. This review also recognized the elements that need to be integrated in order to achieve the objectives and goals.

According to the topic, the research has developed in this paper focusing about the cost saving through BIM and success in order to achieve the profitability and time schedule. The main intention of this study is to ensure adopting BIM in early stage of the construction project can save the cost through supply chain management, involving the user and giving him proper image of his expectation, avoiding schedule delay, variation and rework in construction stage

deliver the project with user satisfaction with accurate data which helps for maintenance and decision making in operational phase.

2. Applications of Building Information Modeling (BIM)

Engineers used very simple tools to create a design such as pen, pencil, ruler and paper till nineteenth century and the process of design has changed and improved with the new technology rapidly (Robbie G., 2005). Next level was "computer-aided design" (CAD) abled to manage the 2D drawings using common data and standard data structures and formats. In 1970, Charles Eastman has been improved BIM maturity level one from 2D to 3D managing CAD. (Eastman, 2011).Early 2000, CAD supplier companies have been improved separate discipline BIM tools which can approach utilise 4D schedule data and 5D cost elements (model with attached data). (Autodesk Inc., 2008). In BIM maturity level 3 has abled to deliver the cooperative open process with integration of data by Industry foundation class (IFC)/International framework dictionary (IFD) managed by collaborative model server. It can introduce as integrated BIM which using in concurrent construction process or iBIM and it causes for many benefits to the AEC industry. *Figure 1: BIM adoption - maturity levels*

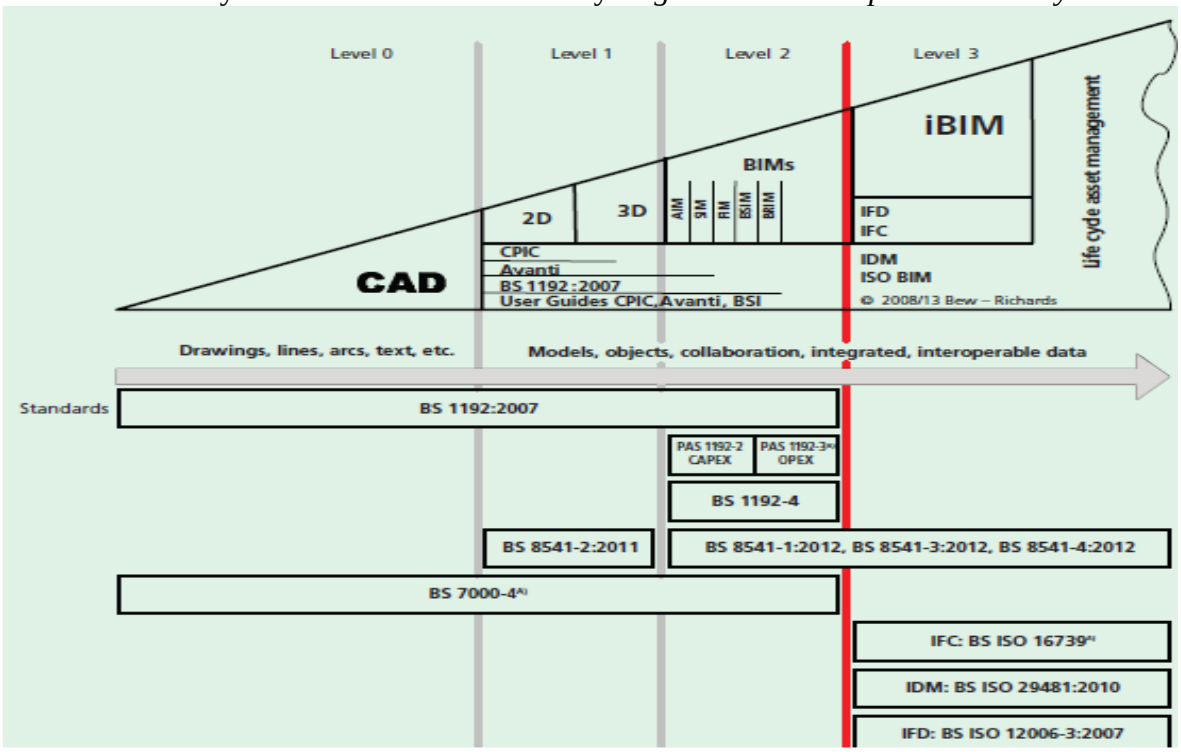

Figure 1: BIM adoption - maturity levels

Source: (PAS 1192-2, 2013)

