# BIM AS A VIABLE COLLABORATIVE WORKING TOOL: A CASE STUDY

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**Abstract.** For the majority of design practices in the construction industry the use of CAD systems have been used to merely automate hand drafting (Cohen 2003). This is the traditional way of working that has changed very little since the introduction of commercial CAD systems. These practices as means of communication are being replaced by a virtual building model environment which encapsulates all of the information for an entire construction project and thereby enables computer-supported co-operative working practices. (Newton 2003) This study aims to determine whether Building Information Modelling (BIM) can, and whether it will, replace traditional communication media as the standard in the industry for computer-supported co-operative working practices in the Architecture Engineering and construction (AEC) sector. The bulk of the research comprises an extensive literature review looking at the principal reasons behind the development of BIM, the potential advantages and drawbacks of the technology, and the barriers and obstacles which inhibit its adoption as a means of computer-supported co-operative working. The findings of the study have been validated and analysed against current practice in the field through a live case study analysis of the on-going Heathrow airport Terminal 5 Project in London (UK). The Terminal 5 case study demonstrates that present software tools, although usable, still present significant implicit technical constraints to wider implementation among Small and Medium Enterprises (SMEs). The case study has also shown that in practice, the success of BIM depends just as much on the working practices and ethos of participants in the project chain as it does on the capabilities of the software itself, in particular the willingness of practitioners to change traditional working practices. The case study has shown that the present investment, in terms of time, cost, and effort required to implementing the technology means that BIM is unlikely to be adopted on small simple projects where conventional CAD is still adequate. It also highlighted that BIM tools currently available are not yet adequately developed to satisfy the requirements of the many procurement and especially contractual arrangements which presently exist and many firms will be frightened off by the unresolved legal issues which may arise from implementing BIM in their practices.

## 1. Background

Computer aided design (CAD) systems have, for the majority of design practices in the AEC industry, merely been used to automate conventional hand drafting, the creation of 2D drawings such as plans, sections and elevations that are plotted onto paper and distributed amongst the project parties as required, explains Cohen (2003). This is the traditional way of working that has changed very little since the first commercial CAD systems were introduced in the early 1980's, and although the software has evolved rapidly, presenting new and innovative features such as conceptual design and 3D modelling capabilities, and most recently the development of Building Information Modelling (BIM), the way in which CAD has been adopted and implemented within the industry so far does not reflect the potential that it has. According to Evans (2003), there is a serious gulf between best practice and common practice, and the most common explanation for this is the fragmented structure of the construction industry.

A decade on from Latham's (1994) recommendations , Cohen (2003), suggests that information technology (IT) has been applied in *"piecemeal fashion"* to various tasks and procedures but not the construction process as a whole, and as a direct result of this situation communication within the industry has become worse rather than better. Cohen (2003) refers to the *"incompatible systems used by individual disciplines creating artificial barriers that had not existed before"*. As a result of this situation the majority of building information and data exchanged on a project is still by means of CAD drawings plotted onto paper increasing the opportunity for error and delays. He goes on to suggest such process inefficiency can inflate the cost of a building by at least 25%. The Building Information Model (BIM) was introduced as an innovative concept in response to these growing problems in the construction industry regarding data exchange and software interoperability.

BIM, according to Khemlani (2003), is *"A way of representing buildings on the computer very differently from traditional CAD technologies, which could have a revolutionary impact on how buildings are designed, constructed, and operated"*. Khemlani (2003) outlines the fundamental problem with traditional CAD as being its use solely of generic geometric entities to represent building objects and their subsequent inability to incorporate intelligence.

