MAPPING ROLES IN AN ALTERED LANDSCAPE – THE IMPACT OF BIM ON DESIGNER-CONSTRUCTOR RELATIONSHIPS

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ABSTRACT

The increasing uptake of Building Information Modelling (BIM) is contributing to pressures and changes in the architecture, engineering and construction (AEC) industry, which require adjustments and adaptation in the roles of almost all participants. One of the most commonly cited changes is the increase in collaboration and a shift to more integrated project teams. Thus the traditional role descriptions for the various professionals involved in a construction project become less distinctly separate, or new roles emerge. Definitions of skill sets and competencies that have been charted over many years are now being unpicked and reshaped as the needs of industry change.

Different organisations, projects and partnerships take different approaches to the adoption of BIM, and consequently there are several different strains of work under this broad umbrella. This has resulted in a wide variety of interpretations of what constitutes successful or appropriate BIM use, and it is valuable to distinguish between the varied concerns. The impact of BIM and its associated process changes vary considerably depending on how it is interpreted and whether a global or an incremental approach is taken within the project or organisation. There is also significant potential for unexpected effects on the nature of the product (the design and construction of the built environment) or on the organisations and industry structure, beyond intended productivity improvements and quality enhancements.

Based on a review of existing literature, this paper provides a typology for identifying current BIM adoption trends in industry, with an analysis of available empirical data to help identify the effects of BIM on roles within organisational and project contexts. The review centres most significantly on the contours of the designer-constructor relationship. It explores the impacts of the varying degrees of collaboration identified and the extent to which a BIM-mediated process reshapes skill sets and competencies.

Keywords: building information modelling, BIM, industry roles, process change, technology adoption

1. INTRODUCTION

A variety of international surveys testify to the growing interest in, and adoption of, building information modelling (BIM) as a central tool in the design and delivery of the built environment. Much of the interest from the industry is focused on the technology of BIM, a diverse range of core tools and software add-ons which address tasks on a continuum from 3D modelling for project visualisation through to the representation of the complete construction process and virtual construction of the building, and for use in the first stages of design through to the building's completion and beyond into facilities management. This focus on tools and technology is only part of the picture, however. Integration of the additional information and management requirements of BIM into existing professional roles is a challenging element in the wider landscape of BIM adoption.

In parallel with the adoption of BIM technology, significant changes are proposed in the project procurement and management structures within which the BIM process is implemented. The adoption approaches documented across the literature fall essentially into three categories, which represent the different levels of collaboration that take place within and around the BIM model. Many proponents of BIM advocate a fully integrated and collaborative project team that shares both information and responsibility. Others suggest that collaboration or integration is more successful when limited to within traditional professional and discipline boundaries, or further restricted to implementation of BIM tools within a single organisation. Additional roles or processes are often suggested to provide checks and balances to ensure that the information flow is supported.

Both the technological and process changes, and the different routes taken in adoption and implementation of these changes, have implications for the roles of many of the players within the design and construction process. This paper provides a review of published case studies to identify the impacts of BIM on the roles and relationships of architecture, engineering and construction (AEC) industry participants, as documented in the literature. Supporting material such as questionnaire surveys and interviews is also drawn on, to help integrate the findings across the case studies. Particular focus is given to the designer-contractor relationship, as much of the discussion around roles centres on the blurring of the boundary between these two previously distinct roles.

2. BIM ADOPTION MODELS

The scope of implementation that different practitioners and researchers consider to constitute "doing BIM" is extremely wide ranging. For some, it is enough to implement a BIM-capable modelling tool within a company or project framework, while for others BIM does not apply to anything short of full project integration. BIM tools offer a wide array of potential applications and actions within a construction project, so the potential exists for many different implementation configurations. The advantages of BIM are evident at every stage of the design and construction process and are clearly not restricted to any specific formula of implementation (Linderoth 2010). Following a review of the literature, three BIM approaches have been identified, labelled here as solo, silo, and social adoption of BIM.

2.1 Solo BIM

A "solo" model exists when a firm uses BIM for its own purposes but does not share the BIM model beyond this. Collaboration on other aspects of the project may still exist, but not around the creation and development of the BIM model. Within the solo BIM configuration, different practices contributing to the same project may each end up creating their own BIM models which are totally independent of one another, and documentation is exchanged on paper or through pdf rather than in model form. One possible example of this is illustrated in Figure 1, where both the Architect and Contractor have developed their own BIM model for a project, but there is no collaboration or information exchange between the two. Other project participants in this example do not use BIM at all.

