University of Huddersfield Repository

Coates, P., Arayici, Y., Koskela, Lauri, Kagioglou, Mike, Usher, C. and O'Reilly, K.

The Limitations of BIM in the Architectural Process

Original Citation

Coates, P., Arayici, Y., Koskela, Lauri, Kagioglou, Mike, Usher, C. and O'Reilly, K. (2010) The Limitations of BIM in the Architectural Process. In: ICSU 2010 : First International Conference on Sustainable Urbanization, 15-17th december 2010, Harbour Grand Kowloon, Hung Hom, Kowloon, Hong Kong. (Unpublished)

This version is available at http://eprints.hud.ac.uk/id/eprint/19678/

http://eprints.hud.ac.uk/

THE LIMITATIONS OF BIM IN THE ARCHITECTURAL PROCESS

P. Coates [1], Y. Arayici [1], L. Koskela[1], M. Kagioglou [1], C. Usher [2], K. O' Reilly [2],

[1]The School of Built Environment,

The University of Salford, Greater Manchester, UK

s.p.coates@edu.salford.ac.uk, y.arayici@salford.ac.uk, l.j.koskela@salford.ac.uk, m.kagioglou@salford.ac.uk

[2] John McCall Architects, 1 The Arts Village, Henry Street, Liverpool, UK

ABSTRACT

Building Informational Modeling has been suggested by some as the panacea to address the interdisciplinary inefficiencies in the construction industry. In many cases the adoption of BIM has numerous potential benefits. But when considering individual disciplines within the construction industry the question is how will BIM integrate with their business process? The term business process here is used to refer to project development in an architectural organization. Although both practice management and project management are also considered. BIM is an enabling tool within the construction process. According to Lean principles tools should only be used where they are applicable to the tasks and tangible benefits can be demonstrated. When applying a new technology such as BIM it is critical to understand the core activities to which the technology is being applied. This paper sets out a framework of actions and interactions that occur within architectural practice. Through this understanding the role and potential of BIM adoption as a basis for re-engineering can be evaluated.

The particular understanding of architectural practice and the adoption of BIM has been gained through action research undertaken as part of a knowledge transfer partnership project. The knowledge transfer partnership was set up between the University of Salford and John McCall Architects.

KEYWORDS

BIM, Architectural Process, limitations

INTRODUCTION

There are those who believe that BIM accentuates the chasm between design and construction that now defines the AEC industry (Deutsch 2010). The challenges of effectively integrating BIM into architectural practice are similar to those that occurred when CAD was first introduced into the architectural industry. CAD or computer aided design in many ways failed in its role of aiding design. With the introduction of BIM there is a new opportunity to align the technology not just with the requirements of design but with the demands of the wider architectural process and the professionals and administrative staff who bring their own expertise and requirements to such endeavors.

Usually BIM is considered as a collaborative tool but the reality is in the construction industry most firms are not multidisciplinary and are in fact relatively small in nature. Therefore the decision on when and how to use BIM are often made from a firm's internal perspective of perceived benefits as opposed to the wider industry gains possible through BIM. This paper explores limitations of BIM in the integration into architectural process. Through a consideration of the alignment challenges of BIM systems and BIM authoring tools, it is hoped that this will form the basis to develop a new generation of better aligned architectural tools combined with the benefits of interoperability with other needs and other disciplines within the building life cycle process.

WHAT IS BIM

To understand the limitations of BIM, it is necessary to define what is BIM (Building Information Modeling). BIM has many different definitions each indicating a partial capability of the holistic BIM philosophy. For example, it is defined as a language allowing interoperability or as a method of codifying knowledge or as a method of human machine interaction or as a method of applying parametric behaviors or as the process of creating and using digital object orientated models for design, construction and operations of projects (McGraw Hill, 2008). Also it has been defined as a solution to building lifecycle modeling. Suermann, (2009), defines as "BIM is the virtual representation of the physical and functional characteristics of a facility from inception

onward. As such, it serves as a shared information repository for collaboration throughout a facility's lifecycle", while Eastman, (et al 2008) defines BIM as "a verb or adjective phrase to describe tools, processes and technologies that are facilitated by digital, machine-readable documentation about a building, its performance, its planning, its construction and later its operation". Penttilä, (2006) describes Building Information Modelling (BIM) is a set of interacting policies, processes and technologies producing a "methodology to manage the essential building design and project data in digital format throughout the building's life-cycle".

