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FOREWORD

Welcome to the 12th International Postgraduate Research Conference (IPGRC15), which is hosted by the School of the Built Environment, at the University of Salford, Media City Campus. The school currently has over 200 postgraduate Researchers engaging in Full Time, Part Time, Professional Doctorate, Split Site and online doctoral programmes, enjoying a vibrant and multicultural research environment with researchers from diverse backgrounds.

This conference creates a wonderful opportunity for researchers from Salford and other parts of the world to share their research interests, and outputs and to network and interact within a professional and friendly environment, with high profile academics and leaders within the built environment.

This year's conference brings together participants from a broad range of countries including the UK, Turkey, UAE, South Africa, Hong Kong, Iraq, Saudi Arabia,

The conference received over 141 paper and poster abstracts, and accepting 74 papers and 13 posters covering the following themes:

- Business, Economics and Finance
- Design and Urban Development
- ICT, Technology and Engineering
- People, Skills and Education
- Property and Project Management
- Sustainability and Environmental Systems

These themes bring to the surface the diverse nature of Built" Environment research, which contribute towards innovative, challenging and timely issues facing the construction industry and various stakeholders within academia and industry.

On behalf of School of the Built Environment, the conference Co-chairs & organisers, we wish you an enjoyable and fruitful experience and thank you and your sponsors for your attendance and for making this conference happen.

Prof. Vian Ahmed

Conference Chair
Associate Head International
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ID 125

Affordances of BIM during the Architectural Design Process

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Abstract

Building Information Modelling (BIM) represents a move away from traditional practices and the formation of digital models to enable optimized decision making throughout planning, design, construction and operation stages of a facility's life. Usage of BIM is increasing, and seemingly has the capacity to transform every aspect of the construction industry, therefore making it essential for architectural practices to adapt and embrace this new way of working. Delivering projects through BIM within the UK construction industry is reaching a state of necessity. With the UK Government's mandate for BIM implementation coupled with developments in the BIM area, industry practitioners are becoming increasingly under pressure to adopt BIM. BIM technology can potentially change the process and product of architecture. According to Gaver (1991), new technologies primarily concentrate on the current articulated needs and tasks of the users and have the tendency to overlook the innovation potential of the new technologies at the same time. Understanding affordances that BIM can bring to the process of architectural design is a significant factor in the verdict of successful BIM implementation. This preliminary research aims to identify functional affordances of BIM and explore how they influence the architectural design process. Data collection was carried out through semi-structured interviews with BIM coordinators, architectural technologists and designers working on BIM projects to understand their perception of affordances that BIM can bring to the process of architectural design. We found that most actors/designers realize the potential of functional affordances of many BIM applications, however only a few utilize this capacity to enhance the design process. The literature and the results obtained through the interviews both revealed a potential additional affordance category which relates to the design stages and the use of BIM.

Keywords:

Affordances, Architectural Practices, BIM, Design Process, UK Construction Industry

1. Introduction

Currently in the UK construction industry architectural practices are adopting Building Information Modelling (BIM) at an increased rate. In this paper we have analysed the way in which design professionals have adapted their BIM-based design activities. Attempts to link the design tools and the functional affordances of BIM technology have been made by applying the affordance categories which were introduced by Gaskin (2010). However the main focus of this paper is to link the affordances at a much higher level of the design processes. By understanding some of the fundamental ways in which designers think we have attempted to link the affordances associated

with BIM technology for the following stages of the design process: analysis, synthesis, evaluation and communication.

The main aim of the research is to identify different functional affordances of BIM in the architectural design process and to explore the perception of their significance to the designer during the design process. Further, the work is expected to contribute towards the ongoing research, which is focused on the broader aim of integrating BIM into the UK construction industry based on Government mandate. This study of affordances and BIM can be placed within the current research stream on BIM's impact on social and organizational practices in construction projects.