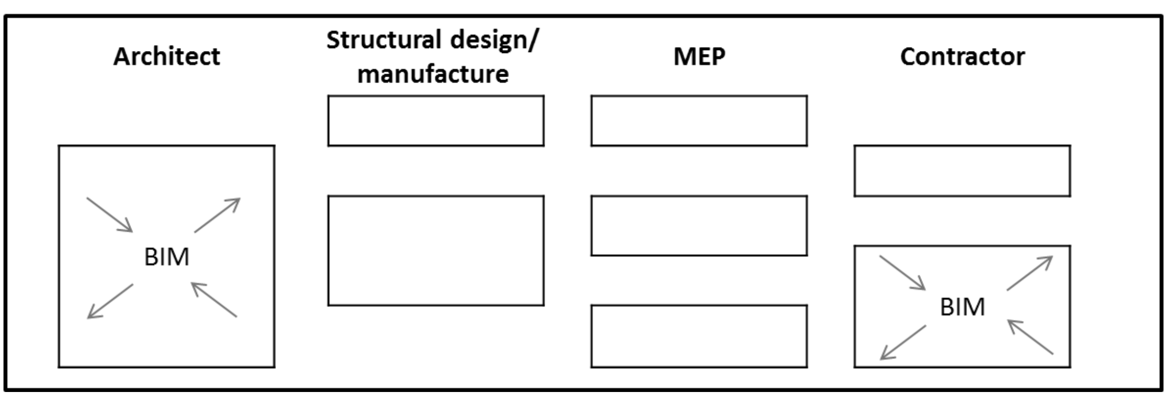

Figure 1: Example of a project structure using solo BIM

Solo use of BIM follows as closely as possible to a "business as usual" mode of operation, and as a result has minimal impact on interactions. However, even within a solo implementation, BIM may introduce challenges to the participants' roles. Coates et al. (2010) examine the introduction of a BIM tool into an architectural practice, and argue that aspects of the architect's role were fundamentally changed, particularly with regard to the creative process. They claim that BIM requires architects to focus on a concrete end product and imposes limits on the design process, rather than facilitating a level of abstraction that allows the architect to fully utilize their design skills. In another paper reporting on the same case study, Arayici et al. (2011) document the process through which a team of researchers assisted the architects to select a BIM tool and integrate it into their practice. While this case study provides little evidence of the changes in practice that this change generated, it concludes that, "(a)lthough the paper had a focus on the BIM technology adoption, it is actually as much about people and processes as it is about technology." (p194).

Another example of solo implementation, from a contractor's perspective, is documented by Babič, Podbreznik, and Rebolj (2010). Again, because the model is not exchanged between different parties there is little or no impact on relationships with project participants outside the contractor organisation. The changes in roles within the construction company do not appear as significant as those described for the architects; however, it is evident that roles do change. The amount of information able to be contributed to the BIM implementation was limited by the need to restrict the workload imposed on site and project managers through increased reporting and data collection needs; conversely, many tasks which previously required paper-based systems were simplified or automated through the new technology.

2.2 Silo BIM

A "silo" approach to BIM occurs when there is collaboration on the development of BIM models within a single discipline or construction task. Similar to the solo model, silo implementation often sees teams from different disciplines creating their own BIM models of the same building, which are totally independent of one another. This structure is well documented in the literature, particularly for the MEP discipline (see, for example, Hartmann, Fischer, and Haymaker 2009; Khanzode, Fischer, and Reed 2008; Neff, Fiore-Silfvast, and Dossick 2010) where the shared model allows subcontractors to manage the high level of complexity in the process, without additional connection with consultants or main contractor. Figure 2 shows an example of a silo approach on a hypothetical project, where the MEP team has developed a BIM model for collaborative use by MEP designers and manufacturers, but the model is not shared with other project partners. In this example, the contractors also have a similar collaborative BIM model shared between different parties involved in the construction phase, but again this is not made available to others in the project.

