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Early Implementation of Building Information Modeling into a Cold-Formed Steel Company: Providing Novel Project Management Techniques and Solutions to Industry

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Abstract The ability of building information modeling (BIM) to positively impact projects in the AEC through greater collaboration and integration is widely acknowledged. This paper aims to examine the development of BIM and how it can contribute to the cold-formed steel (CFS) building industry. This is achieved through the adoption of a qualitative methodology encompassing a literature review, exploratory interviews with industry experts, culminating in the development of e-learning material for the sector. In doing so, the research team have collaborated with one of the United Kingdom's largest cold-formed steel designer/fabricators. By demonstrating the capabilities of BIM software and providing technical and informative videos in its creation, this project has found two key outcomes. Firstly, to provide invaluable assistance in the transition from traditional processes to a fully collaborative 3D BIM as required by the UK Government under the "Government Construction Strategy" by 2016 in all public sector projects. Secondly, to demonstrate BIM's potential not only within CFS companies, but also within the AEC sector as a whole. As the flexibility, adaptability and interoperability of BIM software is alluded to, the results indicate that the introduction and development of BIM and the underlying ethos suggests that it is a key tool in the development of the industry as a whole.

Keywords: *BIM, Masterseries, Navisworks, Revit, project management, portal frame, collaboration*

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1. Introduction

The ethos behind Building Information Modelling (BIM) has existed in the Architecture, Engineering & Construction (AEC) industry for the last 40 years [1]. However, with the UK Government introducing a mandate for BIM to be operational in all public sector projects by 2016, this further justifies the inclusion and adopting of BIM within the sector [2]. The mandate has come about after numerous studies have shown that the construction industry has become somewhat fragmented in the nature of its processes. Nisbet and Dinesen [3] argue that labour productivity has reduced and is lagging somewhat behind other non-farm industries; hence the need for reform is justified. This has been linked to the traditional approach in which many projects are delivered, through the use of 2D Computer Aided Design (CAD) and, the sheer size of some construction firms. The traditional approach impedes the ability to collaborate as roles are often fragmented, and phases such as design and construction are treated separately. Gillies [4], Keys, et al. [5] and Osmani [6] are all in agreement that 2D CAD hinders a collaborative approach whereby architects and engineers produce their own fragmented CAD documents which are not integrated; often information is conflicting resulting in reduced labour productivity. Furthermore this approach does not promote the integration of the drawings with schedule and cost.

It is evident that the manufacturing industry has fully grasped the concept of designing and virtually manufacturing in a collaborative platform. It is now the turn of the construction industry to establish a basis for BIM, improve its inefficiencies and close the labour efficiency gap. To begin with, it must be understood that BIM is not a product that can be lifted off the shelf [7] but a culture of collaboration that requires training, commitment and an element of experimentation. To move away from the somewhat antagonist methods of construction, reflective of traditional methods, it is a means of introducing new ideas and new ways of saving time, money and reducing waste in the industry. Reports by Egan [8] and Latham [9] have been pivotal in making the construction industry aware of its inefficiencies and calling them to act. The Latham Report drew particular attention to improving the link between design and construction. Both reports set targets for reduction in waste, whether it is in the form of construction cost, time or defects, and with the introduction of BIM a paradigm shift is being evidenced in the design and costing process. It is perceived that BIM will have an incredibly beneficial impact in the AEC industries for many years to come.

The structural steel industry was one of the first to integrate parametric 3D modelling before being readily adopted throughout the construction industry [10] but where a gap exists is the application of BIM in the cold-formed steel (CFS) market particularly where this light gauge steel is used as a primary structural load-bearing element. Considered as a ‘new’ construction product, codes and standards have only recently been available with specification for its design being published in 2003 [11]. Published in 2006, after much development, the European standard is now available in Eurocode 3 [12]. As a result of this advancement and the availability of higher strength materials, CFS as a primary framing component has become more attractive and CFS portal frames have been developed as a viable alternative to traditional hot rolled I-sections, especially for more modest spans, around 18m in the UK [13,14,15,16]. As a result of the steel industry’s efforts, the AEC is benefiting from new design, manufacturing and construction technologies. It is important that advancements continue to be made. With BIM being so influential on many projects it is about time that the CFS industry embraces the advantages of BIM, especially in the UK where CFS portal frames are becoming increasingly popular, especially in low-rise commercial, light industrial and agricultural buildings [14].