2. Literature Review

2.1. Design Process

Architecture is one of the fields which is most centrally placed with in the spectrum of design (Lawson, 2007). In the context of architecture 'design' can be defined both as a product and a process (Lawson, 2007; Ostman, 2005). "Architectural design" refers to both the piece of architecture as an end product and the process which the architectural piece is created. This particular study places emphasis on the process of architectural design with the tools that designers are now able to use with BIM technology. According to The Royal Institute of British Architects (RIBA) the design process contains three sub stages; concept design, developed design and technical design which falls between preparation brief and the construction stages (RIBA, 2013). However in reality, the practice challenges the existence of pure sequential building process due to limitation on time, budget, resources and contractual models. Thus there is a certain amount of interplay between unpredictable, highly interactive and non-sequential activities on one side and sequential and regulated activities on the other (Moum, 2008; Sariyildiz and Schwenck, 1996). Similarly affordances may be perceived as sequential. This is when acting on a perceptible affordance leads to information indicating new affordances (Gaver, 1991).

According to Kalay (2004) and Lawson (2007) the creative design process can be described as complex realm of predictable and un-predictable interactions and dependencies among actors and their actions. Lawson (2007) talks about a three stage design process with analysis, synthesis and evaluation which were linked with an iterative cycle. However in Kalay's view this formalized process of architectural design consists of intertwined phases of analysis, synthesis, evaluation and additional element of communication which acts as the glue that connects the rest of the phases together. Thus this paper will focus on the categorization of the following key stages of the design process against the affordances of various BIM tools. BIM technology used by designers has challenged conventional thinking and begun to create a new standard for the entire industry (Di.net, 2009).

2.2. Building Information Modeling

The UK HM Government defines Building Information Modeling (BIM) as a collaborative way of working, underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining assets. BIM embeds key product and asset data and a three dimensional computer model that can be used for effective management of information throughout a project lifecycle – from earliest concept through to operation (HM Gov, 2012). What is important to highlight from this definition is the efficiency of the design process. Penttilä (2006) also supports the influence of design process and defines BIM as "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". Building Information Modelling has shaped the way that designers operate at different working stages of a development. The most prominent market-scale, and academic BIM implementation surveys and ratings have been developed globally by France & Germany (McGraw-Hill, 2010), U.S. (McGraw-Hill, 2012), UK (F. Khosrowshahi, 2012), Finland (T.Lehtinen, 2010), Iceland (I.B. Kjartansdóttir, 2011), Sweden (O. Samuelson, 2013), and Australia (N. Gu, 2010).

BIM creates a 'resonance' between analysis and synthesis within this process of discovery. Kalay (2004) viewed design as a process of discovery. BIM can be seen as an informant with this process of discovery. BIM "put forth unexpected elements of synthesis as key ingredients for discovery". Therefore "discovery is a double relation of analysis and synthesis together" (Blake, 2011: 01). According to Blake (2011) analysis "probes for what is there" and synthesis "puts the parts together". This compliments Kalay's view of design as an act of puzzle making and attempting to create a new whole by synthesizing the given parts. Accordingly BIM fuels up the mind of the designer in pulling these elements together in non-intuitive ways within process of design.

2.3. **Affordances**

Affordances are the fundamental elements of perception. Humans perceive the environment around them in terms of its potentials for actions. Thus affordances show independency from the perception and exist whether the perceiver cares about them or not, whether the perceiver perceived it or not, and even whether perceptual information of the affordance is available or not (Gaver, 1991). A study conducted by Gaskin et al. (2010) on digital design routines across several project based industries have found five elements which are important for the analysis of design activities. These elements consist of: activities, actors, tools, affordances and design objects. Activities are incorporated with actors whom are engaged with tools which are capable of affording the actors the opportunity create design objects. Similarly this paper will look at the ways in which BIM technology and its tools afford actors to create design objects and how this influences the design process.