According to PAS 1192-2 has shown application of BIM in AEC industry. BIM maturity level 2(BIMs) has adopted for Architectural information modeling (AIM), Asset information modeling (AIM), Structural information modeling (SIM), Facility information modeling (FIM), Building services information modeling(BSIM) and Bridge information model (BrIM). And BIM maturity level 3(iBIM) has adopted for Industry foundation class (IFC), Construction operations building information exchange (COBie), International frame work dictionary (IFD), Information delivery manual (IDM), Building life cycle management

(BLM), Product lifecycle management (PLM), Common data environment (CDE), Employers information requirements (EIR) and BIM execution plan (BEP). (PAS 1192-2, 2013), (McGraw-Hil, 2010)

BIM has applied in stages of inception, concept, schedule, budget, design drawings, construction at site, handover the project and facility management for 2D drafting, 3D modeling, 4D programming, 5D costs estimating, 6D lifecycle managing and nD for more advanced facilities in AEC industry in respect to save the cost. *Figure 2: BIM application in AEC industry.*

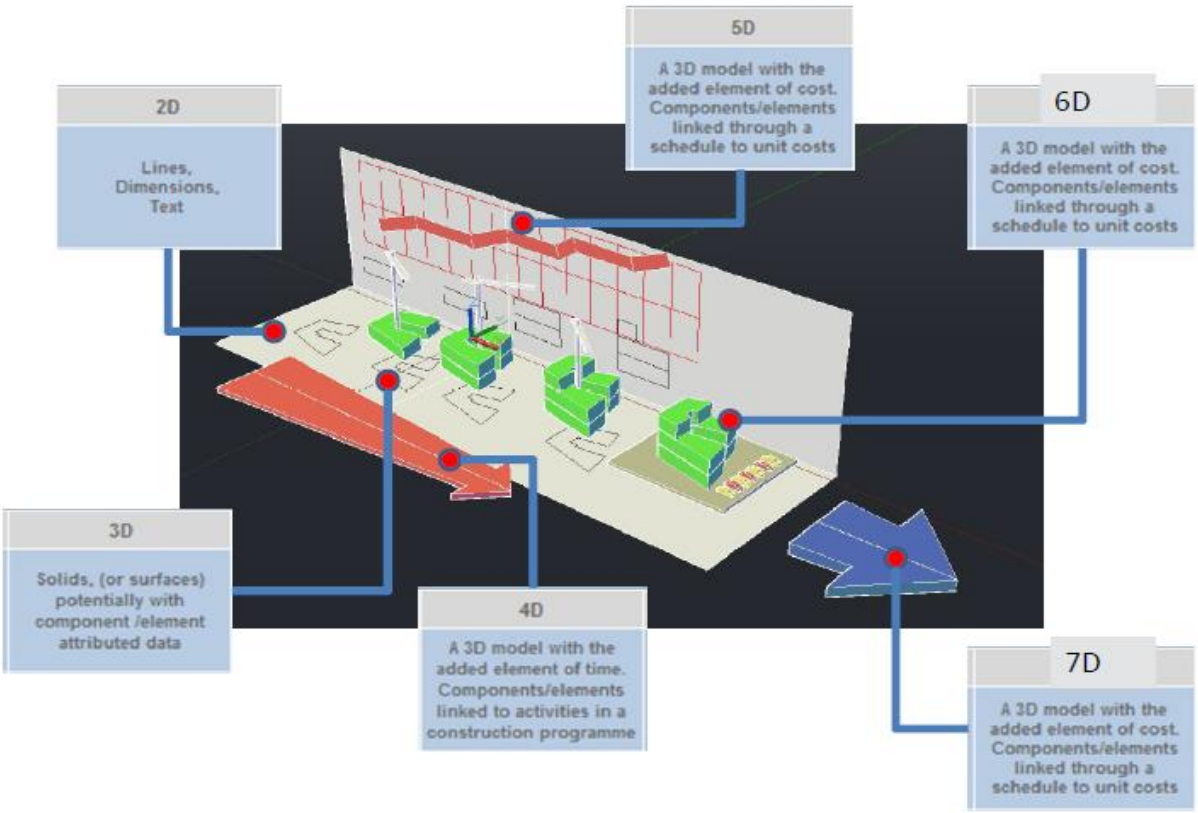

Figure 2: BIM application in AEC industry.