The building information model is an innovative approach to project data integration. It replaces electronic and paper-based documents with a knowledge base describing the entire project. Participants have real-time access to the model throughout the life of the project, contributing their own knowledge and data, and using information contributed by others. Each discipline within the project team uses its own specific software for performing its own aspects of the work, and these tools have the ability to draw from and contribute to the common pool of data and information that is the model database. The key change from present conventional CAD practice is that all discipline specific software can exchange information with the shared building model, i.e. there is potentially complete interoperability within the model environment. According to Newton (2003)[2], *"Building information modelling represents the synergistic coming of age of several* *technologies: 3D objects, parametric design, change management, information reuse for the project lifecycle, and project collaboration".*

Once the building information model is created, all other requirements including 2D documentation, schedules, reports, 3D renderings, and animations can be derived from it. Also, if changes and alterations are made, they are automatically reflected in all individual views and documents within the model environment, therefore eliminating inconsistencies. Furthermore, the model can check for conflicts such as spatial interferences (clash detection) between individual building elements. Cohen (2003) eloquently describes the shared model as *"becoming almost a living organism that can be accessed asynchronously by its many contributors".* According to Seletsky (2003), *"The single building model reflects the future paradigm for most architects and large scale design firms. Properly utilised it saves hours of last-minute construction document changes".*

**2. Rationale**

The software developers are presently flooding the AEC industry with promotional literature and information regarding their building information modelling solutions and the benefits and advantages that they present. However, according to Newton (2003), recent published statements by software vendors fail to address the concept of BIM as a whole, and instead concentrate on their own often insular perception of what the technology should be. Dakan (2003), raises the valid question as to whether 'BIM' is *"just the three letter acronym intended to generate interest and sell products"* - an issue which must be addressed. Day (2003)[2] adds that *"while there is a need to educate users on new technologies, introducing a new three-letter acronym will not necessarily be of benefit to their understanding, its just another label".*

The general consensus amongst CAD journalists and analysts is that the construction industry would be a better place if everyone used a 3D building model to communicate design to all participants in a project, but in order for this to happen there are still significant challenges which need to be addressed before the benefits of BIM can be fully realised. The apparent slow pace of the industry to recognise and utilise the BIM concept as a superior solution to current traditional CAD working practices has been attributed to a variety of somewhat vague factors – from the fragmented structure of the industry to the work culture in firms along the construction value chain, their ethos and the universal resistance to dramatic change.

It is the aim of this research to test whether BIM technology can, and whether it will, replace traditional CAD working practices as the standard in the industry for integrating architecture, engineering and construction. Within this aim the following objective are sought out:

- To outline the potential benefits and advantages to the construction industry presented by BIM over traditional CAD systems and working practices, and to consider any drawbacks which the technology may present. This should establish both the technological and organisational benefits and weaknesses of building information modelling compared to conventional CAD practice.

- To establish the current barriers to the application and implementation of BIM across the construction industry. This should determine all of the factors which presently inhibit the use and future development of Building information modelling.

## 3. Summary of literature review

The most common themes arising from the literature review are the fragmented state of the construction industry, the difficulties of data exchange in projects, and the limitations of traditional CAD systems and procedures. From each literature source however, comes the consistent attitude that the development and utilisation of BIM can potentially remedy and solve many of the problems and difficulties that arise from these three main issues. Some of the most definitive conclusions have been made by Cohen (2003), who states that “the building process would be better served if the entire chain of information from design to construction to operations could remain in one seamless digital format”, Lion (2003), who presents the ‘vision’ of a single model that holds all of the data for the entire life cycle of the project as the solution to remove the obstacles that currently face the industry, and Nour & Beucke (2003), who conclude that the prime objective behind the development of building information modelling is to “bridge the gap between islands of automation”.

The common themes regarding the problem of data exchange and the limitations of traditional CAD practice which have emerged from the literature review so far, are eloquently brought together by Cohen (2003) in a compelling point in which he states that information technology has made “communication within this extended enterprise worse rather than better”, with the reason being the use of mutually incompatible software tools that don’t readily exchange information with each other resulting in the emergence of barriers between disciplines which had not previously existed.
The emergence of BIM in the construction industry can be attributed to many crucial factors which have been reported in the literature. But the concept of the integrated building model, however, is not so much revolutionary, as is proclaimed in many of the promotional documents, but is more, as Khemlani (2003) , the “logical evolution for the building industry from CAD”.

