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# Understanding BIM in the UK Construction Industry using an Activity Theory (AT) Approach

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## Abstract

Building Information Modelling (BIM) is a collaborative way of working, underpinned by virtual digital technologies which unlock more efficient methods of designing, developing and maintaining infrastructure assets in the built environment. For the impact of BIM to be readily appreciated and felt among practitioners within the construction industry and beyond, there needs to be a sound research theoretical underpinning approach that will embrace the physical, environmental, social and digital nature of BIM. One such approach that will bring clarity and support a deeper understanding of the impact of BIM is activity theory (AT). This paper seeks to position BIM activities that are happening within the construction industry by better understanding the different interactions between practitioner and stakeholder as they use the virtual BIM environment to create, design, develop and maintain the physical built environment.

**Keywords:** BIM, activity theory, impact, construction

## 1 Introduction

Building Information Modelling (BIM) is changing the UK construction industry – a vitally important sector that employs more than two million people (6.2% of the UK total workforce) and contributed £103 billion to UK economic output in 2014 (Rhodes 2015:4-5). Over the next decade, BIM technology will combine with the internet of things (providing sensors and other information), advanced data analytics and the digital economy to enable more effective planning of new infrastructure, build it at lower cost, and operate and maintain it more efficiently. Above all, it will enable citizens to make better use of existing infrastructure.

The UK Government (2013:5) aimed to improve the UK design and construction industry by lowering costs by 33%, delivery speed by 50% and emissions by 50%, and to boost exports by 50%. These put BIM at the heart of the government's industrial strategy which aims to keep the country's design and construction sector at the forefront of what is now known to be a global industry (HM Government 2013).

There is a drive towards the use of BIM in built environment projects worldwide, and it has been argued that clients are central to the success of BIM adoption and usage (BCA 2011). BIM is a collaborative way of working, underpinned by digital technologies which unlock more efficient methods of designing, developing and maintaining infrastructure assets in the built environment. Therefore, the purpose of this paper is to establish a clear direction for the usage of activity theory (AT) in understanding, developing and researching into the prevailing issues that will impact on this digital platform.

The paper is divided into five sections, excluding this introduction. First, the literature develops the timeline of BIM technology, with particular emphasis on the UK construction industry. The next section develops current issues of communication problems downstream in the life cycle approach of a project within the built environment. The subsequent section develops the concepts and understanding of AT. The discussion section develops the

application of AT with BIM technology as the dominant focus for appreciating and understanding the impact of BIM innovation on the construction implementation stage of a built environment project. Finally, a conclusion is drawn.

## **2 BIM Implementation – Drivers and Forces**

The UK Government is pushing for BIM adoption and has mandated BIM for all centrally procured government contracts from April 2016. The UK construction industry must, therefore, meet this challenge. This can only be done through implementation of BIM to enable the delivery of more sustainable buildings, in a shorter time and to a more efficient standard. Moreover, BIM is critical to the successful implementation of a wider offsite manufacturing strategy (HM Government 2013). Further, to gain or maintain a competitive advantage in the construction market, many practitioners and contractors started adoption of BIM level 2 as prescribed by government, while others had started its adoption even before then the mandate for the benefits can be gained.

The other drivers for the construction industry adopting BIM are the capabilities its technology possesses. These, it is expected, will contribute to addressing long-standing challenges in the construction industry (Sackey et al. 2014). For instance, BIM can lead not only to improvement in the technology itself, but also to a possible revolution in the design and construction process (Yan & Damian 2008). This is supported by a study conducted by Aranda-Mena et al. (2009) which found that in three out of five case studies reviewed, use of BIM could enhance design development, confidence and buildability. For his part, Eastman (2011) argued that using BIM in design detailing processes would improve the likes of quicker 3D visualisation, with accurate design at every stage of the design and construction process. It is also asserted that BIM technology has the potential fundamentally to change construction documentation and promote information sharing among all parties involved in the delivery of a project (Singh et al. 2011).

Eastman et al. (2011) pointed out that construction plan sequence and synchronisation of lean construction techniques, where materials would be organised in an efficient manner for each segment of the work, might result in cost reduction (material resources for each segment). As stated in the National Building Specification (2015) BIM report, 63% of respondents surveyed think there would be reduction in costs. In another survey conducted by Eadie et al. (2013), cost of implementation was ranked last in response to a question about the impact of BIM adoption. Bryde et al. (2013) found that in 60% of the case studies they reviewed, cost reduction or control was seen as the most positive effect of BIM.