Sources: (Laing O'Rourke, 2011)

It has shown according to the research 2006, BIM has resulted as potential cost saving from 15 to 40%. (Holness, 2006) In 2008, the survey conducted by McGraw has estimated that ROI is at moderate level in the companies who using BIM from reducing field coordination problems, better visualization through 3D, enhancing of productivity, enhancing of winning new projects and sustainability value.(McGraw-Hill, 2008).Evaluation of cost impacts from case studies(Ex. St.Helens & Knowsley hospital, palace Xchange) done by Avanti have shown, medium size projects can save 80% from early commitment of BIM and according to Avanti's case studies, 50% to 85% cost saving from reuse of information and formatting, 75% to 80% cost saving from design coordination, 50% cost saving through estimation and collaboration of supply chain management. (Avanti, 2007)

Where there is waste, there is opportunity. (Koskela, 2002) BIM has been an answer for the waste in AEC industry in line with lean principles. BIM has focused on the delivering the project eliminating non-vale adding activities and enhancing the value for employer/customer by using an efficient work flow. And also it has abled to improve the productivity by eliminating 7 wastes according to lean theory such as Over production (over production of information to make employer understanding about final product), Waiting (waiting for the information which is not available), Unnecessary process (unnecessary meetings regarding the drawings), Unnecessary inventory (unnecessary inventory of materials), Unnecessary movements (unnecessary movements of paper drawings and schedules), Defects (poor quality and rework). (PAS 1192-2, 2013)

Even BIM has shown strong benefits in construction industry, still many companies are leading to the downturn because of BIM awareness and adoption is less in massy industry. Those who have adopted BIM are shown that BIM can improves visualization, co-ordination of construction documents, productivity, cost efficiency, speed of delivery, profitability and BIM makes traditional Bill Of Quantities (BOQ) and specifications redundant. Hence clients and contractors are increasing every day. It shows the attitude of BIM in construction industry has improved with experience and reports of companies who use it. Below comparison research data is showing the current situation of BIM and it is clarifying why some companies choose the BIM while others do not - *Figure 3: Attitudes towards BIM*

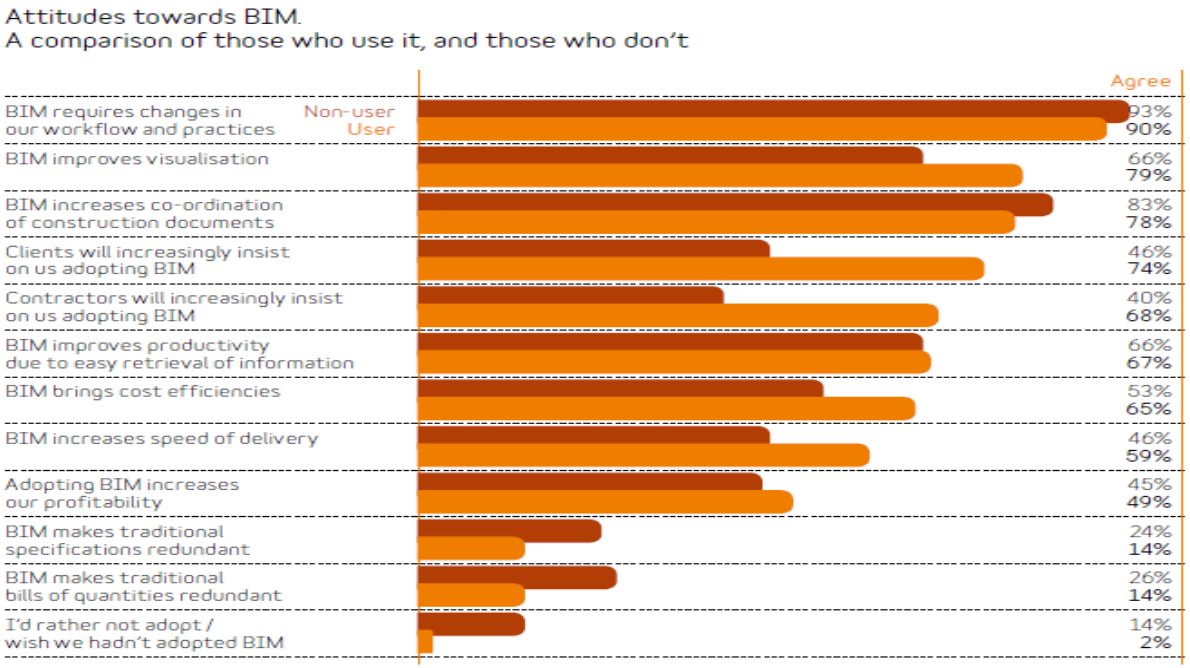

Figure 3: Attitudes towards BIM

Source: (Adrian Malleson, 2012)

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Cost overrun is a major problem in construction industry (Choi, 2009) and managing cost in the construction industry may be very simple or extremely complex. The cost control process and protocols need to be established at project commencement with the correct level of appropriate resource at each stage running through the whole life cycle of the project. (Memon, 2007)