This paper looks to examine the cold-formed steel portal frame industry, which has not yet embraced BIM within their practices, but is aware of the ideology and seeks to discover how, through its implementation, their systems can be improved. This project has been created in close communication with one of the largest CFS designer, fabricators in the UK to ensure that they achieve useful feedback regarding the study.

The underlying hypothesis suggests that by fully utilising BIM software, a CFS project can be fully modelled and the information contained within the model will enable decisions, made by the involved parties, to be fully informed. By engaging BIM software with the use of Computer Numerical Control machines wastage in fabrication will be minimised.

There are numerous BIM applications available, some more suited to specific sectors. Autodesk has invested significant resources in developing a suite of software that co-exists and can be readily operated with one another and, as such will be the main focus of this report. Autodesk Revit is one of many BIM software packages available to architects, engineers and contractors alike, allowing its users to, design a building and its components in 3D, annotate/embellish with further detailing in 2D and access building information from the models database. This research provides a basis on which to aid in providing a reference point for the CFS industry and how CFS buildings can be created using BIM and, the interoperability between the ranges of software demonstrated.

To validate the study while also acquiring and documenting the relevant information, a qualitative approach is adopted. A thorough literature review is conducted to define and gain an understanding of BIM, from its introduction in the 1970s to its current state. The mandate for its adoption within the UK will be explored and the level to which AEC industries must comply. In addition, benefits of BIM will be investigated with particular attention drawn to its role in managing a project and integrating project delivery. To further validate the study, a series of exploratory interviews will be conducted with industry experts. These will be subsequently analysed using qualitative analysis software, nVivo 10, enabling the creation of word clouds, expanding themes and promoting discussion of those most prevalent to the study.

To demonstrate a number of BIM capabilities, a cold formed steel portal frame is modelled. The model will be created using information supplied by the UK’s largest CFS design company and thus involve the creation of bespoke components, unique to a CFS company. To aid CFS companies in making the first step towards BIM utilisation, the benefits are documented, drawing attention to any key issues that will ensure a smooth transition of adoption.

By documenting and demonstrating the benefits of BIM, not just in CFS context, it is perceived that the benefits can also be applied to the AEC sector; thus aiding in the advancement towards the 2016 government mandate for stage 3 BIM implementation.

2. Advancement of BIM

As BIM is becoming more ingrained in the Architecture-Engineering-Construction (AEC) industries some attention will be focussed on the UK Government mandate for 3D BIM by 2016 and the strategies implemented by construction companies to optimise project delivery through all phases of design, construction and fabrication.

Within the AEC industries there is increased interest in BIM [17]. This revolutionary technology and process is beginning to reshape traditional forms of design and construction by allowing project stakeholders to visualise, in a simulated environment, what is to be built. This has a number of advantages; more notably the ability to quickly identify any issues with regards the design, constructability and operation of the project, and through close collaboration with the affected parties, mitigating its potential impact [10].

Although it is possible to trace back the origins of BIM to the late 1970s [10], where it was representative of parametric modelling research, it was only beginning to be implemented in projects from the mid-2000s [18] and in the past few years has evolved from being an add-on to becoming the core collaborative tool of major projects in the AEC industry [19].

Interestingly there is still no widely accepted definition for BIM as it can be defined in different terms dependent on whether it is a model, a representation of the design data or a tool used for construction management. Sacks, et al. [20] defines BIM from a three dimensional (3D) perspective as a "conceptual approach to building design and construction that encompasses three dimensional parametric modeling of buildings for design and detailing and computer-intelligible exchange of building information between design, construction and other disciplines."

While Penttila [21] refers to BIM as Building Product Modelling or Product Data Modelling, appreciating that BIM is more than a 3D CAD system that creates a building's geometrical data, but a methodology, essential to manage the project data in a digital format throughout the building's lifecycle, this may be through interacting policies, processes and technologies [22].

This ability to share such rich information is pushing the AEC industry forward as at handover the as-built information contained within the BIM becomes a living tool for operation and maintenance. The role of the supply chain is not only to create a physical building but to provide a 'knowledge service' [1].

