TIME KEEPS ON SLIPPIN', SLIPPIN', SLIPPIN' INTO THE FUTURE: BIM, IMAGING AND TIME ON CONSTRUCTION SIGHTS

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Digital visualisation is central capability of Building Information Modelling (BIM) and proponents of BIM claim that BIM will change everything. For example, the International Alliance for Interoperability initiative now known as BuildingSMART defines BIM as, "a digital representation of physical and functional characteristics of a building." In current BIM research BIM is linked to Lean Construction, Augmented Reality (AR), project and trade scheduling, safety management, progress measurement on sites, design visualisation and even architectural education. As the BIM industry has arisen, numerous and in some ways glamorous, case study images are published and promoted as examples of successful BIM implementation. Representations of BIM as evident in diagrams, flow charts, conceptual drawings, user screenshots and representations of computer drawn BIM 3D and 4D models abound in BIM research. For these reasons these digital images and simulations emerging from BIM research literature deserve being examined — as representations of BIM theory or practice — to see what they suggest about the current methodological developments in BIM research. In order to understand the modes of BIM representation employed in BIM research an analysis is developed which counters current BIM research with broader research methodologies in Construction Management and the French philosopher Gilles Deleuze's concepts of the cinema. In addition a comparative analysis of these representations in the research literature is made with images gained from a real construction site. This approach reveals how concepts of time are inscribed into BIM research and how these differ from reality. It will be concluded that the use of non-linear and topological concepts of time on construction sites is relevant to future BIM research. This is particularly the case when virtual BIM models are seen as simple linear and sequential constructions over time.

Keywords BIM, design, computer visualisation, research methodology

INTRODUCTION

Time keeps on slippin', slippin', slippin' Into the future Time keeps on slippin', slippin', slippin' Into the future I want to fly like an eagle To the sea Fly like an eagle Let my spirit carry me I want to fly like an eagle Till I'm free Fly through the revolution

The lyrics of the Steve Miller band's song 'Fly like an Eagle' (1976) serve as a useful introduction to the concepts of time that emerge from the representations, diagrams and simulations associated with an analysis of current Building Information Modelling (BIM) research. In these representations time is linear and easily progresses into a future where BIM enables seamless collaboration across a range of different construction workflows. The predominant viewpoint presented in the various

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diagrams and images that litter BIM research papers is often that of an eagle, or angel, freed of all earthly constraints and propelled towards a future BIM revolution. But unlike the critical theorist Walter Benjamin's discussion of Paul Klee's iconic image of an angel, looking back on the wreckage of progress, these seductive images of BIM appear to suggest that every technical innovation succeeds and that technology need not have a social-technical dimension (Chrostowska 2012).

In theory, BIM project models paired with collaboration tools offer a number of significant improvements and benefits over traditional design, delivery and supply chain processes. Proponents of BIM claim that the BIM will change everything. In current BIM research BIM is linked to Lean Construction, Augmented Reality (AR), project and trade scheduling, safety management, progress measurement on sites, design visualisation and even architectural education. The linking of 3D CAD models to project time schedules to enable what is termed four dimensional or 4D BIM is claimed as the next frontier for BIM (Sacks et al. 2010). BIM is primarily a visualisation tool and 4D BIM allows construction and project events to be visualized over time. Given the claims that BIM is a new mode of visualisation which can directly embody and simulate real-time itself, it is worth focusing on how time is conceived of and embedded in representations of BIM in the research literature. These various representations in the literature include strategic and operational diagrams, flowcharts, screenshot images and stills of digital animations. The objective in analysing these images and the concepts of time they suggest is to map the methodological extent of BIM research. In other words, the digital images and simulations, emerging from this snapshot of BIM research literature deserve being examined — as representations of BIM theory or practice — to see what they suggest about current methodological developments in BIM research. Whilst this analysis is limited to published BIM research it sets the scene for how we might consider the plethora of images regarding BIM that now also exist in the public domain.

Concepts of digital visualisation are central to definitions of what BIM is. A report sponsored by the Australian Institute of Architects (AIA) on BIM collects together a number of these definitions. For example, the International Alliance for Interoperability initiative now known as BuildingSMART defines BIM as, "a digital representation of physical and functional characteristics of a building"(Consult, AIA 2012). Australia's 'National Guidelines for Digital Modelling' developed by the CRC for Construction Innovation define BIM as being a "three-dimensional representation of a building based on objects which also includes "information in the model or the properties about the objects beyond graphical representation" (Consult, AIA 2012). However, it is difficult to know in this latter definition what is meant by the word 'object' and how objects go beyond graphical representation. Does this refer to a physical object, a 3D visualisation or a class of software code? The USA NBIMS - National Building Information Model Standard Project appears to bring these aspects of BIM together by defining BIM as "a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition." (Consult, AIA 2012).