Pre-construction Phase

Concept, Scheme and Detailed Design

An advantage of the use of BIM is the ability to develop and convert the 3D model into a design visualization tool where the client is able to see and interrogate precisely what is being proposed so that it is understood. This reduces the probability of client induced changes in the design thereby saving costs through negating the need for any abortive work. (Love P., 2010)

Supply Chain Integration

The UK Government has mandated the use of BIM technology to BIM Level 2 by March 2016 for all public projects. Part of this initiative is enhancing efficiency by the integration and sharing of BIM object libraries from the supply chain. This allows for early integration and coordination of true building components at an early stage in the design process saving time and cost at a later stage. (David P., 2016). Additionally, the object library data may be loaded with cost, programme, specification and FM meta-data which can be further extracted from the module and linked to an excel spreadsheet BOQ, allowing for real-time costings to be included in the costing process direct from the supply chain.(Hannah George, 2012)

Resource

Less resource is required to identify design clashes and issues as the design coordination process using BIM is more automated and efficient (McGraw, 2008).

Cost Planning, Budget and Estimating

Adopting BIM in tender stage, allow professionals to link components of three-dimensional computer models to costs databases and collaboration at micro and macro level thereby reducing the risk of human errors, refocusing the team on the end product and reducing time. High quality staff can always provide a clear commercial sense to the management to control the finance. (David Miller, 2012). BIM can quantify accurate material quantities and it helps for proper cost estimate in early stage. (Eastman, 2008)

Revit can give exact quantity schedule of materials. It is easy to maintain and much more accurate than human quantifying for the same. Not only accurate schedules but also changes to the digital model updating automatically in the schedule much quicker and more efficiently than in normal CAD. Estimator can miss the items in taking off and also there can be errors due to the design changes. BIM reduces the transposition errors as design changes are link to the model updates. (Khemlani, 2006)

Construction Phase

Rework and Quality

If any design changes entered, the model is updating automatically and it helps to avoid the re-works due to the drawing errors and changes required from the user. (Eastman, 2008) McGraw stated "BIM is very helpful for reducing the re-works during the construction stage". According to the research conducted by McGraw, 80% people have agreed that BIM can achieve the project goals reducing the re-works. (McGraw, 2008)

A survey conducted by the National Economic Development Office (NEDO) in London, found that 90% of construction failures occurred due to a "combination of design and poor workmanship" in the industry. Quality has a great impact on unnecessary future expenditures. (Abdul, 2008)

Time Management

In the construction industry, one of the main challenges is to deliver the project on time (CIDB, 2007). Industry experience shows that more than 90% of project delay has been a result of cost and time overrun. (Abdullah, 2009) According to Sambasivan, project delay is cause for not only time cost overrun but also disputes, arbitration and even total abandonment (Sambasivan, 2007). A realistic time schedule is very important since it has become a Key Performance Indicator (KPI) of the project and efficiency of contractor. (Chan, 2002) BIM helps in quickly reacting to the design problems. (Eastman, 2008) BIM can also transfer the information easily than traditional way of RFI. (Azhar, 2008) Project decision-making and authority has centralized, often hindered progress and communication and response is very critical. (Sidawi, 2012)

Clash Detection

Correcting of clash between structure and services cost is very high during the construction phase in addition to wasting unplanned time by searching for appropriate solutions (Laura, 2006). There are a number of software packages that can carry out varying degrees of clash detection, produce clash detection reports and also record the history and close-out of design clashes in a single model environment.

1. Collision detection; this method is verifies if two objects with geometric collide. Spheres and Axis Aligned Bounding Boxes (AABB) are found as fast algorithms. (Gottschalk, 2000), (Plamer, 1995), (Hubbard, 1996), (Klosowski, 1998), (Zachmann, 1998), (Bergen, 2005)

2. Ray triangle intersection; this is the most accurate method of calculate the detecting collisions. (Moller, 2003)

3. IFC (Industry foundation classes); allows user to exchange the data or sharing the data between applications. (Liebich, 2009)

4. BIMserver; technology can use for design data sharing. All the parties can logging to the system and add their changes/revisions. With the collaboration of all the data, BIMserver is performs clash detections. (BIMserver, 2009)

Clash detection is a main key factor of measuring which company saving time and cost using BIM. (McGraw, 2008) Through 3D visualization, it is easy to combine the structural elements and services in the design model and identify the clashes at early stage. (Tucker and Newton, 2009) BIM can work very fast to show the possibility of decisions when owner needs changes in construction stage (Van, 2013). There is less communication between 2D drawings. Hence changes in one drawing is not updating in other drawings which related to the same structure. BIM can eliminate this issue and it can increase the construction speed reduce the unnecessary cost thereby avoiding the legal disputes. (Eastman, 2008)