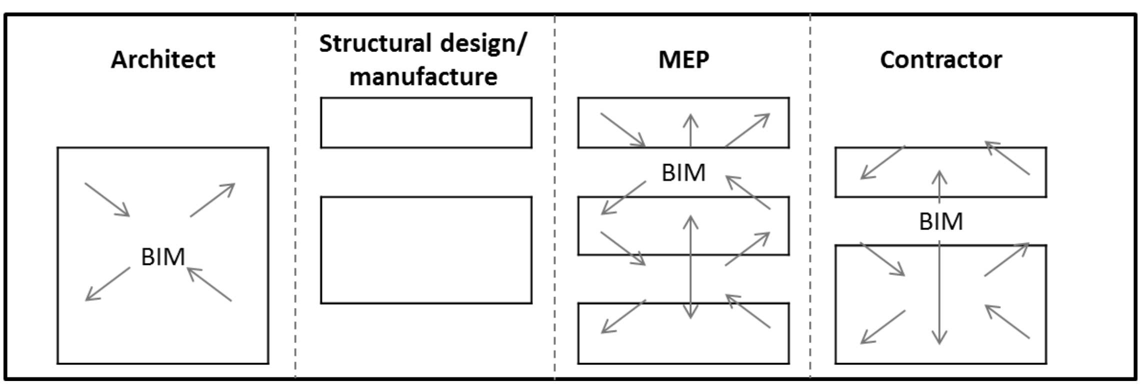

Figure 2: Example of a project structure using silo BIM

Silo BIM use requires some degree of alteration to traditional working patterns and roles, and, depending on the nature of the silo in which it takes place, may also impact on professional relationships. Neff et al. (2010) describe the silo approach found in case studies of project teams making the transition from paper-based to computer-based production, "Architects, engineers, and builders utilized digital models for their own distinct purposes rather than sharing and collaborating within the BIM digital environment as it had been designed to do." (p566) While this might be considered to be multiple solo implementations, a silo approach was seen with the use of a cross-organisation but within-discipline BIM model that allowed the MEP subcontractors on the project to co-ordinate and integrate the detailed design of the mechanical systems for the case study project. However, the model did not cross the discipline boundaries to include input from architects or project engineers, and the MEP team experienced a great deal of frustration as a result of this segregation. They could not access information as they needed it, nor was it easy for them to pass suggestions for improvements back to the designers. Despite this expressed desire for greater collaborative use of the model, many other participants stated that it was practically impossible to create a unified model that both presented a coherent view and provided a basis for all disciplines to work from. Because of the variety of needs and uses of the information, collaborators would need to understand the nuances behind the model, and have the discipline-specific knowledge to interpret it appropriately.

2.3 Social BIM

The most extensive adoption approach is "social" BIM, in which a significant level of collaboration around data exchange and creation takes place between a number of firms and disciplines on a project. Social BIM does not necessarily involve all contributors to a project team, but takes place across at least some of the discipline boundaries. A common structure for social BIM implementation is shown in Figure 3, involving the architect, structural engineers, and MEP team, but excluding the contractors. In this limited form, social BIM represents an evolution from solo or silo forms of BIM, rather than a transformation of practice.