### 3.1 POTENTIAL ADVANTAGES AND DRAWBACKS OF BIM

A concise but detailed account of the advantages over traditional CAD systems is provided in an article by Khemlani (2003), in which she explicitly states that BIM can achieve “faster, cheaper, and better buildings”. All of the problems associated with traditional CAD can be avoided owing to BIM’s utilisation of intelligent building objects that are aware of themselves and their relationships with other entities. Her argument is supported by Cohen (2003), who goes on to say that objects within the model carry with them more than just the dimensional data of traditional CAD entities, but also additional valuable attributes such as specifications, code and performance data, cost and scheduling etc. One of the foremost technological advantages that BIM applications have over traditional CAD systems, and one which is made apparent in almost all of the relevant literature, is software interoperability. As Cohen (2003) explains, each discipline in the building information model environment is able to continue to use its specialist tools to carry out its own element of the overall work, and unlike conventional CAD systems these tools are able to extract from and contribute to the common model database.

Khemlani (2003)², in a comprehensive article which looks at the technological benefits of BIM, regards interoperability as one of the key advantages of the technology, stating that the same building data model can potentially support computer applications for different aspects of design and construction, which "leads to a better integration of multi-disciplinary workflows".

With regard to weaknesses of the technology, Holtz, Orr & Yares (2003), interestingly point out that the BIM solution raises, but does not directly address key questions as to who owns the data in the model, who is responsible for updating it, and how to coordinate access and ensure security in the model environment. Darst (2003), picks up on the data ownership problem and exemplifies the issue saying that "the architect will 'own' the wall type but the services engineer will 'own' the wall's u-value". He goes on to bring up questions of sensitivity and accuracy in the data i.e. how important is the data? And does the downstream user know its level of accuracy? He concludes by raising the intriguing issue of individual investment in information modelling with two typical questions; "Why should I enter this data when I don't have any vested interest in its use?" and "If I publish information that I use for a very specific reason and a later application interprets it incorrectly, am I liable?"

In identifying drawbacks and weaknesses of BIM, it is important to understand, from a technological perspective, how the data in the model is structured. Dakan (2003), states that at present, the information model is conceived and structured in two ways; the consolidated single database and the federated distributed database. With the single database he points out that the primary concern and potential weakness is the possible size and "unwieldiness" of the single file. Bentley & Workman (2003), in the only promotional document to identify any significant drawbacks of the technology, enlarge upon this problem stating that many current BIM applications face difficulties regarding the ability to comfortably handle a large, shared, mixed volume of data, and serve hundreds of varied, widespread project participants. They refer to this issue as "scalability", i.e. the ability to successfully handle both small simple and large complex projects.

Khemlani (2003)6 reinforces Seletsky's point, in her article capturing the main themes from the 2003 Technology in Architectural Practice Conference in California. She highlights the concern of designers as to the ability of BIM to accommodate the creation of complex and interesting architectural forms without, as she graphically puts it, "being straitjacketed by the form making limitations of BIM solutions".

At this stage in the development of current BIM applications, the large majority of literature sources seem adamant that the technology can remedy the present difficulties and limitations of traditional CAD practice and institute a better and more efficient way of working in the construction industry. However, as Day (2003)2 crucially points out "we have to be careful that we are not throwing out one solution at great expense, to implement another with just a different set of problems".

3.2 CURRENT BARRIERS TO THE APPLICATION OF BIM

The literature has identified a host of varying factors from long standing traditional working practices to the simple cost of implementing the software. In determining whether or not BIM will replace conventional CAD practice, the research will attempt to validate these factors and identify those which present the greatest resistance to the industry-wide adoption of the technology. The principal findings of the literature review regarding this objective are listed as follows:

- Existence of a new technology unknown to potential users
- Unwillingness to change traditional working practices
- No clear indication which disciplines may de disadvantaged and which will benefit
- Lack of research and development by the industry's major institutions
- Companies frightened off by unresolved legal issues which may arise
- Companies unwilling or unable to meet training costs
- High cost of software
- Technology unsuitable for coping with varying procurement systems
- Personnel intimidated by complexity and steep learning curves associated with the software
- The age factor - mature workers uncomfortable with new technologies