Eastman, et al. [23] recognise the value of BIM for construction management; that is by using their tools, architects can produce models that contractors can subsequently use for estimating, coordination, construction planning, fabrication, procurement and other functions. The contractors can also further develop the model to include further detailed information. Contractors on many occasions are now taking ownership of the modelling process, even creating their own models from scratch to make the models useful to them.

Where the model does not contain parametric components or relations between them the model may only be used for the likes of clash detection, visualisation and visual planning as the model will not define discrete quantifiable components to support quantity take-off or trade co-ordination. The National Building Information Modelling Standards (NBIMS) promise greatly improved practices through innovative information technologies and develops the idea of BIM [24].

By integrating CAD with BIM, it allows design and engineering to be managed in parallel without sacrificing co-ordination; this will most certainly lead to shortened project spans and savings. As a result many countries have shown noticeable interest in BIM, including Finland, Norway, Denmark, Japan, Germany, France, UK, North-America, Australia, Singapore, Italy and most recently, China. A number of companies have also made BIM technologies an essential core of their business strategy, a Finnish example being Tekla who have developed product model based CAD-tools and technology for structural engineering (Tekla Structures) and also for the municipal sector [21].

It is apparent after numerous studies and not to mention the influential reports of [8] and [9] that there is a vital need to improve efficiencies of the AEC industries. The construction sector is a major part of the UK economy representing some 7% of GDP or £110 billion per annum of expenditure [25]. Thus it is imperative that BIM becomes ingrained in the AEC, and through its development and understanding will provide a means of facilitating and ensuring greater success in the industry.

As NBIMS has made clear [24], BIM is a process and by creating a data-rich, object-oriented, intelligent and parametric digital representation of the facility decisions are much better informed and thus the delivery better executed [10]. Although the introduction of BIM comes with significant overhead costs, this is due mainly to the purchase of software and the training of personnel, Marasini and Patlakas [26] argue that the benefits outweigh the cost associated with its implementation.

On looking ahead to 2016 and the government mandate for BIM implementation, the UK has one of the most advanced and ambitious programmes in the world and thus the prospect of taking a global leadership role with regards to its service provision and development of its standards [27]. While various single elements of BIM have been used in practice, recently there is a push for widespread use on a national level [26]. This is mainly due to the current inefficiencies in the construction market and the need to make savings. The construction industry is lagging behind other industries in developing and applying labour saving ideas [3].

BIM is seen as a means of improving efficiencies through improved visualisation and collaboration strategies. Holzer [28] recognises that BIM is not simply a software application or a combination of software packages. To the contrary, it sees BIM implementation by construction companies as a strategic decision requiring mid-to-long term investment in infrastructure as its implementation requires a cultural and methodological change in the way digital models are developed and utilised in decision making throughout the lifecycle of a facility.

Reports produced by the NBS [29] and the BIM Task Group [30] suggest that BIM can bring significant cost savings from design to construction as well as in facilities management.

Table 1 produced by [26] presents some quantitative data highlighted in various case studies to give an indication of savings achieved through BIM implementation. These are obviously case specific and should not be generalised as such, but are produced to build a case for BIM.

Table 1: Benefits of BIM

Sources	Features	Savings Claimed
[31]	Collision Detection	3 to 5 times of BIM cost
[32] based on comparison of without BIM and BIM assisted scenarios	Request for Information	34-43% reduction
	Change Orders	37-40% reduction
	Return on Investment	16.2- 1654%
[33]	Drawing time	40% reduction
[10]	Unbudgeted change	40% reduction
	Cost estimation accuracy	Increase by 3%
	Time to generate a cost estimate	80% reduction
	Clash detections	Savings of up to 10% of contract value
	Project time	7% reduction

Within the UK, 4 maturity levels have been defined (0-3) by to articulate the operational requirements of BIM implementation [34] with the 2016 requirement being for level 2. That is the government will require "fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic)" [35].

The Royal Institute of British Architects (RIBA) have published a BIM overlay to the RIBA Outline Plan of Work that provides further insight into the subject of BIM maturity levels and is designed to be a catalyst to encourage further thought and development towards BIM's future development. The RIBA, [36] recognise that by adopting industry wide processes and collaborating with successfully managed teams, companies will be able to move smoothly from one BIM maturity level to another, encouraging innovation, and driving waste and inefficiency out of the construction industry.