With the above definitions in mind this survey of research includes published research in, but not limited to, Automation in Construction, Construction Management and Economics, Journal of Construction Engineering and Management and the International Journal of Architectural Computing. As a point of reference the concepts underpinning BIM research and 4D BIM are compared to real time activities on an

actual building site as captured through time-lapse photography. Given that BIM simulations are intended to represent a reality that is supposed to mimic real construction a comparative analysis of the representations gained from a real construction site is worthwhile. This leads to a discussion and analysis which counters current BIM research with broader research methodologies in Construction Management and the French philosopher Gilles Deleuze's concepts of the cinema. This approach is not meant to lead to an overly philosophical or arcane discussion about the essential nature of time and duration in BIM. On the contrary, this points to the problematic nature of current BIM development in relation to actual design and construction and suggests the need to look at BIM innovation in a different light; by proposing the potential of new methodologies for BIM research in the field of Construction Management.

BIM in Recent Construction Research

As the BIM industry has arisen as numerous, and in some ways glamorous, case study images are published and promoted as examples of successful BIM implementation. Riese (2011) highlights screenshots of various tasks related to the model for the One Island East project in Hong Kong. The colours employed are seductive and this is a key feature in numerous BIM screenshots. A shimmering green is contrasted with yellows for services and purple. The viewpoint is from a point looking above or below and is positioned to emphasise the overlapping of different systems and suggests a layered complexity constituted by the juxtaposition of many different small scale construction elements. With these images as support Reise (2011) claims that BIM can improve workflows through clash detection and coordination, better two dimensional drawing extraction, automated quantity take-offs, supply chain integration and Facilities Management integration. Rowlinson et. al. (2010) examine two BIM implementation case studies. They argue that the opportunities of traditional 2D design is outmoded by BIM practice. They contend that BIM implementation will mean that effort, and hence time, in the construction lifecycle will shift from being centered on the construction phase to being centered on the design phase; BIM means that more decisions will need to be made earlier in the design and construction process. They publish two BIM diagrams. One figure depicts a low viewpoint of a BIM model with all the layers switched on while the other shows a user interface highlighting the capabilities of BIM in relation to clash detection. They claim that BIM has now progressed beyond 3D representations to encompass 4D representations(Rowlinson et al, 2010)

BIM visualisation and design

One of the key areas in which representational and visualisation issues come into play is in the area of design. Iterative hand drawing or sketching is central to design practice. But, Ambrose (2012) argues that BIM represents a new mode of visualisation that will overwhelm traditional conventions and working tools of abstract design thinking such as the "traditional conventions of communication; plan, section, elevation". In this view, BIM is a radically new tool for abstract design thought because of its "ability to virtually simulate the building construction and architectural assemblage" and "is perhaps the most important transformation and architectural production in the last several hundred years". Ambrose proclaims that "Every other discipline that has adapted simulation as its primary model of design and fabrication has benefited from increased efficiency and economy. Simulation is the destination of contemporary digital design"(2012). He illustrates this argument with three figures

from BIM models. Paradoxically, each one is not dissimilar to traditional axonometric or isometric orthographic projections. Nevertheless, each one shows how BIM can replicate abstract design thinking by showing both separately and in combination different building elements.

Lean Construction has also emerged as a domain where BIM's visualisation potential has been identified, andresearchers have argued for a natural fit between these two paradigms. Sacks et. al., (2010) propose that a "synergy exists" between BIM and Lean Construction and explore this conjunction of synergies through a comparative matrix comparing BIM "functionalities" with lean "construction principles" and then identifying constructive "interactions." In identifying the common theoretical fundamentals of each paradigm, the result is the improvement of construction processes "beyond the degree to which it might be improved by application of either of these paradigms independently" (Sacks et al. 2010). This conceptual alignment between BIM and Lean Construction is further elaborated in a CIRIA guide which argues that Integrated Project Delivery (IPD) is where Lean Construction and BIM reach maximum potential (Dave et. al 2013, Raisbeck et.al., 2010).

Like Ambrose (2012) Dave et. al (2013) also argues that BIM visualisation is superior and that "traditional design methods do not support sophisticated and accurate visualisation or rapid iteration and evaluation of ideas that will help clients decide the option(s) to select." Invoking parametric design and seeming to limit and lock in strategic or conceptual design they state: "The Lean and BIM processes and tools not only provide a much more accurate and sophisticated 3D visualisation capability, but also help evaluate the options from a range of criteria set by the client" Dave et. al (2013) Echoing an anti design sentiment they argue that conceptual design work will be contained because once a design has been formed under BIM it will not change: "Through parametric design and collaborative processes, the value loss is minimised when the conceptual design is passed along to later stages" Dave et. al (2013).