Operational Phase

Sustainability

There is less capability of performing sustainability analyses in early design development stage. (Azhar S, 2008). Lack of sustainability analyses in design development leads to an inefficient process of modifying the design to achieve the building performance criteria and high maintenance cost in operational stage. (Schueter & Thessling, 2008), (S Blanchard, 1998) It is important to get comprehensive set of knowledge regarding building materials, technical systems and context which required in order achieving the building performance in early design stage. (Autodesk, 2008)

BIM has ability to provide the accurate detail of building knowledge which helps to achieve the building performance. (Mcgraw, 2010) The AEC industry has improved the building sustainability through BIM as example, "architects can use a building information model to analyze a building's mass and form to optimize envelope and balance glazing ratios. Engineers can use this model to reduce energy demands through energy modeling, which uses the 3D model to calculate light reflectance and penetration. Contractors can analyze site conditions, including wetlands and protected habitats, and use the site model to coordinate logistics better to eliminate potential issues. Subcontractors can use BIM technology to reduce waste and combine shipments to further reduce carbon Footprints." (Hardin, 2009)

Even there is initial cost of hardware, software and training, still it has showing big cost saving with high fee income. DMA in UK has carried out research of "Fee income against BIM cost" and the result shown the "cost has flattened out and fee income has continued to rise" as shown in – *figure 4*

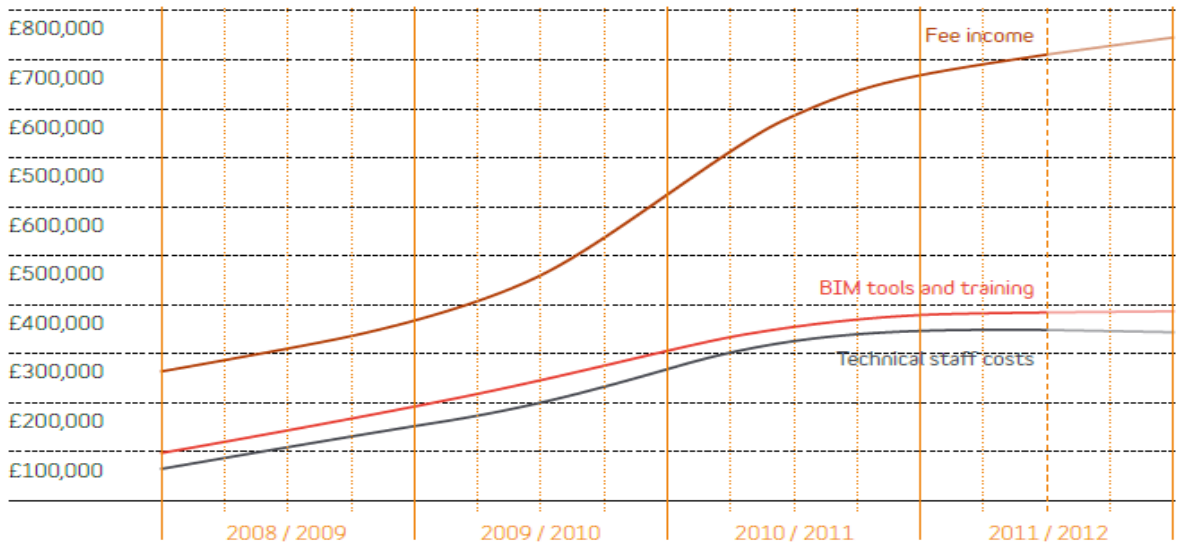

Figure 4: Fee income against BIM cost

Source: (David Miller, 2012)

Conclusion

BIM gives us greater predictability of project outcome, including a greater level of cost certainty by utilising the tools in correct time as highlighted within this paper.

BIM can gain value for the management to make decisions related to the commercial and save cost from collaborating the detail and all the parties from the beginning of project by providing accurate cost, quantities and resources. It also able to keep all accuracy and completed data from design stage, updated through construction stage to help operation and maintain (Facility management) the building by hand over the all detail properly. BIM can save time and money of both client and contractor and also satisfy the user. The ROI analysis has shown BIM's return was increased significantly. BIM implementation will be worthy investment since it has great benefits to the company

BIM is a challenge for the Construction industry which still following the all traditional methods for decision making and also solution to the blaming culture of industry.

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