The UK government has recognised that a number of companies are already working at or above this capacity, with nearly a third of professionals within the UK integrating it into their projects, up from 13% in 2010 [29]. But through the use of incompatible systems, standards and protocols, and clients/designers differing requirements, BIMs adoption has been inhibited. To combat the problems the Cabinet Office is co-ordinating the Government's drive to the development of standards enabling all members of the supply chain to work collaboratively through BIM. This will be a phased process working closely with industry groups, in order to allow time for industry to prepare for the development of new standards and for training [25]. It has to be recognised that aside from objects being in 3D, the building data is all interconnected in BIM projects, when changes are made their impact can be exponential compared to CAD so to understand all aspects of what is related companies are now employing BIM managers to coordinate the models and properly support the design team [17].

BIM and project management and integrated project delivery are closely aligned due to BIM being a process that is supported by technology and collaborative working. By adopting the BIM process it attempts to overcome any lack of process and standards and reuse data pertinent to the project in an efficient manner. By implementing a clear strategy, information can then be delivered in a clearer manner, improving communication and allowing a more sustainable, efficient and quality delivery. This approach thus requires a shift from more traditional working practices through effective leadership to change the workflow for the future [7]. Traditional approaches have become increasingly adverse and antagonistic to the effect of being counterproductive and it is crucial that rather than parties becoming obsessed with risk avoidance and compensation that they adopt the principles of shared risk and shared reward, a trust based collaboration encouraging parties to focus on project outcomes rather than their individual goals).

3. Methodology

In order to gain a detailed insight into the topic of BIM and CFS, it is essential to carry out a number of detailed explorative processes. These processes include three core aspects. Firstly, a detailed review of the available literature is undertaken to familiarise the research team with the topic, while also aiding the assembly of information for further discussion. Secondly, a comprehensive review of the various types of software available is conducted to ascertain the various interoperability issues that may emerge. Thirdly, a number of semi-structured interviews within industry professionals and practitioners are undertaken.

3.1. Literature Review

A detailed critique of the literature is undertaken including, but not limited to, peer-reviewed journal publications, conference proceedings, books, web-pages and supplementary information provided by the various software venders in the market. This will provide the research team with an extensive grounding on the subject; essential in the identification of apt software for consideration while also ensuring that the interviewees are knowledgeable on the subject in discussion.

3.2. BIM Software

Autodesk have become a dominant provider of software solutions and their latest portfolio of products provide virtual design and construction management solutions that aid in improving overall planning, coordination, and control of a project from beginning to end.

By using Autodesk Revit 2013 in combination with Autodesk Navisworks 2013 one can demonstrate how software as a service can aid a company:

- Explore and evaluate a project's constructability before it's built
- Improve cost reliability
- Visualise construction processes through 4D simulation and clash detection
- Increase coordination between stakeholders throughout the design and construction process, and;
- Better predict, manage and communicate project outcomes

This is all beneficial in reducing requests for information (RFI's) and change orders, producing better coordinated schedules, catalysing well-orchestrated fieldwork and ultimately lowering costs.

3.2.1. Autodesk Revit 2013

Autodesk Revit 2013 allows for the creation of the project model to the required level of detail and is used as a platform for evaluating, and enhancing the constructability of designs to improve the project delivery process. Tools within Revit allow for quantity and material take-offs at the click of a mouse and with the advancement in IFCs, as mentioned in the literature, the model can be exported to a continually expanding number of programmes to allow for further enhancements. Autodesk are responsible for a number of BIM capable software and one, which is becoming ever more utilised, is Autodesk's Navisworks, and being an Autodesk product, interoperability between Navisworks and Revit is of no concern, allowing for the seamless management of models across platforms.