THE ARCHITECTURAL PROCESS

In some architectural practices procedures of practice, roadmaps and checklist are used. These define the tasks to be undertaken to create the type of architecture produced by the firms. These standardized working practices are often the basis of quality systems and ISO 9000 accreditation. But these explain little of the ways that the development of architectural design is achieved. Many of the actions in architectural practice are undertaken using tacit knowledge, which although effective in its application may not be understood in a formal way by the architect using it. In order to revaluate and understand the practice of architecture we need to strip it back to its key operations. Then by reconsidering these key concepts in the light of new ideas such as lean and with an awareness of new technologies such as BIM we can look to establish new improved processes and process maps.

An architectural practice is a business which takes the needs and requirements of a client and translates those predilections and concepts into a holistic buildable form. Services of providing construction information and site administration may also form part of the architectural duties. The scope of architectural responsibility and level of development of deliverable is defined by contractual agreements. To achieve the scope of works requires the processes of communication, creation and management. The actions required are illustrated in Figure 1 below.
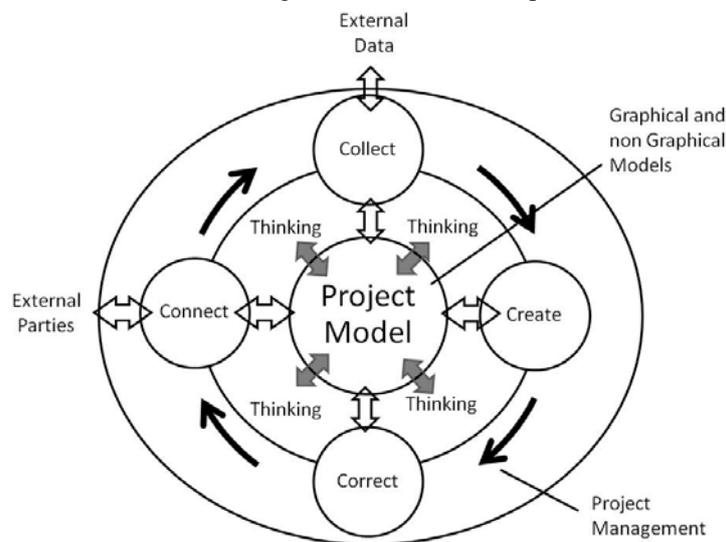

Figure 1: The core of the architectural project process

This shows an approach to the architectural process that incorporates thinking, collecting, creating, correcting and connecting. The project model may comprise of both a BIM graphical model and project support data. This support data maybe in the form of letters, emails, reports, certificates, photographs, spreadsheets and CAD or hardcopy drawings. At John McCall Architects a project support database was created and it is hoped in future to integrate this with the BIM graphical data store.

The exact methodology of thinking, collecting, creating, correcting and connecting maybe simple or complex as the project demands and the application is often project specific. In this paper these activities are considered through the perspectives of people, processes and technology.

In order to undertake this architectural process effectively these five areas need to be managed and facilitated. This paper attempts to evaluate BIM against these five key areas of architectural process to measure out its contribution and limitations in fulfilling these architectural tasks.

THINKING AS PART OF THE ARCHITECTURAL PROCESS

The action of thinking is integral in the collecting, creating, correcting and connecting activities. These activities can have the added bonus of facilitating thinking by doing in the development of architecture. Thinking may take place individually or as a collaborative process. The architecture studio has traditionally been the preferred environment to facilitate individual and collective architectural thought. Such studios may be purely architectural or multidisciplinary in nature. Now with the use of technology the opportunities for virtual studios as well as physical studios exist. Technology has developed and is developing to allow collaborative interaction as part of BIM systems. The Teamworks[TM] server used as part of ArchiCad 14 [TM] is an example collaborative tools embedded into a BIM authoring tool.