Architecture, engineering and construction (AEC) Industries have great potential to transform their information, communication and technology (ICT) resources into compatible and interoperable software (Grilo & Jardim-Goncalves 2010). While BIM might combat this interoperability issue through collaborative working environments, traditional techniques such as 2D drawings (commonly referred to as blueprints) and 2D and 3D CAD have a limited amount of communication that could be conveyed, and the message received might be different to what was intended.

Aranda-Mena et al. (2009), who examined two case studies, found that BIM could improve collaboration between consultants and stakeholders. However, the level of BIM maturity that a company aimed to achieve should be assessed before presumptions of potential BIM benefits would be understood. One of the findings by Khosrowshahi and Arayici (2012), from interviews with industry practitioners, was that seamless collaboration between project participants was achieved. Humphreys et al. (2001) suggested that inter-organisational information systems (IOIS) could be seen as key to allowing the flow and sharing of accurate and well-timed information (e.g. project documents), thus facilitating competitive advantages in ways such as eliminating duplication. Bryde et al. (2013) observed that adoption of BIM could be the key approach to ensuring that integration and a shift from a document paradigm to an integrated database paradigm happens. Additionally, Eastman (2011) concluded that stakeholder collaboration would minimise mistakes in that field. BIM is impacting not only the design, construction and management of buildings, but also the cultural process for the design and construction sector. One way to address this impact is to use the AT approach.

### 3 AT Concept and Application

AT advocates a robust concept of mediation in which all human experience is shaped by every tool and sign system employed. It is a clarifying, descriptive tool rather than a strongly predictive theory (Nardi 1996). It is a tool for analysing the operations of social structures both at points in time and over time. The AT concept was originally developed by Leavitt (1965) as a conceptual framework from the socio-cultural tradition. The tool demonstrates the interactions between different parts of social systems in pursuit of a particular objective. These parts are grouped into six elements: subject; object; tools; rules; learning community; and division of labour (Engeström 1999; Pearson 2009), as shown in Figure 1a.

Although from the literature review presented it can be said that both BIM innovation and AT application are found mainly in the design management stage of built environment projects, very few studies with regards to BIM or AT can be found within the construction or implementation stage of a project.

In the implementation of the design to realise a construction project in particular, the six elements of AT are as follows: the subject is the stakeholder (e.g. BIM practitioners), the object is the project, the tool (i.e. artefact) in this case is the BIM technology, the rules are construction project management practices (i.e. inclusive of all the processes, rules and procedures required to bring the project to fruition), the community of practices are all the practitioners, the client and stakeholders, as well as the general public. The division of labour is the practitioners that are essential for the construction phase of the project or, more realistically, the organisational management structure for implementing it.

### 4 Research Methodology

This paper focuses on only the first phase of research. The focus is on understanding the impact of BIM on AEC industry practitioners using AT. The methodology will be more qualitative in approach than quantitative. As such, the first phase of the project is to assimilate all relevant literature in understanding our study domain. This will entail literature on BIM adoption by the construction industry, AT approach and the impact of BIM implementation on practitioners. The research instrument to obtain data will be an eclectic interrogation of the literature (Creswell 2013), which will involve both a deductive and inductive understanding of how to acquire the knowledge for future synthesis of the data gained.

The sources used in this study came from the following areas: peer-reviewed academic journal papers, conferences and e-databases. A keyword search technique was employed in this research to find information that was relevant to the impact of BIM implementation on practitioners. The relevant terms used were: BIM; socio-technical systems in the built environment; innovation in BIM; and activity theory in the built environment. The information collected was then categorised as key information and supportive information, based on its relevance to the research study and how it would be used.

### 5 Communication Issues of Built Environment Information and Models used

We live in a competitive world that is ever changing in technology, processes and the way we procure and develop business organisations. Companies are always on the lookout for how best to carry out their business functions and also be resilient in this environment. Organisations within the built environment are no different. The UK Government as the client in the driving seat (HM Government 2012), the built environment company is now focused on beneficial exploitation of BIM technology.

There is an apparent consensus that BIM technology is proven and that its design management benefits are clearly established and widely used. Recent industry surveys of designers suggest adoption figures to be as high as 64%. In construction management, getting the right information to the right place means overcoming the challenges of organisational fragmentation and the site-based location of work (Davies & Harty 2013). However, in construction management, the BIM technology landscape is different and not yet a properly established area of understanding. Within construction management studies, there are not many published on BIM usage.