3.2.2. Autodesk Navisworks Manage 2013

Navisworks Manage 2013 is essentially a means of reviewing a project in its virtual state and anticipating potential problems before construction, thus minimising expensive delays and rework. Earlier insight into design and scheduling problems are crucial to project success and a means of better coordinating disciplines, and resolving conflicts. Clash detection alerts the user to any interference within the model, Timeliner allows a 4D simulation of the construction, this can be integrated with a project schedule stored in Microsoft Project or Primavera, and the latest version of Navisworks (Navisworks 2014) allows for accurate model based quantification. Accurate cost forecasting and control is crucial for a successful construction project and the tools available through Autodesk mean that construction managers and estimators can more easily measure, count and price building objects to gain an in-depth understanding of project costs from design through delivery. This allows further benefits, allowing the track of changes between model revisions, the performance of destructive and constructive take-offs and the assignment of material and labour resources to items in the model.

3.3. Exploratory Interviews

The third aspect of the qualitative investigation is the undertaking of explorative interviews with industry practitioners. The exploratory interviews are in the form of guided, semi-structured interviews and are undertaken with professionals currently employed in the construction industry, a number of which will be experienced with BIM. Both of the previous qualitative aspects and the resulting data is merged and included in the interview process, aiding in the development of the topic for further discussion.

It is not the aim of the interviews to gain quantitative data but rather to explore the thoughts of those involved in industry with regards BIM and its role in the future of the AEC industry. A semi-structured interview is the preferred method of initial investigations into the study, as it will form a guide to the interview whilst allowing the opportunity to ask spontaneous questions to glean further information. Being discovery orientated, the interviews will aim to expand the interviewer's understanding of what attitudes and types of experiences exist. The information can then be analysed qualitatively.

3.3.1. Qualitative Analysis

Qualitative research refers to any non-statistical method and generally involves asking open-ended questions to a small number of interviewees to gather data on particular research questions. According to Sugarman and Sulmasy [37], qualitative research methods allow the exploration of a person's personal experiences and perspectives in a contextual circumstance.

Rubin and Rubin [38] recognise that yes, many important questions can be answered by surveying, analysing and experimenting but communicating by summarising statistics is not always appropriate. "Numbers do not tell a story people can easily understand" [38] by presenting data in a form unreadable by most you risk losing the context and complexity that gives research that realism. By interviewing those directly involved in the management of CFS portal frames and/or BIM, the most relevant information upon which to form a discussion and compare and contrast with existing literature is obtained.

In total, fourteen potential candidates are identified to participate in the research. The identification procedure is based on selective over convenience sampling of industry professionals due to the essential criteria identified for selection. The criteria for selection are knowledge of BIM, consent to participate and industry experience. Of the fourteen potential candidates identified, based on industry contacts and contacting various BIM hubs, four interviewees emerged and are interviewed.

The interviews are individual, semi-structured and guided, where required, to ensure that the information collected would address the issues covered within the literature and provide key points for discussion. Not only would this provide more focus than a standard conversational approach but also allows a degree of freedom for the interviewer in the approach of retrieving the relevant information. Semi-structured interview procedure is selected over unstructured and structured due to the amiable environment created while also providing ample opportunity for the interviewee to discuss, at length and at will, the various points that (s)he feel is important to the discussion. This also provides the interviewer free rein on the structure, ordering and content of questions, while also ensuring that the conversation did not deviate from the subject in question.

The first exploratory interview is conducted with a BIM expert who has spent seven years working for an independently owned software solutions company. The interviewee is now employed by an experienced architectural practice based in Belfast and is knowledgeable in BIM management software including Autodesk's Revit and Navisworks Manage.

The second exploratory interview is conducted with a PhD student from Queen's University whose studies involve the use of BIM software as well as the design of CFS structures. The student has over five years' experience in industry before returning to education in pursuit of a PhD in the subject of BIM and CFS structures. The student has been active in helping companies implement BIM software into their working processes and thus has a wealth of knowledge and information to share with regards the benefits of BIM, the limitations of current processes and those issues most pertinent to implementing BIM within a company.

The third exploratory interview encompasses a leading expert in the CFS industry currently working for one of the UK's largest CFS design and fabrication company. Having a Doctorate in engineering and vast experience in the CFS industry, the viewpoints of the interviewee are again of interest, particularly their views as to how BIM can improve the AEC industry with particular focus on the CFS industry. The interviewees experience uncovers the difficulties of current working practices and how they believe BIM can not only provide an effective solution but also increase the profitability of AEC companies through the tools it provides.