The objective of architectural education is to produce professionals with the necessary thinking skills to undertake the architectural task. The practice of architecture is both a scientific process and an artistic activity. The primary method of gaining scientific answers is to apply the known-facts to generate the answer. The artistic process on the other hand applies stimuli to generate ideas. In architecture both processes are necessary. Where the enabling software used is not intuitive and requires thought this reduces the mental faculties that can be applied to the design process.

The development of architecture may involve many issues and at times has it has become too complicated to keep everything in one's head. Thus the need to use technology and processes has developed in part to manage this project complexity. Software should be malleable to fit the way architects think. While some architects advocate changing how we think about our work in order to use computers, interface experts tend to disagree with that opinion. Donald Norman (1992), for instance, writes, "Make the task dominate; make the tools invisible." We must be careful to distinguish between thinking differently to do better, more efficient work, and thinking differently to use a tool. The first is admirable, but the second is the sign of a faulty tool (Johnson 2000). The tools need to focus the architect's attention on what is important. Misalignment using BIM does occur. BIM focuses thought on objects, but the aim of architecture is to create spaces defined by objects. The effectiveness of spaces is often determined by ergonomics and anthropometrics which are a critical element of the architectural thought processes yet as yet not integrated into BIM systems. Sustainable design is also a growing concern which BIM systems are starting to address. The tasks of BIM systems in the future are therefore to represent a wider variety of a design's properties, in terms that are familiar to architects and those who influence design. BIM is the language of construction (Architectural output) door, window, wall, slab etc. that is to say, it is a language of parts. If so, what is the language of architecture, ideas, concepts, community, relationships, values, meanings, forms, functions, anthropometrics and aesthetics? In other words, what is the language of holistic solutions? In short, BIM currently represents digital Lego, not the digital clay.

To develop successful architecture the right thought processes have to be adopted at the right time. There are many different methods of thinking: proprioceptive thinking, forming patterns, empathizing, role playing, modeling, transforming, synaesthesia and synosia, dimensional thinking, synthesizing, analogizing, observing, imaging, abstracting and pattern generation. To be effective a BIM system should allow and enhance this range of thinking types and act as a decision support system. BIM machine readable model forms may align themselves to some but not to all of these thinking processes.

Many forms of models and representations exist each with its own particular ability to change data into information. By providing the BIM user with a greater range of model and visualization outputs (Figure 2) should assist the architect in his or her thinking processes.
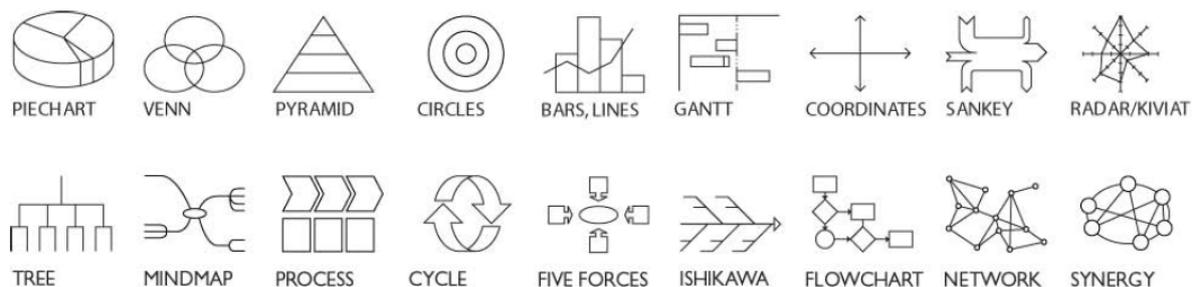

Figure 2: Forms of Knowledge Visualization (Eppler, M. Burkhard, R. 2005)

As computer processing power increases it becomes possible to envisage the BIM process using the interface of virtual worlds. Secondlife provides scripting and modeling capabilities for the development of content applications, however integration with external databases and applications is required for more advanced applications to be supported (Pathmeswarn el el 2008). Links with Open Sim may also be developed.