The literature review also highlighted various gaps and deficiencies in the existing knowledge. The more obvious of these are listed below and the resolution of these shortcomings will be a prerequisite of the process of collection and analysis of data

- The extent to which the BIM can support computer applications for different aspects of design and construction, i.e. interoperability
- The benefits of the technology beyond the design and construction stages of a project
- Whether design changes can be made with greater ease in the model environment compared to traditional CAD applications
- Whether 2D documentation can be created more efficiently in terms of time and cost than with traditional CAD practice
- Whether building information modelling is a truly scalable solution for both small simple and large complex construction projects
- Whether the BIM concept should be built upon existing systems or completely replace present CAD applications
- Whether present construction contracts and procurement systems can accommodate the new way of designing, constructing and maintaining buildings using intelligent 3D models rather than 2D CAD drawings.

**4. Methodology used**

The aim of this project deals not only with the technological side of BIM, but in examining the long term future of the technology, it takes into account the more subjective aspects such as the work culture and ethos of organisations along the construction value chain, the perspectives, attitudes and preferences of CAD users, and the ideologies and incentives of software developers. Therefore, the data collection phase of the study lends itself to a qualitative approach.

Because current BIM solutions are of recent development, their application across the construction industry is, at the moment, confined to a small number of projects. Because the use of this new technology is very restricted, quantitative and statistical analysis of BIM practice in the industry is not an option. As a method of validating the issues and theories raised by the literature review, the case study is ideal as it presents the opportunity to analyse and evaluate current practice in the field. However, there are no accessible well documented case histories regarding the use of BIM in the industry. Therefore, the best option is to conduct the data collection phase in a live case study environment.

Heathrow Airport Terminal 5 in London was chosen and access granted for a period of ten days. The project is the largest, most complex and innovative example. Therefore, although not truly representative of the overall industry, it represents a benchmark for the application and implementation of the technology in the AEC industry. It is “a landmark in smart design”, Says Lane (2003), and presents a potentially invaluable opportunity to conduct research in a live BIM working environment.

Following a period of evaluation of data collection techniques, a combination of questionnaire, semi-structured and open interviewing, and observational analysis was deemed most appropriate for the collection of data. However, for this study it has been agreed with members of the design team that a questionnaire be sent and distributed amongst various project participants prior to the data collection visit so that on arrival the findings may be analysed and used to further aid the research process.

## 5. Summary Analysis of Findings

Due to restrictions on paper length, this analysis will discuss some of the major points highlighted by the live case study and the questionnaire. The conclusions, however, will discuss all the issues raised in this research.

Looking to the first claim that it is faster and easier to create and edit building entities in a building model environment, out of the 30 respondents, 8 replied ‘yes’, 11 ‘no’, and one ‘don’t know’. The outcome to the following question, as to whether design concepts can be more quickly explored, evaluated and presented, was more clear-cut with 25 answering ‘yes’ and only 5 ‘no’. A construction engineer commented on the fact that working in a 3D model environment allows structures to be analysed and understood with far greater ease than with traditional CAD systems. This was also the case with the ability to express more complex design ideas in a BIM environment, with 23 agreeing, 4 disagreeing, and t3 not knowing.

The literature review makes much of the fact that one of the foremost advantages of BIM is its ability to implement design changes and variations with greater ease and simplicity compared to traditional systems. However, in response to this claim 8 participants agreed, whereas 12 did not. One CAD technician commented on the fact that 3D changes in the model environment actually take more time to implement. There was also a general consensus amongst those in disagreement that ease of implementing alterations was largely down to the user and not specifically the software.

One of the foremost benefits which the literature claims for BIM is the ability to identify spatial interferences and clashes between building entities which stems from the seamless data exchange which BIM facilitates. With regard to this claim, a high total of 28 professionals were in complete agreement that this is a major advantage over conventional CAD practice.