The final exploratory interview involves an architectural technician and IT manager who has over fifteen years' experience working in a wide variety of building types through Ireland, Romania and, more recently, the Middle East. His forte is on the early feasibility and design stages of projects and has recently been looking closer at BIM and how it can benefit current work practices within his company.

To remove potential bias and undue influence from the research parties, qualitative software is employed to assist in the dissemination and catalogue of the factors which are extracted from the interview process. In doing so, nVivo 10 is introduced; a powerful qualitative analysis tool capable of recognising themes throughout the interview. This allows for the analysis and coding of data using powerful search, query and visualisation tools. For the purpose of this research, its primary use is in creating a word cloud based upon the word frequency, creating a visual depiction of the interview for discussion. The ability to create nodes surrounding specific information allows themes to be recognised and displayed more prominently in the word clouds. Thus giving an accurate picture of the issues discussed across a range of interviews. These themes will be the basis of the discussion and ultimately, the conclusions reached.

4. Qualitative Analysis

On scrutinising the four interviews in unison, the following figure (Figure 1) depicts the most prominent words and phrases discussed throughout the semi-structured interviews.

Figure 1. Word Cloud Summarising the Semi-structured Interviews

To provide a focused approach in the dissemination of the information from the four detailed semi-structured interviews, the information is digested using nVivo 10 and the results coded to its relevant node to develop underlying themes. These nodes are subsequently used to create specific word clouds that can be discussed with greater certainty, knowing that the frequency of words is in direct relation to the main theme. Word clouds illustrate in a graphic nature, give greater prominence to phrases that appear more frequently in the interview; thus aiding in the dissemination of information into a more concise and meaningful script. In total, four themes emerge are summarised in the following four word clouds. The basis of these themes provides the premise on which to discuss the findings herein.

5. Discussion

Each of the four themes which emerge from the coding to the relevant nodes is discussed sequentially, while introducing word clouds to depict, in a graphical nature, the contents therein.

5.1. Current Processes Adopted and Their Limitations and Issues

It is important to gain an understanding of what the interviewees identify as limitations within AEC/CFS industry with regards to the current processes adopted and their implications for future competitiveness. The word cloud generated from the coding is shown in Figure 2.

In all, sixteen references are made in relation to the current limitations found within company practices. The first issue that is evident is the inability to always satisfy the needs of the client. Interviewee three illustrates three core points. Firstly, the difficulty in trying to adapt their current software to meet the needs of their clients is voiced. Secondly, current software also continues to be a frustration when it comes to presenting the final product, particularly when the appearance of the drawings can have such an impact on sales. Thirdly, being able to only present 2D drawings has a knock-on effect when it comes to seeking building approval, particular because CFS is relatively new to the UK and the building techniques are not readily practiced. By having a fully interactive 3D model it can be expected that the whole process of explanation would be made easier.

Figure 2. Processes Adopted in the AEC/CFS industry, their limitations and issues

The 'new' form of construction, that is with CFS as a primary structural element is also seen to be a hurdle by Interviewees one and two. This is documented as being primarily down to the lack of education with regards its use.

Another prominent issue, accepting that a number of companies have already adopted BIM, is the varying range of BIM capabilities within the AEC sector; a frustrating point echoed by all parties interviewed. This is not only a limitation in some current practices but can also be viewed as a limitation to BIM adoption. Interviewee one also views the current (traditional) process as being restrictive in nature recognising that by adopting BIM it

"…opens up opportunities for wider engagement and earlier engagement from contractors and specialist sub-contractors." It is clear to see from conducting a series of interviews with a number of experts in the field of AEC that current process present a number of limitations, particularly with regards adaptability and the ability to remain competitive in such a tightly fought industry. These limitations are only a few that exist and where BIM aims to provide solutions.

5.2. Current Understanding of BIM and the Solutions/Tools for Industry

It is essential to identify the interviewees understanding of what BIM is, and how it can benefit industry (Figure 3) and in particular, the CFS industry. Many of the opinions voiced agree with literature in many respects, validating many attributes of the attributes voiced earlier. Interviewee one is quick to note that BIM is not a single piece of software - it is a process. This relates back to David Light's [7] input from literature, where he states that you can't buy a box of BIM. This is echoed by the interviewees and is relayed in this paper.