COLLECTING AS PART OF THE ARCHITECTURAL PROCESS

Today there is an ever increasing number of interests, technologies and factors than impinge on the architectural process. Examples of the breath of this range are subjects such as bio mimicry and psychology which are in some practices used as precursors to architectural design. Considering the effectiveness of BIM is not possible without considering the informational requirements of building projects. There is the information that is necessary to bring the building into existence and there is the information that is required thought the whole building lifecycle. It is this second category of information that is usually considered as part of the BIM model. Referring to the definitions on the Tekla^{TM} website the acronym BIM is described both as a building information model and also building information management. Gradually more information is being linked to BIM models with links to specifications such as NBS and Masterspec having been developed. With both information for development and information for life cycle use issues of fitness for purpose exist. The collection of information and knowledge which either purpose remain an intrinsic and critical part of the architectural process Figure 3.
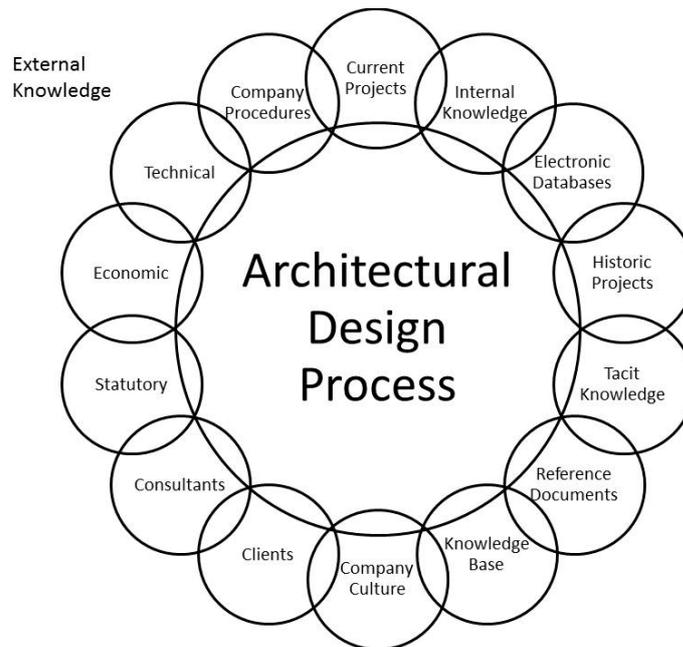
Figure 3: Sources of knowledge in Architectural Practice

The collection process and the timely application of knowledge into the creation process is profoundly important. Koskela (2004) notes that making do (progressing with inadequate information) results in a considerable was in the preconstruction and construction process. Architectural projects often encompass unique requirements. As a result collecting of new knowledge necessary to undertake projects. Historical knowledge is not enough, as architectural creations will exist and a future as opposed to a historic world.

But the role and skills of the knowledge worker are changing as technology changes. There are many methods traditional and new were by architects can collect the knowledge and information they need to undertake their projects.

- Architectural Press Blogs and discussions
- Architectural Databases
- Architectural Publications
- Seeking Information from experts
- Search engines

- Crowd sourcing
- Reality capture technologies

Knowledge and information may be provided in many forms: include stories and storyboards, proverbs, scenarios, content inventories, analytics, user surveys, concept maps, process flows, style guides and design patterns.

Technology can assist in the collecting process in several ways. Technology can provide a framework for storing knowledge collected. It can facilitate the collection of information though the use of the internet. Technology can assist in the automated collection of information by the use of agents. For example, there are digital tools such as the Sensemaker Suite (www.sensemaker-suite.com) for the collection of data and information. However, these tools have not been integrated with BIM.

BIM facilitates the process of documenting predefined designs and there are tools that assist in the organization of collected data such as Trelligence Affinity®. But BIM tools need to be developed further to address the needs of the information gathering process.

CREATING AS PART OF THE ARCHITECTURAL PROCESS

BIM offers the double-edged promise of displacing abstraction with simulation. The work of an architect is to bring concepts into being. Thus converting the potential into the actual. The C.K. Theory (Hatchuel and Weil 2002) proposes a set of dualities of concept and knowledge iterations that occur in the development of design. Iterative design can be described as a process of testing scenarios from anchored objects. User feedback is given and then the anchored object are modified and improved. Thus BIM tools need to facilitate this iterative cycle.