Table 1. Lexical model of Affordances (Gaskin et al. 2010)

Affordance	Definition
Representation	functionality enabling users to define or change a description of a design object
Analysis	functionality enabling users to explore, simulate, or evaluate alternate representations or models of objects
Transformation	functionality to execute a significant planning or design task
Control	functionality enabling the user to plan for or enforce rules, priorities or policies governing or restricting the design process
Cooperative Functionality	enables users to exchange information with others
Support	functionality to inform users in which context production and coordination technology will be applied
Infrastructure	functionality to transport knowledge, skills or methods to other projects or planning situations
Store	functionality allowing information to be housed within a device

3. Methodology

This is an applied research inquiring into architectural practices. Background and preparatory reading was used to identify and formulate the research problem. In addition this was expected to provide assistance in selecting an appropriate research methodology for the study. A mix of both inductive and deductive approaches was used within this research with an overall leaning towards the inductive process. Deductive approach requires a clear theoretical positioning prior to its testing through empirical observations (BUSM, 2007; Tan, 2002). In contrast, the inductive approach involves moving from the observations of the empirical world to the construction of explanations and theories about what has been observed (Gill and Johnson, 2002).The literature review is expected to provide the necessary frame of reference and background with the gradual move towards overall inductive approach by collection of data.

During the literature review the concept of affordances focuses on the actionable properties latent in the environment. Affordance of BIM in the Architectural design process forces on the actionable properties which BIM can bring in to the architectural design process. The research was aimed to identify and evaluate affordances of BIM and evaluate different affordances against the context. Therefore the research was required to adopt a research philosophy which provided a framework for understanding, measurement and evaluation of the behavior related phenomena such as affordances. Semi structured interviews involving six BIM coordinators/architectural technologists/designers were carried out. These interviewees were chosen on the basis of competencies in the use of BIM applications and involvement on projects implemented through BIM. Interviews were conducted face-to-face. The interviews were focused on reconfirming the findings of literature survey with UK construction industry context. Interview questions were structured to follow the RIBA design stages to inquire into the nature that BIM affected the design team member roles at different stages of the development, as well as the tools and procedures used

at each stage. The stages discussed were Preparation and brief, concept design, developed design, and technical design. Further findings of the literature survey were also used as appropriate as stimulus materials during discussions. Additions and omissions in the themes and areas were made to in the structure to some extent during the interview depending on the flow of the conversation and the situation. It gave the flexibility to explore in depth on certain aspects and areas sometimes crucial to each organisation in terms of their own work flow, procedures and standards. The interviews were recorded, transcribed and coded in order to identify BIM tools and affordances comprising the design routines under study. (Fig 2.)

4. Results

4.1. Function Task Interaction Matrix

Based on the interviews, functional affordances were identified linked with the tools that have been outlined by the BIM coordinators and designers. Figure 1. Displays how each tool has been mapped against Gaskins Affordances categories. The Function Task Interaction Matrix (FTIM) proposed by Galvao and Sato (2005) identifies affordances as the intersection between artifact structure and user tasks. A similar approach has been applied with Figure 2. Identifying intersections between BIM affordances outlined by the designers and Gaskin's categories of affordance. This matrix has been used to map out the functional affordances of the BIM tools which were outlined during the interviews. Each BIM tool or function identified during the interviews has been placed in the function matrix against Gaskins categories of affordances. Even though all the tools were familiar to the interviewees the frequency at which they are actually used in practice varies. An emerging functional affordance outlined by all of the interviewee's in relation to BIM implementation and design stages remains validation/checking. This is a category which was not introduced by Gaskin, potentially due to the limitations of CAD tools as a whole.