Figure 3. Current Understanding of BIM and the Solutions/Tools to the AEC/CFS Industry

All of the participants are aware of the ability of BIM in improving current processes and simplifying the exchange and management of project information between party stakeholders. Interviewee one articulates the importance of BIM's ability to "unite all the stakeholders in a project to a more collaborative approach with the end in mind." This 'togetherness' approach is with the aim of reducing waste in all sectors of a construction project and is commonly known as 'lean construction'. This opinion is in agreement with the views of [1], [21] and [22] alike.

Interviewee three supports BIM's claim that "all the information is gathered in one place… drawings can then be retrieved from that single or central model, a much simpler process than having to create each view in separate CAD drawings…is going to improve the current processes and improve the business point of view… you can change any property or sections and this will update through other drawings." This versatility is also addressed by Interviewee two "BIM does it all, in Revit (or Tekla) you create a portal-frame structure and all drawings are created from a central model, and any time you have to make a revision, which there will be countless times in the design process, once you update that central model, every drawing updates automatically."

What can't be ignored, and is one of the main reasons for the emergence of this paper, is the UK's Government mandate for BIM to be a statutory requirement for all public sector procurement by 2016. This has primarily come about as a means of improving communication between all parties to a project with the aim or reducing waste, be it in the form of material, time or money ([8], [9]). Interviewee two, three and four all made mention of this mandate and how it is necessary to for companies to remain competitive.

As the focus of this project is on BIM use in the CFS industry the interviewees are able to predict how the CFS industry could benefit through the use of BIM in projects. Interviewee two and three accept that the CFS industry is behind in the UK with regards to BIM implementation. Interviewee two argued that CFS could become more competitive with the addition of BIM, "CFS, in some cases for small-to-medium span, CFS over the LCA (life cycle assessment) and LCC (life cycle costing), material, cost on site is more advantageous, there are more savings than in the HRS… with the addition of BIM it can allow the client to visualise what CFS sheds would be like in the UK…extract the tonnages, piece together all the building information to form an LCA and LCC very easily, for their product then they can compare this against the traditional HRS product to get a very quick comparison, regarding the tonnage of steel, the savings, the ease of transportation, recyclability and reuse of the steel".

5.3. Prevalent Issues Inhibiting BIM Implementation

Figure 4. Prevalent Issues Inhibiting BIM Implementation

It is beneficial describing how BIM can improve productivity and increase communication, etc. but a thought has to be given to issues that may be preventing a company from making the leap to BIM (Figure 4). It has been established, that regardless of companies concern, they will eventually have to succumb to the pressure of a competitive market and adopt BIM technologies, otherwise they risk losing future work. The interviewee's give an insight to a number of concerns within the market.

A primary concern voiced by all four participants is the time required to learn the software, having cost implications (workstation, software and employee time constraints), ultimately requiring a large investment on behalf of the company. This to get to the stage where the team is capable of operating effectively through being BIM proficient. It is not only the detailers who will have to learn the software but also the engineers, quantity surveyors, project managers etc. Interviewee three view the issue of licencing and annual renewal as being their primary concern and that beyond that, integration of the software shouldn't be an issue. Interviewee one draws on the same concerns, by highlighting this as one of the key barriers, particularly in small and medium sized companies.

The issue of educating all parties concerned is also reinforced as being a difficult hurdle to overcome as the processes must be understood to ensure all BIM parties are working on the same level.

Beyond the financial impact and the need to invest in effective education of the processes, there are a number of other underlying issues that plague any new software that enters the markets; interoperability. From the literature it is evident that various teams have been created to tackle these issues, Building SMART have already developed and are maintaining the IFCs, which are designed to allow 'open data exchange' and this is also the aim of various other software vendors, such as Autodesk and Tekla Structures ([10,39,40]). Interviewee two articulates the issue where one organisation excels in BIM, while their stakeholders fall behind. This results in the concept of the organisation becoming a BIM-island where a company may very well have the capability to operate using BIM but unless the other parties in the project are as capable, the cross party exchange/communication of information will not be effective. Time will be wasted downgrading information to be used in inferior products and then subsequently updated manually again to the BIM software. (A fully functioning 3D model can be exported to CAD but the detailed information contained within will be effectively lost. Once the CAD file has been edited to suit a sub-contractors design, the CAD file cannot be uploaded with the same level of detail and time has to be spent updating the BIM model to suit the amendments).