According to Davies and Harty (2013), site management work is still dominated by paper, whether in the form of drawings and other design information or in the use of paper notes and forms for capturing information. Proponents of increased use of on-site digital technologies point out the costs, errors and delays associated with translating paper-based data to digital and vice-versa as information flows back and forth from site to office. Innovation researchers understand construction as a 'complex systems industry'. For each particular construction project, a diverse group of actors and organisations has to be brought together in a network for delivery. The other significant feature of the construction industry for understanding construction innovation is the project mode of delivery (Davies & Harty 2013).

Munns and Bjeirmi (1996) considered a project as the achievement of a specified objective, which involves a series of activities and tasks that consume resources. From the Oxford Dictionary (1990), 'criterion' is defined as a standard of judgement or principle by which something is measured for value. Lim and Mohamed (1999) construed 'criterion' as being a principle or standard by which anything is or can be judged. Owners, designers, consultants, contractors and sub-contractors have their own project objectives and criteria for measuring success. However, clients may value other dimensions more highly than those areas considered a priority by practitioners (Chan & Chan 2004). Hence, there is a need to establish performance indicators that will address the conflicting area of practitioners and clients focusing different objective lenses on project success.

Key performance indicators (KPI) are the instrument used for measuring project success. Their purpose is to enable measurement of project and organisational performance throughout the construction industry (KPI Working Group 2000; Chan & Chan 2004). KPI may include both objective and subjective measures. The former include time, cost and accident rates, while the latter include quality, functionality, client satisfaction and construction team satisfaction. Until recently, most KPI in construction are a theoretical construct that is refined in practical applications. The downside, though, is that there is no continuous history or evolution of how such KPI are refined and improved in successive construction projects. As every innovation or technology goes through a period of growth and maturity, so too should KPI evolution which should be refined to address issues that may be the 'cost drivers' elimination for success (Sadeh et al. 2000). Considering the various issues that will represent a successful project from a stakeholder perspective, it is apparent that most will involve technological and sustainable issues, as well as the social elements of the project. This may be viewed as constituting socio-technical understanding of the project.

## **6 Socio-technical Systems of BIM Usage**

Perez (2002) suggested that there is a mismatch between technological and social-institutional development. Technological changes driven by competitive pressures proceed apace, while institutional changes have a strong inertia and lag behind. New technologies are brought to organisational structures that were developed during the previous technological paradigm. Models were frequently and creatively used by construction engineers on site for quantity calculation, procurement and scheduling, as well as for guiding the work of sub-contractors on construction sites (Miettinen et al. 2012).

During the life cycle of an engineering project, a voluminous amount of data and information is usually created to deliver the processes of construction products, as the construction team must consider a wide variety of information when controlling the project and making project decisions.

Important relationships between different pieces of project information are not communicated effectively, as construction information is not integrated and used effectively within the AEC industry. At present, some data models have been established for integration purposes. BIM is a computer model database of building design information that may contain information about the building's construction, management, operation and maintenance (Wu & Hsieh 2007).

Therefore, scholars have assumed that reforms in organisations will be executed smoothly once change has been adequately specified, designed and technically or strategically implemented with new management frameworks or practices (Schweber & Harty 2010).

The critical issue is that collaboration is implicit in the work of the construction profession; thus, software designers must have a broader understanding beyond technical abilities to include the complex work context in which technologies are used, in order to facilitate the dynamic interactions that take place in project delivery (Eastman et al. 2011; Sackey et al. 2014).

Further, although building a federated BIM model and ultimately delivering an efficient project to the client is the central focus, designers, engineers, and the other construction team members have their individual work to do; therefore, motivations and concerns are quite different (Brown & Phua 2011) for each type of practitioner.

In any purposeful organisation, activities are required to be performed, the desired outcome being achieved through the actions of both the social and the technical system. Also, to understand the work system, one must understand the environmental forces that are operating in it. This type of analysis is based on the observation that implementing a successful technology requires a thorough understanding of the organisational context, such as its structure, work and the workplace.

Building on the relevant literature, this paper has focused on the implementation of a BIM solution in an intra-organisational construction practice and provides an account of how novel technological artefacts, in the form of products and concomitant process solutions, were mutated across multifarious functional units in the historical context of the organisations assessed.

Miettenen et al. (2012) introduced an activity-theoretical approach for studying the conditions of implementing and utilising BIM in the AEC industry. They stated that the first methodological principle of the AT approach is to have a realistic conception of the potential of BIM. Further, an ethnographic study of the uses of BIM by different disciplines and practitioners, and collaborative uses in particular, needs to address the following areas:

- Ethnography of the uses of BIM tools
- The object-orientated nature of BIM modelling
- The developmental contradiction as a foundation of change and learning
- Developmental interventions of AT.