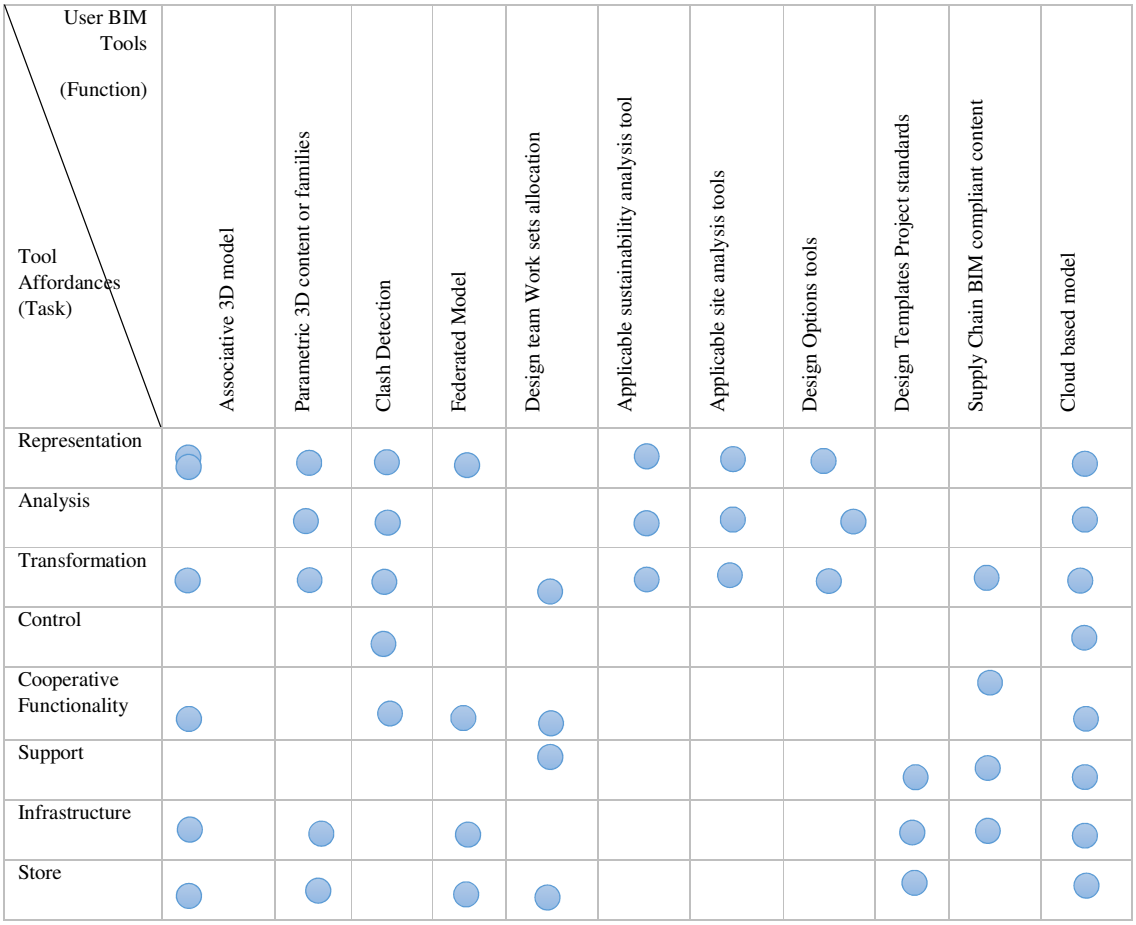
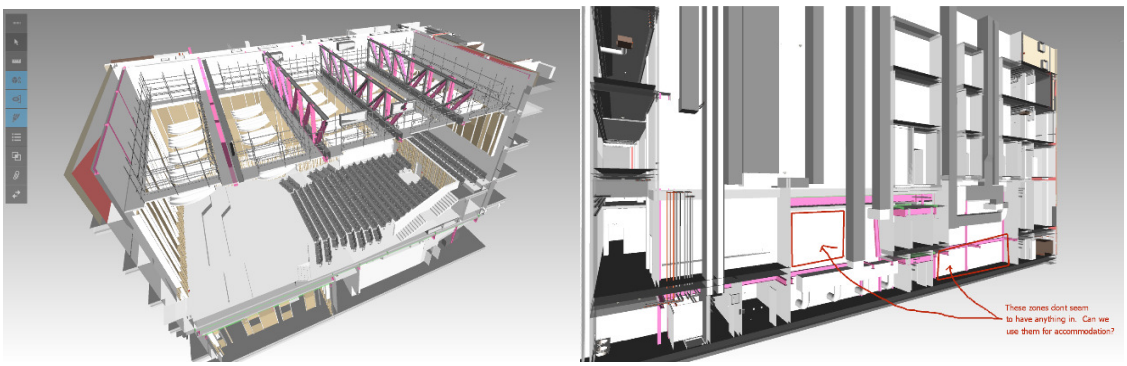