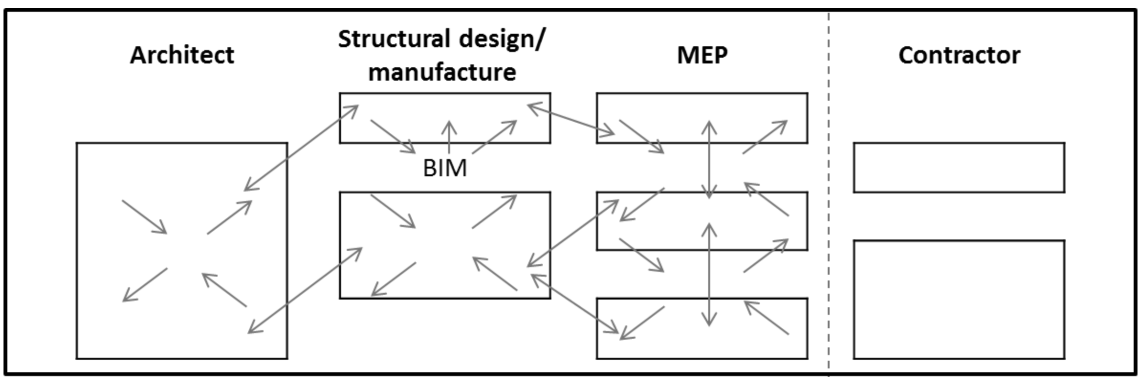

Figure 3: Example of a project structure using limited social BIM

Social BIM requires the greatest co-ordination effort and introduces significant concerns around ownership and responsibility, and hence has a substantial impact on professional roles and relationships. A case study by Sebastian (2010) focuses on the introductory use of BIM by a group of small consultants in a project in the Netherlands, and identifies the need for integrated working arrangements in order to derive the greatest benefit from BIM processes. Sebastian (2011) presents another two much larger case studies in The Netherlands where social BIM was implemented throughout the design phase of the projects. Both of these projects followed a traditional procurement process which excludes the contractor from the design stages of the project, so integration of construction knowledge into the design was not evident; however, all of the design disciplines were involved. A significant development from the social BIM approach on these projects was the emergence of a BIM/model manager role.

Eastman et al. (2008) present ten case studies demonstrating a variety of BIM applications. Of the seven case studies which included the construction stage, four used a traditional design-bid-build process. Of these, only one had successful contractor use of the BIM model, while the others reverted to a paper-based or 2D process for the construction stage, in an arrangement similar to that shown in Figure 3. The remaining three cases adopted either a design-build approach or guaranteed maximum price arrangements that incentivised or mandated an integrated design and construction process, where contractors worked alongside designers and other consultants to develop the BIM model for a smooth transition through the design stage and into construction. Figure 4 provides an example of this more transformational use of social BIM, which shows the increased integration of the roles and responsibilities of project participants.

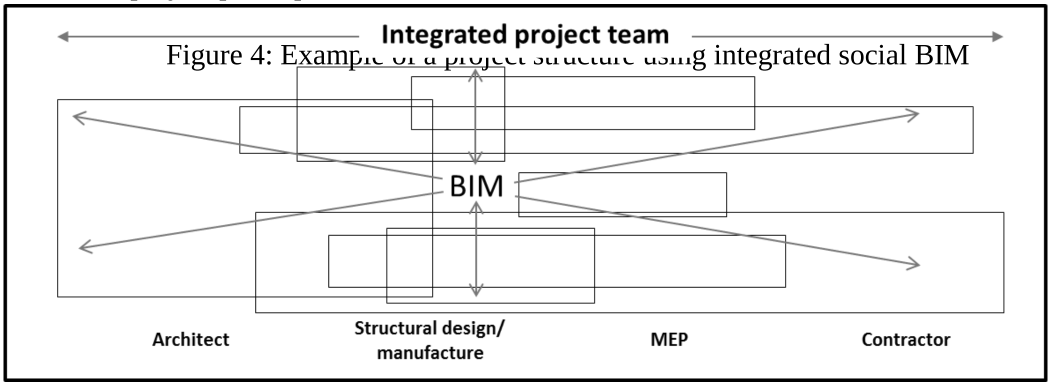

Figure 4: Example of a project structure using integrated social BIM

3. BIM AND THE DESIGNER-CONSTRUCTOR RELATIONSHIP

3.1 Role identities

The most likely source of conflict on a construction project, as identified by Burr and Jones (2010), is between the architect and the contractor. The long-established division between the design phase and the construction phase of projects has created an adversarial environment where the two parties are frequently seen to be in opposition. One of the widely heralded impacts of BIM on the construction process is the greater integration of the contractor into the design team, overcoming this traditional division and creating a greater level of collaboration between the two (Sebastian 2011). However, this rapprochement does not appear to be realized in practice.

Part of the disparity between the two roles is the difference in focus, articulated by Bernstein (2005), between delivering the service that leads to a built outcome (the architects' perspective) and delivery of a constructed product (the contractors' perspective). This is also reflected in the expectations both parties have from the use of BIM in a project environment. Zuppa, Issa, and Suermann (2009) elaborate on the different benefits and challenges that the two groups experience on BIM-enabled projects. Architects focused on the benefits to their own practice, in terms of better design and coordination, as well as improved business opportunities. The challenges they identified were around skills acquisition and the transition to BIM. Contractors on the other hand identified the improved level of construction information to be the major benefit, including estimating, scheduling, and a reduction in requests for information. The architects saw BIM as a skills development challenge, whereas contractors considered that BIM requires new roles. These findings suggest that for architects, BIM represents a technology evolution, while for contractors it is a process and policy level change.