Because BIM is a transitional process, this study includes the relationships between the use of BIM tools, non-BIM software tools and traditional tools. For the development of BIM, it is also important to determine to what specific forthcoming use key participants imagine it can be applied, and why they find these areas important. BIM offers an environment in which an AT framework can be developed and used to understand not only the BIM environment but also the socio-technological nature of the project being developed.

## **7 Discussion – towards an Activity-BIM based Framework**

According to the diagram given in Figure 1b, to appreciate the impact of BIM, one of the six variables will have to be fixed when the others are studied. For example, if we are assessing the success of a project from the client's perspective, then what are the client's performance indicators that will give us an understanding of its success? If the client's requirements are met effectively and executed efficiently, these will be the objective on which the object will focus. An explanation of Figure 1b is given below.

- The tool – BIM technology is the database that will have all the rules needed during the construction of the project; it will also be connected through algorithms or macros for practitioners to update areas that are required to be populated, such that indicators for success of the project can be investigated
- The subject – mainly project stakeholders; essentially, for this study the client is considered the stakeholder.
- The object – the project being developed from the design elements in the construction stage, as included in the BIM database. Hence, the object in this case is dynamic, as it comes to realisation over time.
- The rules – all processes and procedures that govern successful implementation of the project. They are the specification, costs, quality standards and H&S management.

- Community – those actually involved in the development stage of the construction of a built environment project.
- Division of labour – mainly the organisational structure required for the implementation or construction of the project.

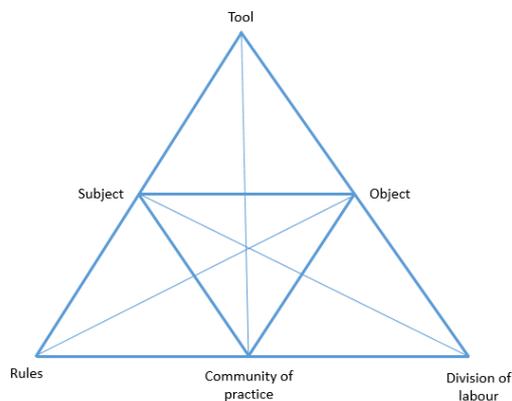


Figure 1a: AT model (adapted from Engeström 1999)

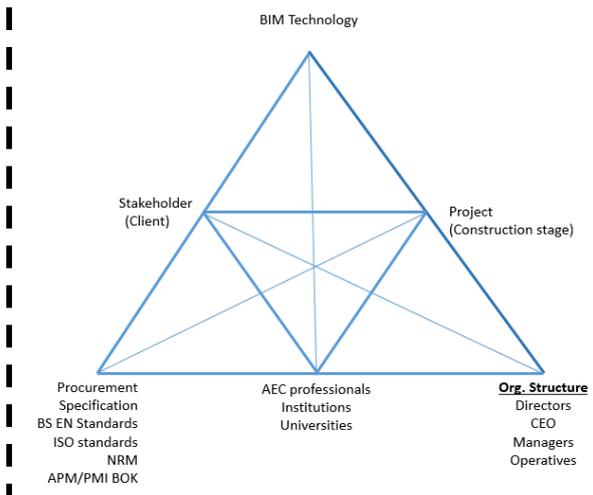


Figure 1b: AT BIM framework

Therefore, for a project to be deemed successful depends from whose perspective the subject of the model is viewed. When KPI are fully developed in this research, one can actually see their trend when compared with other similar projects as control variables. Also, according to AT, studies can be conducted at different level of abstraction, at different project stages. For example, the project manager can be the subject for a particular work package that is being implemented in a project to be studied independently.

## 8 Conclusion

It can be concluded that until a very proactive approach is taken to understand how BIM innovation and practice have changed the workings and communication practices of construction practitioners in the built environment, the real impact and benefits of this innovation will remain elusive. Understanding of its impact will only be gained through a sound theoretical underpinning study, which AT offers. Moreover, without a theoretical understanding of the trends and patterns that are evolving in harnessing the power and applicability of BIM innovation and practice, it would be difficult to carry out a comparative study as to how the impact is felt worldwide. AT offers BIM activities a sound foundation in which the technology can be understood, both in its interaction with the environment and the human elements that actually use it in their day-to-day work. Hence, with regards to the UK industry, we will be able to acknowledge that the idea of level two BIM has been surpassed and that level three is now in place. This research is focused on large construction organisations, as such, the understanding can later be translated to SME industries that are not currently major players in the application of BIM technology.

Further work in this research involves the development of KPI and algorithms within BIM technology, if its impact on the success of a project is to be appreciated. This research also intends to use the AT application for projects at a detail level once AT and BIM are fully understood and integrated at a macro level.

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