Figure. 1. Function Task Interaction Matrix: Adopted for Gaskin's BIM tools and Affordances

Cloud based modelling tools enabled most affordances from the 8 outlined categories. Figure 2 shows how the 3D model can be integrated and viewed by design team members, as well as used as a communication platform to inform design decisions. Cloud based models as shown in the FTIM enable multiple stages of the design process to be explored: Analysis, Evaluation, Communication and Synthesis. Figure 1.b. displays communication on design elements between the Design team members accessing the cloud based model**.**



(a) (b)

Figure 2: (a) Linked models of the architectural, structural and mechanical models of a BIM coordinated project in Autodesk Glue. (b) Display of Autodesk Glue; a cloud based data sharing platform for the integration of 3D models which enables communication between the different members of the design team.

Figure 1. can be used to view the overall affordance appearances for each BIM tool. This will enable the understanding of how the tools used can fit into a number of the affordance categories. The focus of this matrix is to display the number of affordances applicable for each tool. For certain tools we can see a higher number of functional affordances associated than others. The FTIM matrix when mapped against the affordance categories indicates the way in which cloud based modeling and data sharing fits into all of the affordance categories outlined. It is through cloud based modeling where interviewees have confirmed the correlation between cloud based technology and its impact on the design processes. It has a direct correlation in communication between design team members. Interviewee C: "*We can use BIM 360 Field to impact the way in which designers coordinate and communicate with each other*" As well as communication cloud based BIM management shows impact in decision making. Interviewee C: *"…designers can directly communicate with relevant contractors designers and make design decisions directly within a few hours…*" This supports the argument in direct influence of the design processes such as synthesis and analysis.

5. Discussion

FTIM matrix (Fig 2.) figuratively demonstrates which of the BIM tools commonly referred to by the interviewees fit with Gaskin's Affordance categories. An important factor to note is that Gaskins categories of affordances were outlined in relation to CAD tools. During the interviews it became evident that validation and checking of linked files is a crucial functionality, which has only recently been applied in practice through data integration of common BIM compatible file formats such as IFC files. Transformation which according to Gaskin allows the functionality to execute a significant planning or design task. Transformation as an affordance is being enabled by the following BIM tools; Associative 3D model; parametric 3D content or families; Clash Detection; Applicable sustainability analysis tool; Applicable site analysis tools; Design Options tools; Cloud based modelling. This was also supported by the discussions with the interviewees. Interviewee A; "*It's informing the designer about their design decisions based on a 3D model…*"

If we look at the same table from the context of design processes it becomes evident that representation is an affordance that allows analysis related functions. Another significant affordance is Representation. According to Lyytinen et al. (2009) representation is particularly important to design, as iteration across representations is the fundamental activity of all design activities. Representation is yet another significant affordance associated with a number of the tools outlined by the designers. Synthesis is a reoccurring design process stage which can be linked with the affordance of representation. This can be seen enabled by the use of 3D models and integration of associative 3D models.

Primary benefit of using BIM technology and application in the production of design is the reduction of time. Drawing production and amendment can be a time consuming process, BIM applications enable a significant time reduction. Some of the tools made available through BIM applications were never really explored prior to the shift to 3D information modeling. BIM technology is promising to manage even some of the more vague building and design criteria, such as design richness or even overall building quality can be managed though BIM technology (Penttilä, 2006). While most designers agreed that the tools enabled efficient and quick means to produce drawings and schedules, there is a negative impact on time at the later stages of the design. Interviewee E expressed that more time should be given at Concept Design stages. While the tools enable quick designs models are embedded with more information than required at concept design stages, this can also be a hindrance at later stages of the design process. Whereby the client is shown more detail than required at Concept stages which can further affect the overall process of the design development. According to Coates et al. 2010, BIM concentrates too much on providing a representation of the final form of the design, whereas designers also need a continual stream of abstractions, advice and information to move from information to the distillation of knowledge. Few BIM tools can accommodate the ambiguities of early design. To accommodate concept design stage Pauwels et al. (2009) recommends that the concept of architectural informational modeling should be developed as a precursor to BIM in the design practice. This concurs with what Interviewee E discussed during the interview. Interviewee E: "*The concept stage should be stretched to allow stakeholders to have an input, before you sign off feasibility. Once you have a concept model it's almost too tempting to start populating it with information …The perception is that if that information is embedded in the model it must be right*." Some of the modeling tools through BIM applications actually act as a hindrance at these early design development stages, due to their level of detail attached with the 3D objects. Their tools can be seen as limiting the amount of time spent on developing and valuating designs. On the other hand Interviewee B discussed how "*the more traditional methods of pen and paper design will never fully disappear, and the designs are only enhanced to evolve quicker through the use of 3D representation*". This 3D representation helped develop the designs which were initially made by the more senior practitioners, used with the more traditional means of design development.