In creating building designs consideration should be given to what is functional, sustainable, practical and affordable. Architects manage not only information about the building but also about the user organization. Therefore, information systems for architectural design ideally should be able to handle both building and organizational data (Ekholm 2001). Different design facets will be evaluated at different stages of the design. Ideally the system used to develop architectural design should be able to enhance the facets of architecture under consideration. This contributes to the design development dialogue. Some designers like to design projects from the inside out, other prefer to design from the outside in. Currently BIM tools do not allow for these personal nuances' in the design process. Few BIM tools can accommodate the ambiguities of early design. To accommodate these ideas, recommendations have been made that the concept of architectural informational modelling should be developed as a precursor to BIM in the design practice (Pauwels et al. 2009). One system that attempts to address this problem is the Onuma Planning System [TM] (OPS). OPS enables architects to perform rapid prototyping and multiple scenarios (Tardif 2007). The objective of architectural practice is to design buildings to meet the requirements of the client, the end user and the community. So effective design is dependent on effective collection and distillation of user requirements.

It seems likely that physical models and sketching will continue to have a place in the creation process. Referring to physical model Mills (2005) states when used as an integral part of the design process, study models are capable of generating information in time comparable to drawing and offer the strongest exploration methods available. Physical models can also have a tactile quality the computer models do not. Sketching on the other hand gives immediacy and is an effective method of exploring concepts. Some designs may be the final result of hundreds of concept sketches. The fluidity of the sketching process does not restrict the thought process of the designer. In fact some designers need to sketch to facilitate the thought process. Sketching like modeling can be seen as a cognitive tool augmenting memory and informational processing by relieving the mind of some of those burdens (Tversky 2002). BIM continues to miss the simplicity in design that pen and paper offer, pen and paper offer on the fly analysis of complicated systems that allow the human brain analysis of multiple options at once (Burns, 2006).

BIM moves the focus away from the needs of the end users by focusing on objects of construction as opposed elements of architecture. For an architect BIM concentrates rather too much on providing means of representing the final form of the design, whereas designers also need a continual stream of abstractions, advice and information to facilitate in the move from information to the distillation of knowledge. Although using lean concepts we wish to create a flow of idea and concepts developing through the architectural process the differences in the thought processes between design, production and practice management make this difficult.

CORRECTING AS PART OF THE ARCHITECTURAL PROCESS

Correcting brings to mind the concept of errors or mistakes. For course it is important that non conforming product is identified and rectified. But correction here is as much about evolutionary design development of the product as it is about error correction. Correcting as part of the design process can enable better design solutions to be reached. The important factor here is that the models or abstractions are generated cheaply and rapidly. This is the key to rapid prototyping and artful making (Austin & Devin 2003).

There is a concept in Lean engineering of reducing the water level to reveal problems. As a result of the automation features built into many BIM tools certain historical problems are less likely to occur. Firstly there is likely to be consistency between the plans, elevations and schedules if these are generated from a single BIM model. 3D geometric errors are less likely to occur because 3D buildings are constructed as 3D models not 2D representations of 3D forms. Specification errors are less likely to occur when the specification is directly linked to the BIM model. Clash detection has the ability to assist in interdisciplinary coordination issues. Where BIM systems use constraints dimension driven design and automated code compliance are possible. An example of this would be the knowledge based design integration using blue think applications, (Opdahl, 2009).

BIM has the potential to illuminate certain errors and omissions. Yet it is necessary to be aware than several sort of errors will not necessary be flagged up using BIM systems (Love 2010)

CONNECTING AS PART OF THE ARCHITECTURAL PROCESS

BIM systems have the potential to transfer richer data than the CAD systems they replace. There are two facets to the connecting process. Firstly information from the architectural process needs to be transferred accurately. Using IFC as the method of transfer varying levels of success for informational transfer can be achieved (Kiviniemi, 2010). It is reasonable to assume that this transferability of information will develop and improve. Such transfers may need subsequent editing filtering and manipulating to make the comprehendible and usable by the recipient. The second facet of connecting is to make information supplied fit for purpose in line with the recipients requirements. Currently few recipients in the UK require deliverables as BIM models and insurance issues remain if such models are supplied. This situation is again likely to change over time.