BIM according to almost all reviewed literature sources brings a greater certainty to the costs, time etc, of a project at an earlier stage in the design and development process compared to traditional CAD systems. In response to this claim, 8 participants agreed, 10 disagreed, and 12 didn’t know.

On cross-discipline software interoperability being one of the fundamental advantages of BIM as outlined in the literature review. With regard to whether it is easier to exchange and share data between different software applications compared to traditional systems, the response was considerably mixed with 13 replying that it was, 11 thought that it was not, and 6 didn’t know. Amongst building services professionals the general consensus was that the quality of interoperability was largely inadequate. One respondent commented on the fact that they have to create all of the model backgrounds in which to run their services models, as they are unable to receive the required data from upstream in the project, and this was costing a large amount of extra time and effort. A CAD technician went on to say that interoperability is severely affected by project planning miss-alignment, which can make seamless data exchange almost impossible, a point corroborated by a Civil design engineer who said that “The success of the building model environment relies on every team constantly updating and releasing their files for use by other teams – which is something every team at times fails to achieve”. This is an issue which, although not linked directly to the technology, has a considerable effect on the success of inter-process interoperability in the model environment and deserves consideration.

As for the software being presently too complex and often restrictive and inflexible, 21 of the 30 respondents were in agreement with this, 9, on the other hand, were not. A Civil design engineer stated that “A major problem seems to be the complexity of the software and systems”, and notably pointed out that “CAD operatives often seem to work outside the model environment for ease of producing drawings – and then spend time putting into the model when the drawings are complete”. According to one CAD Coordinator, who was in complete agreement that the software systems were over complex, “project teams are spending more time actually progressing the software tools and systems than actually progressing the specific project tasks”.

The literature review has shown that scalability – the ability to successfully handle both small and large projects was a serious concern with regard to present BIM applications. In this case only 9 respondents agreed whilst 21 thought that the size of the project did not present a problem to the building model paradigm. Those who did, however, did not see the problem of scalability as principally a software concern, as did the literature; they regarded the issue of work culture as important and relevant. A Civil Design Engineer commented on the fact that because the building model environment requires so much training, time and costly software, it would not play a significant role in small projects for the near future at least, with a CAD Operator adding that *"There are clients who will not want to pay for the model environment, especially on a simple or small project where normal traditional 2D work can be done"*.

In relation to the problem of data ownership in the model environment, an issue highlighted quite extensively in the literature, 20 recipients agreed that ownership of data was problematic whilst 10 disagreed. A CAD Coordinator commented on the fact that "Greater policing of who owns what has been necessary". Data ownership presents a definite problem says another CAD Coordinator, "but it is less of an issue in a design-build project such as Terminal 5".

Regarding whether some disciplines were given too high a profile in the building model environment, to the detriment of others, a prominent issue highlighted in the literature. With regard to this, 17 agreed whilst 13 gave the opposite view. The benefits of BIM seem to be unevenly distributed throughout the project. Observational analyses have shown that some disciplines were pushing the model concept to a greater extent than others in terms of implementation and adoption, believing that this would raise their own project profile. However, this was having a detrimental effect in terms of collaboration and coordination with other project parties that had advanced to a lesser extent with the technology.

The apparent inability of current BIM solutions to model organic and free-form architectural entities was identified as a significant weakness in the literature. The response to this claim was certainly clear-cut with 27 out of the 30 respondents in complete agreement. A building services software consultant notably pointed out, however, that the inability to model free-form objects was actually being used to an advantage as it "prevents the user from overriding the present parameters of purchased items". According to a senior CAD modeller the traditional extrusion methods associated with conventional CAD applications are at the moment more flexible than intelligent architectural objects because current object libraries are simply too limited. One CAD Coordinator commented generally on the whole issue stating that "freely modelling organic shapes has historically presented a challenge to the CAD industry".