During the interviews conducted with the Coordinators and designers, it became evident that the practices that were practicing a higher level of BIM maturity had a better understanding of the available tools for the designers and their functionality. The number of tools utilized when implementing projects at a higher BIM maturity level increased for both the designers and other stakeholders. This was in particular demonstrated by Interviewee C when discussing how their projects were linked through cloud based platforms. As demonstrated in the results Cloud based modelling tools is associated with all of Gaskins categories. Following this is 'Clash detection' tools made available through BIM applications. This is also associated with almost all of the affordance categories.

This paper has explored Gaskins work by an in depth discussion of the similarities and differences of the design routines within the UK architectural practices, though new digital design tools such as BIM. This paper is limited in that we did not provide a longitudinal perspective identifying if and how these design routines change over time, when more dimensions are linked with the BIM model. Each year the tools available for designers to extract and analyse new dimensions of a project increase. Deploying a longitudinal perspective explaining how new modelling dimensions i.e. 4D, 5D,6D etc. will influence the cognitive design processes of the actors could be a worthwhile avenue for further research. The design process and its stages are a reoccurring phenomenon during the project development stages. However for projects that are being implemented at a Level 3 or above evaluation and synthesis becomes reoccurring tasks given to the designers with the help of checking and auditing. An example of a new dimension that is currently underway for BIM technology has been introduced by the BIM Task Group. This will enable a checking existing designs and auditing their compliance with regulations. 'BIM4Regs' in the UK is aiming to link building regulations with working models Lewis (2013). Clash detection can be seen as a means of correction in design. Coates et al. (2010) stated that correction 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.

6. Conclusion

Evidence from this study suggests using BIM tools and technologies provide more capability for the designers during the architectural design process. The potential affordances of these tools are only realized though the 'actor' or designer. Although these tools as shown in Figure 1. provide affordances and can be used in most of the stages of the design process, the benefits of realizing the affordances require comprehension from the designer's side. Therefore an 'actor' or designer becomes more important than the tool used at hand. These tools can enhance procedures but without understanding of these tools the list of affordances associated with that tool will fall short. The benefits associated with the affordances of the tools are only as good as the users behind the design understanding how those tools work. By fully understanding the functionality of different tools offered through BIM technology the designer opens up their possibilities of affordances. Therefore it could be added that within an architectural organization resources should be allocated to updating the understanding of latest tools and technology and for the exploration into tools that may enhance the efficiency of design stages. Future areas of research are related to the organizational management of practices in terms of allocating a designer whom is both proficient in design and well informed of the tools that are being used to facilitate that design.

Findings also show that the function to audit enhances the merits of using integrated models in BIM. The information of a BIM model affords the use of checking and auditing for various purposes such as costing, regulations, minimum required distances, and structural compliance. Furthermore, BIM applications enable designers to check and detect clashes. Clash detection tools can be seen as a crucial step towards better synthesis and evaluation of designs. These functions are enabled in various software platforms i.e. Revit, Navisworks, and Solibri. One distinctive affordance of implementing BIM technology is the ability to check models produced by various design team members as well as the supply chain. With this affordance, BIM projects are moving towards enabling the users to further check their information within the model.

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