Communication of architectural concepts is necessary with other disciplines such as planners, building control officers, end users, clients and contractors (Figure 4). The precise format and content that is required by each of these parties is different. Also the level of understanding of each of the parties varies. This means that semiotic issues come into play.
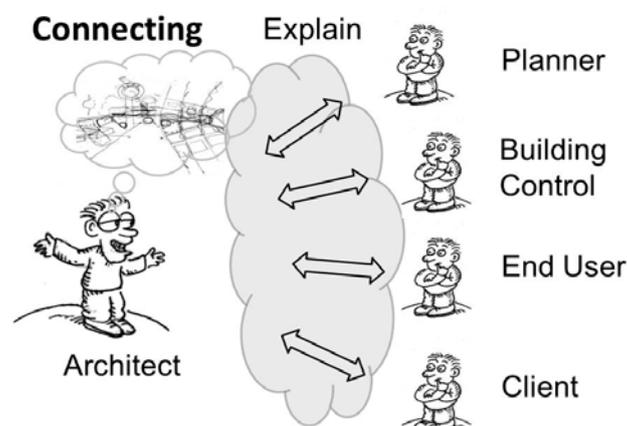
Figure 4: Connecting with other disciplines and parties

While 2D representations remain the method of informational delivery even from 3D models, consistency of information issues remain. A major advantage of using BIM is that 3D printing of physical models becomes an option as does the creation of animations and virtual environments.

INTEGRATION OF BIM WITH OTHER TECHNOLOGIES AND BUSINESS SYSTEMS

IFC based BIM embodies digital machine readable documentation that has the potential in future to integrate with a range of digital design tools and philosophies that are available. Thus BIM can become more effective through a convergence incorporating enabling technologies. The five areas previously identified need to integrate with the wider management roles and systems taking place in architectural offices (Figure 5). Many systems arising from different needs operate within architectural companies, ERP, PIM, CRM, QMS and KM. Where these systems are digital in nature, BIM has the possibility and opportunity to integrate with these systems. It is wrong to view these systems in isolation and it is more appropriate to think of a change from a document driven process to integrated data/ information / knowledge driven process linked by data exchange. Whether we are talking about data, information, knowledge or wisdom many mechanisms exist for its transfer. Ideally this transfer should be automated to avoid data atrophy. This integrated approach aims to take advantage of the synergy of business systems. This can be achieved by linking and normalizing data across the whole business operation.
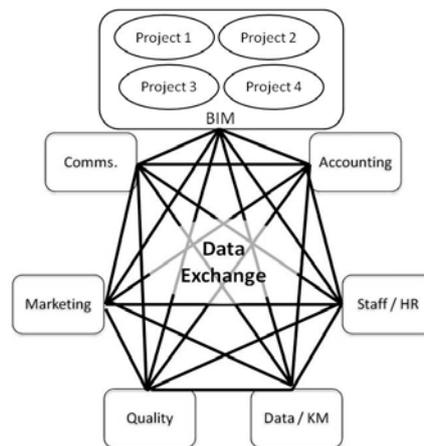

Figure 5 : Systems within an Architectural Practice

Yet a large amount of information and systems used in architectural practice currently are not IFC compatible (Figure 6).
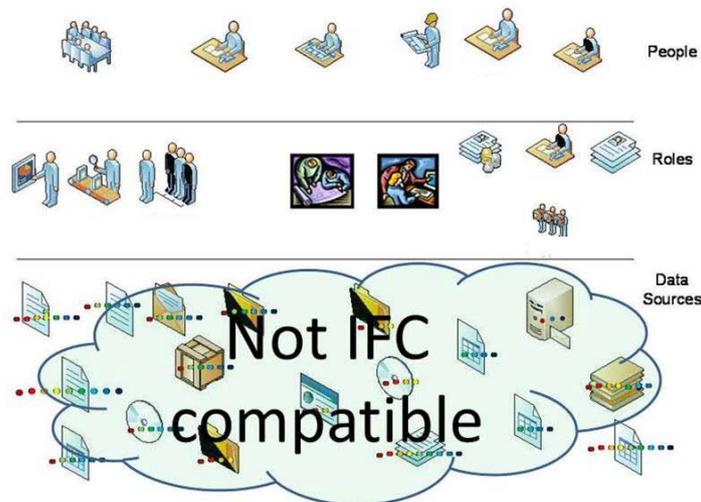