BIM representations and spatial information

Perhaps because of its seductive visualisation capabilities BIM has been linked to other visually rich modes of digital technology that embody spatial data such as GIS and computer games. These new forms of digital-technical visualisation can be distinguished from socio-technical systems. This is because BIM in that they concern the flows to, and the interdependencies between, digitised data and information and physical construction technologies and processes. For example, in identifying the migration of architects to BIM from CAD formats, Yan et al. (2011) look at the possibilities of linking BIM and game engines into design visualisation. A socio-technical interaction between people and users is eschewed in favour of digital-technical interactions. Like a computer game a play process developed by Yan et al. (2011) is centered around a BIM model that is intended to simulate both physical features and life activities. Characters are embedded into the model as virtual building users and they can then access the game space from either an avatar viewpoint or third person viewpoint located outside of the screen image. But,the primary digital-technical representational mode of the game is an "omnipresent" viewpoint. in what is described as, a "photorealistic" mode. Yet, the rooms of this game space are limited visualisations of a residence which is claimed to be a "customised building" with a "realistic environment." The published images of the environment that have been created by this method have a low ceiling and the slabs or slices of space that are depicted are not unlike those find in computer games such as the World War II themed 3D game Wolfenstein (ID Software, 2009)

In a similar vein Wang et al. (2012) develop a framework for integrating BIM with Augmented Reality (AR). Their aim is to create a digital-technical visualisation that enables construction activities to be "visualised in real-time".They contend that using BIM and AR together can provide subcontractors with an interactive model that can be used to understand details and aid on-site design. Jiao et al. (2012) also examine AR in a BIM context that is linked to the cloud and social networking services. They provide proof of concept of this connection. But as they note few AR applications have been designed to link to either BIM or even Project Management tools. Irizarry et al. (2013) pursue digital-technical processes by considering how supply chain processes can be enhanced by linking GIS systems with BIM order to track materials in supply chains. In their research diagrams these researchers uses a case study approach in order to establish the data and visualisation capabilities of linking BIM and GIS in a single model. This enables building product data from manufacturers to be linked to GIS in order to facilitate the mapping of costs, ordering, transport, warehousing. These researchers depict the construction supply chain network as being linear: directly running from the design phase to the construction phase without any iteration or feedback loops.

Becerik-Gerber et al. (2012) also see possibilities in BIM being linked to and supporting Facilities Management information systems. Through an online survey and 22 expert interviews with FM professionals they highlight the synergies between BIM and FM. The areas of benefit were seen as locating building components and creating Knowledge Management databases using information from a BIM model. Digital-technical visualisation is a central theme of this study and the authors illustrate this argument with a depiction of a BIM based digital interface. This shows a simplistic orthogonal three story structure with columns beams and floor plates reminiscent of Corbusier's Domino house prototype. BIM's efficacy and potential also extends to construction safety. Zhang et al (2012) argue that BIM has a role to play in construction safety and they develop number of algorithms that can analyse a BIM model to detect and suggest solutions to safety hazards.

BIM and 4D simulation

As early as 2007 Tulke and Hanff (2007) argued that 4D simulation in BIM models had the ability to visualise complex time scheduling of data which would ordinarily only be available in quantitative spreadsheets. They claimed that in BIM practice their approach would compress time and assist project managers in optimising construction processes. To this end they proposed a new 4D simulation approach to enable the creation of time schedules and 4D simulations using data stored in a BIM model. They came to this conclusion by attempting to create a 4D model which connects together what they call a CAD or BIM product model with a time schedule process model (Tulke and Hanff, 2007). More recently, Kim, Kim and Kim (2013) look at how 4D CAD models can be easily updated. As they note updating 4D CAD models can be time consuming because this is not a workflow automated by software. In order to overcome this they propose a image processing methodology that uses site image data, employing filters and image templates, which is compared to the projects 3D CAD reference model. They explain this research using a deck segment of a cable-stayed bridge structure. The entire process is described in the research using a serious of screen shots that are limited to 3D CAD models, excel spreadsheets and graphical user interfaces. In separate research, Kim, Kim and Kim (2013) develop a method for measuring construction project measurement using a 4D BIM model linked to 3D data gained from remote sensing technology in the form of laser scanners. This research

claims that it's contribution is to go beyond previous methods based on simple geometric and scheduling information.