5.4. Transition from Traditional Practices to Full Collaborative BIM

Having established the core limitations with current industry practices, how BIM can provide solutions to such issues and indeed better the process must also be reviewed. This is crucial to enabling companies to integrate the technologies with as little disruption to their work while building a solid base from which to continue to evolve and update the industry. The following word cloud in Figure 5 provides a good indication of the means available when creating a programme for BIM implementation.

Interviewee two is keen to state that the CFS industry should be proactive in its pursuit of becoming BIM proficient as it can only be to their advantage. Various BIM hubs and seminars are identified by interviewees one, two and four as being one of the best ways of becoming and maintaining up to date knowledge on BIM and the practices within the sector.

The educational aspect ran through the series of interviews and what becomes clear is the role universities/educational institutes have to play in helping companies integrate BIM's philosophy. The interviewees articulate that today's graduates have effectively been taught the new BIM programmes as part of their studies and have access to a plethora of software, in most cases for free (student versions). This result in students that are well positioned to promote the technologies and best apply them in practice be it in engineering, consultancy or an architectural remit.

Interviewee two has experience of the current educational material on offer through institutions but believes in the importance of making learning specific to each company and their relevant protocol and procedures. It was also recognised from the interviews that the training offered by service providers alone is not enough, but rather the need for specific training, in order for one to excel in the use of BIM software. This is relevant to the CFS industry where CFS is not commonly modelled as a primary structural element.

Figure 5. Transition from traditional practices to Full Collaborative BIM

Further learning could be supplemented by specific seminars and presentations on real example of the projects within the CFS Company. As well as universities acting as knowledge providers, the interviewees drew upon the need for further government support. Such avenues as government led knowledge providers who can work alongside a company aiding implementation is viewed as one of many possibilities to assist in the dissemination of information regarding BIM within the sector.

6. Conclusion

This paper has given an account of the increasing popularity of BIM in the AEC market and how, by its integration into the CFS industry, it can improve the CFS industry's position through increased efficiency and smarter collaboration. With the governments mandate for fully collaborative 3D BIM by 2016, it is clear that those companies who wish to stay competitive will have to consider the increasing popularity of BIM.

A qualitative approach is used to illustrate the current CFS market and BIM. Through a detailed review of the literature, semi-structured interviews and subsequent analysis, the importance of BIM within the sector emerges. Therefore, based on the results herein, it is imperative that the CFS industry pays heed to the capabilities of BIM and at least begins to invest in discovering how it can benefit their construction sector.

The software currently employed by CFS companies to create its portal frames has its limitations with regards the configurations possible. This is where BIM will have a particular impact, i.e. its ability to model non-standard buildings. This will increase the company's flexibility in the works that they can procure and facilitate growth in the future.

The opportunity to analyse the structure within the BIM software also provides another element that is not existing in current CFS practices. BIM software will now allow the CFS buildings to be analysed in 3D and the optimum solution achieved, as all the different load combinations on the various components can be analysed individually and thus optimised, reducing the overall cost.

These findings enhance our understanding of BIM and make a welcome contribution to the CFS industry through demonstrating its ability in the creation of a fully collaborative 3D model of a CFS portal frame. The results of this study indicate that BIM does indeed have a major part to play in the CFS industry, and will aid in the transition required by the government, resulting in improved efficiencies in the construction industry and bringing productivity more in line with other manufacturing industries.

The relevance of the study is clearly supported, not only in the literature, but also by those interviewed. The interviewees believe that such a study is more relevant, as it is industry lead, practical and timely with the government mandate requiring the use of BIM in all public sector projects come 2016. With the advancement of CFS technologies and ability to be used as a primary structural component, it is now in a position to be more competitive in the UK market, particular when it comes to the design and construction of small-medium spans (approx. 18m). In combination with BIM, the CFS market will only become more competitive and enable its successful integration with other project teams who are BIM proficient throughout the construction industry.

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