Figure 6 : A large amount of variant architectural information located discretely in traditional practice

AgcXML has been designed to address to an entirely neglected body of information (Tardif, 2009). Development of effective systems in this area have untapped possibilities in the Architectural Domain.

CONCLUSION

Although BIM may currently be a very effective tool from a lean perspective in the building industries toolkit, it is by no means the only tool and over time other new and more effective tools are likely to become available (Basalla, G. 1988). BIM is not a silver bullet. As noted in this paper many issues and problems in its application remain to be addressed.

Areas for development include:
a) Better alignment with the architectural thought processes
b) Improved intuitive operation, reduce the mental overhead of using the system
c) A building method of information collection, evaluation, structuring and sharing
d) Further develop of BIM linking it more effectively to real world capture and feedback and customer feedback technologies
e) Providing a greater range of models and abstractions to assist with the creative process
f) Further development of BIM using total emersion technologies
g) A built in learning and error correction system
h) A better system of tailoring issued information to meet the needs and capabilities of the recipient
i) Better integration with other practice business systems, combining, aggregating and visualizing business data
j) Better integration with contextual information and GIS systems

Acknowledgement

REFERENCES

Aliakseyeu, D., 2003. A Computer Support Tool for the Early Stages of Architectural Design. *PhD Thesis*, Eindhoven, The Netherlands, ISBN 90-386-1598-1.**s**

Akini, B. 2010 Reality Capture Technologies and Building Modeling for Situation Awareness and Assessment, Management Arena, Managing IT in Construction / Managing Construction for Tomorrow, Keynote Papers Taylor & Francis Group, London ISBN 978-0-415-56744-2

Austin, R., Devin, L., 2003 Artful Making- What Managers need to know about how artist work. Prentice Hall ISBN 0-13-008695-9

Basalla, G. 1988 The evolution of technology, The press syndicate of the University of Cambridge 1988 ISBN 0-521-29681-1

Burns, J. 2006, Will BIM Be the Death of Design? AIA *Archblog* http://blog.aia.org/aiarchitect/2006/10/will_bim_be_the_death_of_desig.html

Do, E. in Filiz Ozel and Patricia McIntosh (eds), "The Right Tool at the Right Time -- drawing as an interface to knowledge based design aids" *Proceedings, Association for Computer Aided Design in Architecture*, (ACADIA '96) p191-199, 1996 National Conference, University of Arizona, Tuscon

Eastman, C., Teicholz, P., Sacks R., and Liston, K. (2008). "BIM Handbook: A guide to BIM for Owners", Managers, Designers, Engineers and Contractors, Wiley publication, ISBN 978-0-470-18528-5.

Eckblad, S., Ashcraft, H., Audsley, P., Blieman, D., Bedrick, J., Brewis, C., Hartung, R. J., Onuma, K., Rubel, Z., and Stephens, N. D. (2007). "Integrated Project Delivery - A Working Definition." AIA California Council, Sacramento, CA.

Ekholm, Anders 2001 Modelling of User Activities in Building Design Architectural Information Management [*19th eCAADe Conference Proceedings / ISBN 0-9523687-8-1*] Helsinki (Finland) 29-31 August 2001, pp. 67-72

Eppler, M. & Burkhard, R. (2005) Knowledge Visualization. In: Schwartz, D. G. (Ed.) Encyclopedia of Knowledge Management. Idea Group Reference.

Deutsch, R, Notes on the Synthesis of BIM, AECbytes Viewpoint #51 (April 7, 2010)

Gross, M., Yi-Luen Do, E., 1996. Ambiguous intentions: a paper-like interface for creative design. *In: Proceedings of UIST'96, November 1996,* Seattle. ACM Press, pp. 183–192.