Seven deadly sins of BIM

Whilst much of the research into BIM emphatically argues that BIM is a digital-technical paradigm which will revolutionise design and construction there are still voices that counter this view. Bynum et al. (2012) point out that very little BIM research focuses on sustainable construction. In support of this they develop a survey to ascertain expert opinion. They find that "sustainability was not a primary application of BIM and that project coordination and visualization were instead more important." They go on to write that "Although BIM is perceived as a multidisciplinary tool, problems with interoperability continue to persist among the various BIM applications in the industry" Bynum et al. (2012). Khosrowshahi and Arayici (2012), in research assessing the level of BIM implementation and maturity in UK construction, describe a diagram that structures BIM maturity and implementation into 3 stages. In a comprehensive study the authors devise a roadmap for BIM implementation in the UK industry concluding that their is no evidence of BIM use at the penultimate maturity level. In other countervailing research Sebastian (2010) examines BIM using hospital building projects and concludes the full complement of BIM functionalities has not been utilised in these complex projects

Holzer (2011) brings some useful analysis to the fervent claims of BIM proponents commenting on the gap between fervent BIM idealists and the practicalities of BIM design practice. Using a number of research resources based on his own experience Holzer identifies "Seven Deadly Sins" of BIM implementation. These include: privileging software implementation over an organisation's design culture and ambiguity around the actual productivity benefits of BIM, Holzer also questions the data on which the MacLeamy graph is based as well as it's conceptual underpinnings. Holzer notes that collaboration between disciplines between early design stages is problematic. This is due to the difficulty of using BIM models to quickly test and evaluate different conceptual design options (Holzer, 2011). Clearly more research should be done on the MacLeamy graph's premises.

Construction site comparison

A new Faculty building being constructed at Melbourne University serves as a useful point of comparison to the representations that characterise BIM research and marketing. This alternative viewpoint is constituted by 3 timelapse cameras in different positions take hourly images as the building is constructed. To date (June 28) these cameras have documented the demolition of the building and the excavation of the site for the lower floors. What distinguishes these representations and images is the fact that one is witness to a performance of machine and people. Over the time of the photographic sequence there are tracks and traces which do not appear to follow any particular order. The telescopic crane positioned on the site does not follow a simple sequence of movements. The amplitude of its movement from east to west is not consistent and the time lapse images give the impression that the crane is moving as a result of the wind. Similarly the movement of demolition workers and other equipment in and around the site do not follow predetermined linear tracks or production lines. Whilst the risks in this process have been carefully managed and anticipated the time lapse photography and video stream indicates that the actual movement on site is not the result of predetermined production techniques but the result of stochastic processes and random performances.

DISCUSSION

A dichotomy emerges in the published BIM research between two different types of images. On the one hand there are many seductive images of BIM models. But, the representational modes of BIM research are limited because on the other hand many of the rendered 3D CAD buildings linked to BIM models are often very simplistic and naive orthogonal designs. Often these designs seem to have been developed as simplistic projections of plans. Perhaps it is harsh to expect more of research diagrams and examples but these are at odds with the BIM models of complex buildings that are shown as exemplars. These representations often rely on colorful computer graphics which present singular, static and complete—rather than incomplete—images of a particular project that has used BIM. BIM animations and simulations in the public domain such as those found on YouTube and as promotional images of software also appear seductive and unambiguous in what they present. In the research literature, it is the new architects of BIM, the software coder, CAD operator or BIM engineer whose viewpoint is often seen as being paramount. Other subjectivities of either the model itself, multiple viewpoints or the avatars embedded in the models are never presented. The diagrams of the IT architecture of BIM processes in the literature often have at their centre an digital-technical entity called the BIM model. The BIM model is a largely static and centralised conceptual entity. It is often described as a component of a flow chart. It is usually represented as an object that is complete and well formed. The BIM model is conceptualised as a black box into which everything connects from which representations emerge. In all of these representations non-linear or stochastic notions of time are not often considered in the research discourse.

Given the increasing prevalence of digital-technical processes and workflows in design and construction new research methodologies, instruments, and perspectives are required. As argued above the prevailing discourse on BIM has viewed project time and conceptions of time as simply being about speed and compressing activities into smaller and smaller time frames. Time is regarded as being linear and a part of a production or manufacturing line process. Design and construction workflows are seen as sites where an all powerful operator manipulates a screen image and linked database. There is no iterative work or feedback loops between new and so-called old design techniques conceptual drawing and sketches simply cease to exist in this context. In current BIM research the building model or object, as it is represented, is not seen as a spatial entity embedded in cultural milieu.Instead the diagrams and representation of buildings in this research skip between glamorous images of a BIM future and simplistic buildings embedded in graphical user interfaces. The actions that take place in these screen based models are highly prescribed and robotic. There are no traces of random or stochastic processes of movement in these theatres. BIM models are rendered as being complete solutions where there are no misteps and ambiguities in the construction processes that 4D BIM and AR models hope to mimic. They are closely related to the lineage of lean construction with its intellectual in product manufacturing.