## 6. Conclusions

The aim of this study has been to determine whether the BIM paradigm can, and whether it will, replace traditional CAD practice as the standard in the industry for integrating architecture, engineering and construction. The literature review has established that BIM is the logical progression from conventional CAD systems and that the potential advantages presented by the technology are prolific. However, it has also highlighted the fact that present software tools, although usable, are still technologically immature. The case study analysis has corroborated this and shown that there are still significant technical constraints implicit in the software. The case study has also shown that in practice, the success of the model environment depends just as much on the working practices and ethos of participants in the project chain as it does on the capabilities of the software itself.

There exist significant barriers and obstacles which inhibit the use and future development of the BIM concept, and of these it is the present work culture and unwillingness of practitioners to change traditional working practices that present the greatest resistance.

For BIM to replace traditional CAD it must become completely scalable, i.e. the functionality and benefits of the technology can be realised on both small simple and large complex projects. The literature review has identified scalability as being primarily a software concern; however, the case study has shown that the present investment, in terms of time, cost, and effort required to implementing the technology means that BIM is unlikely to be adopted on small simple projects or by SME's where conventional CAD is adequate. One Terminal 5 CAD Coordinator said that "BIM adoption needs the stimulus of a design-to-destruction owner", adding that "PFI projects are one example of this".

As the literature review has established, the present benefits of BIM flow primarily downstream from the design phase to members in the design/construction team and the client/owner. Out-with the cooperative and collaborative environments of design-build type projects, the downstream beneficiaries of the model environment do not offer the upstream design professionals any additional compensation for their costs and effort in adopting the technology. Therefore, within the small design practice working with traditional project delivery methods, the model environment is unlikely to be widely used.

From the study it is clear that the building information modelling tools currently available, although a significant step forward from conventional CAD practice, are not yet fully developed to satisfy the requirements of the many procurement and contractual arrangements which presently exist, and as the research has shown, many firms will be dissuaded by the unresolved legal issues which may arise from implementing BIM in their practices.

The questionnaire survey asked recipients whether they thought BIM would replace traditional CAD practice in the construction industry and of the thirty respondents, an even split of fifteen agreed that it would and fifteen thought that it would not. Amongst those who disagreed, a CAD Coordinator said that "Traditional CAD will always be needed at some point in the process. However the amount of 2D drafting that takes place on any project will reduce over time". A Senior CAD Modeller commented saying "BIM will never completely replace traditional CAD, although I would like to think that more projects adopt a BIM approach in the next ten years". A Civil Design Engineer added that although the BIM paradigm would not replace conventional CAD applications it "is vital for improving construction's productivity and quality".

There was a general consensus amongst project team leaders that the move to BIM, as has been the case on the Terminal 5 project, should be an evolutionary one, with the technology being built upon the concepts and systems with which users are familiar, so that the transition to the BIM working environment becomes almost seamless, rather than adopting a revolutionary approach whereby existing systems are swept away to be replaced by new technology. Of the respondents who agreed that traditional systems would be replaced by the model environment, there was a strong consensus that this would not occur in the short term owing to the reluctance of practitioners to change long standing traditional working practices and the present not fully developed and tested technology. Coinciding with the findings of the literature review, respondents suggested that full and complete implementations of BIM across the industry would be up to ten years away. However, in the field of IT generally ten years is a very long time and there is every possibility that the technology as it relates to the AEC industry still has remarkable developments to contribute.

To conclude, it is clear that potentially the building information model paradigm offers a more efficient and productive way of working which eradicates many of the problems and complexities associated with traditional CAD practice and has the potential to unify the presently fragmented construction process and potentially help reduce project costs. However, at this early stage in the development of BIM, the technology has a long way to go before the potential benefits will be fully realised. In large cooperative project environments the building model can be seen to bring significant advantages, yet for small, traditional design practices and projects the barriers and obstacles simply outweigh the benefits of the technology. To directly answer the research question, at present BIM cannot replace conventional CAD practice in the industry, particularly in small and medium size practices which represent the overwhelming majority. The technology will, however, continue to develop and advance, and traditional applications will undoubtedly be overtaken over time and replaced by more intelligent information-centric systems.

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