Hatchuel, A, Weil, B. (2002) La théorie C-K : fondements et usages d'une théorie unifiée de la conception. *Colloque sciences de la conception*, Lyon, 15-16 march 2002

Hurley, A., 2008 BIM Technology Side Benefits of BIM, ARCHITECT November 2008 , November 11, 2008 http://www.architectmagazine.com/bim/side-benefits-of-bim.aspx

Johnson, S. 2000. Should designers learn to think differently in order to better utilize digital design tools?. *ACADIA Quarterly* 4, 19: 2

Kiviniemi, A. 2010 Challenges of Interoperable BIM in a between organization http://aarch.dk/fileadmin/filer/Sune/Arto_Kiviniemi.pdf

Koskela, L., 2004 Making-Do – The Eighth Category of Waste, 12th Annual IGLC Conference on Lean Production, (2004) Denmark http://www.iglc2004.dk/_root/media/13091_088-koskela-final.pdf

Lawson B CAD and Creativity: Does the Computer Really Help? *Leonardo*, Vol. 35, No. 3 (2002), pp. 327-331 (article consists of 5 pages) Published by: The MIT Press S URL: http://www.jstor.org/stable/1577126

Littlefield, D. Designing by numbers, Building Design 18 March 2005 http://www.bdonline.co.uk/story.asp?storycode=3048424#ixzz0mnaieHv1

Love, P. 2010 In search of the magic bullet: Building Informational modelling, garbage in, gospel out, Working Paper Curtin University July 2010

McGraw Hill Construction (2010) Smart market Report, Business Value of BIM in Europe, Getting Building Information Modelling to the Bottom Line in the United Kingdom, France and Germany

Mills, C., 2005 Designing with models, a studio guide to making and using architectural design models, second edition, John Wiley & Sons, Inc

Norman, D. "Why Interfaces Don't Work" in The Art of Human-Computer Interface Design. Brenda Laurel (editor). Addision-Wesley. 1992. 209-219.

Opdahl, P. Olsen, Y. 2009 Knowledge based design integration using bluethink applications CIB IDS 2009 10-12 June Espoo

Pauwels,P. Verstraeten,R. De Meyer,R. Van Campenhout, J. 2009 Architectural information modeling to address the limitations of BIM in the Design Practice, CIB-W102 Rio de Janeiro, RJ, Brasil, 17 – 19, June 2009

Penttilä, H. 2006 Describing The Changes In Architectural Information Technology To Understand Design Complexity And Free-Form Architectural Expression. ITcon, 11**,** 395-408.

Pathmeswaram, R. Wu,S. Bakis, N. Zhang, X. Aouad, G. Ahmed, V. Abbott, C. 2008 The construction research potential of second life, Salford Centre for Research and Innovation (SCRI)

Seaman, Building Information Modeling: Panacea or Pandora's Box? http://video.google.com/videoplay?docid=4486911304731500794#

Senate Properties: BIM Requirements 2007 Volume 3: Architectural Design http://www.senaatti.fi/tiedostot/BIM_2007_Vol3_Architectural_Design.pdf

Suermann, P. Issa, R. 2009 Evaluating Industry Perceptions of Building Information modeling (BIM) impact on construction, itcon – Journal of Information and construction – ISSN 1874 -4753

Szalapaj, P., Contemporary Architecture and the Digital Design Process

Tardif , M. 2009 Looking Beyond BIM to Business Information: The Role of agcXML in Streamlining Information Exchange AECbytes Viewpoint #49 (December 14, 2009) http://www.aecbytes.com/viewpoint/2009/issue_49.html

Tardif, M, 2007 AIArchitect Vol 14 Aug 17 2007 Architect Creates Design Synthesis Software Onuma Planning System allows integration of vast amounts of information

Tversky, B. 2002 What do sketches say about thinking? AAAI Technical Report SS-02-08 Spring Symposia

Yan, H., Damian, P. Benefits and Barriers of Building Information Modeling, Department of Civil and Building Engineering, Loughborough University, UK