As noted by Pink et al. (2010) some of the ethnographic methodologies developed in the social sciences are occasionally being imported into the field of construction management research. They explicate and explain that ethnographic methods should be rigorously applied in construction research. They note that construction site ethnographies describe how people learn, know, transmit knowledge, and move. Ethnographic viewpoints thus have an aesthetic component in that it might identify the way people move, and vocalise, especially if this movement is the result of craft based

knowledge and traditional construction practices. Traditional ethnographic research methods focused on observation of human agents have now been augmented with participatory, collaborative methods that use new techniques to observe, record, notate, reflect, and test theories as they emerge. In the construction Industry participant observation studies have sometimes involved the researcher participating in the process or workflow that the researcher is observing. Pink et al. (2010) focus their work on safety issues in construction. But their conclusions also apply to digital-technical work practices and point to the need to develop ethnographic methods and critical theory in relation to the rise of BIM. As they argue, ethnographic methods can help us to understand BIM as a 'shared and embodied form of "knowing in practice" (Pink et al,2010) which can help us to understand the workflows and processes of communication involved with BIM implementation.). As Phelps et al. (2009) note, qualitative-theory building methodologies and ethnographic methods aligned with ethnographic studies offer a different and necessary viewpoint to quantitative and positivist research methodologies. Alongside these perspectives, the predominant digital-technical nature of current BIM research and practice may also be usefully interrogated by viewpoints from critical theory and philosophical traditions. As Brown and Phua (2011) argue in a discussion of the concept of identity in construction research their is a need for 'multi-layered, nuanced, unfolding and dynamic relationships between self, work and organization.'

The French Philosopher Gille Deleuze's encounter with cinema is a useful critical framework in this context. Deleuze wrote two philosophical books about cinema. Deleuze saw cinema as a "new practice of images and signs, whose theory philosophy must produce as conceptual practice." (Deleuze, 1989, 1985: p.280) Deleuze's concern is not a philosophical investigation of cinema's essential nature. Deleuze did not simply proclaim cinema as a technological revolution. Rather, he was interested in interrogating the cinema for its possibilities about what it might become. (Rushton, 2012) As Rushton notes, Deleuze argues that cinema establishes the problems of traditional subject orientated epistemologies. Deleuze cites Henri Bergson as a philosopher who opposed a view of the world that is predicated on a static and centred viewpoint or subject. Deleuze sees in Bergson a philosophy that accounts for the early technological advances of cinema as well as anticipating its later developments. But, Deleuze also sees the cinema as constituting a language of images. Deleuze's conception of image is something which is neither representation, secondary copy, imitation or mimesis. These perspectives suggest that construction R&D should oppose a concept of BIM that privileges linear sequences, singular perspectives and robotic notions of construction that ignore the randomness of craft. As Simone Brott notes in her investigation of Deleuze and architecture states 'Deleuze saw the cinematic image not as a picture or representation of something but an entity with the presence of both colour and movement.' (Brott 2011*)* BIM should be theorised in a multi-layered and nuance way which accords with Deleuze's philosophy of cinema and: "puts into play a moving image, a moving image in which the centre of the image is also constantly in movement: a camera which moves, editing which constantly shifts the centre of perspective and emphasis of the shot, an emphasis which might at one moment be seen from one character's perspective, at the next moment from another's, then from the perspective of no character at all" (Rushton, 2007)

CONCLUSION

The above considerations suggest that new methodological approaches are needed in the area of BIM research if BIM is to reach it's full potential as a tool which saves

resources and allows better design outcomes and project risk management. Future BIM research needs to recognise the power of different representational modes, stochatsic and random events, social milieu and avoid seeing a building as a simplistic digital-technical object or diagram linked to a database. Stochastic processes which are random and are capable of using agents and swarms to predict what will happen within BIM models may reveal more than the static and mechanical models which plague BIM research today. Notions of time should be seen as being multi-layered and interdependent of sequential BIM animations and screenshots. BIM models should be conceived as entities which develop over time from the beginning of the design process where there is a iterative transfer of information between designers, teams, and 3D representations of buildings built in computers. In BIM research ethnographic approaches and critical theory should be employed to ensure that future designers and builders do not relinquish their canon of knowledge regarding the craft of building as the industry moves to digital databases.

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