3.2 New roles

In many case studies, the introduction of BIM is presented as simply an upgrade in the drawing production process from CAD to BIM. For these projects, the "BIM team", while described as a new function, is effectively an upskilled version of the CAD operators or manual draftsmen from pre-BIM project delivery. Merschbrock (2012) presents a case study from Norway which illustrates a limited social BIM implementation involving architects, engineers and builders in a traditional design-bid-build project. Despite the participants' use of BIM-ready interoperable systems and people trained to use them, the BIM implementation did not function much beyond a substitute for a traditional CAD system. This case illustrates the point that BIM skills and BIM tools are not sufficient to produce a "full-blown" BIM implementation. Although the use of BIM delivered some advantages to the project, the benefits of full BIM functionality could not be realised without reconfiguration of the relationships and communication processes between project participants, which did not take place. Even in a project which has made a level of commitment to adopting more collaborative processes and a shared model, Whyte (2011) further identifies that CAD and BIM production practices are often required to operate in parallel, to accommodate the requirements of stakeholders such as regulatory bodies and clients who are not BIM-ready.

Other case studies document the need for introduction of a new role or roles to implement BIM successfully. Rowlinson et al. (2009) mention both a "BIM team" and "BIM co-ordination engineers". The BIM team were technicians who took 2D CAD drawings from the architects and structural engineers on the project, and used them to produce a 3D model. It is unclear whether the co-ordination engineers were part of the BIM team or a separate role, but their function was to identify clashes, conflicts and missing information, and liaise between the architects and engineers to resolve the issues identified. In this case, the BIM team and co-ordination engineers worked in parallel with, and independent from, the architects and engineers.

Porwal and Hewage (2013) document a case which had no single role leading the BIM process. The architect took the lead in development and maintenance of the BIM model, with some design collaboration with the structural engineer. The owner's representative, an independent project manager, was responsible for issuing the BIM model to consultants and subcontractors, and managing model changes. The BIM manager, in this case one of the researchers, operated in parallel with the project team, and was responsible for developing modelling and document exchange guidelines for the project, checking and co-ordinating 2D and 3D documentation, identifying clashes or other co-ordination issues. In their recommendations, Porwal and Hewage (2013) advocate that both the owner and the contractor employ a "BIM architect", coordinated by the project manager, and also include a "BIM manager" as part of the project team, operating in an over-arching model management role. However, the contractual or reporting responsibilities of this role are not defined.

Sebastian (2011) discusses the function of the "model manager" as a liaison person who effectively translates and co-ordinates the inputs of the various participants. In two separate case studies he presents different interpretations of the role in practice. In the first instance, the model manager was independent from the design team; in the other case, the role of model manager was taken by the architect. Apart from this question of responsibility it appears that in both cases the tasks undertaken were similarly varied and drew on expertise from both IT and construction domains. These tasks included, from an IT perspective, developing information exchange protocols, creating object libraries, and converting files and managing file types. From a construction process perspective, the model manager was expected to maintain information flows between the various parties involved, define and co-ordinate the collaboration process, identify appropriate tools for modelling and analysis tasks, and develop the BIM into an as-built model for use in facilities management.

The much lauded Sutter Health Castro Valley project employed a specialist "project integrator" company to lead the BIM process (McGraw Hill 2012). This company's role was essentially to facilitate data exchange through technology and process solutions, manage access to project data, and monitor information flows. Each discipline created their own models using their preferred BIM system, and the BIM integrator had the technical role of ensuring that these disparate models were combined into a coherent and consistent single project model. In this case the role of the integrator went beyond BIM and was also responsible for managing lean processes and workflow systems.

There does not appear to be any consensus around the definition of the new roles created to manage BIM, or clarity on whether this needs to be one role or several, within an organisation or project framework. Barison and Santos (2010) reviewed the technical literature and identified over 30 different job titles or descriptions for BIM specialists, with further role variations and combinations depending on project size or professional affiliation. Whyte (2011) suggests that different approaches to drawing and model development is institutionalised in professional roles, with architects taking a direct role in model production, whereas engineers conduct the fundamental design and analysis but pass instructions to technicians for transformation into the required drawings or model. Contractors have less of an institutional process around the design and development stages as they are not traditionally involved in production of drawings or models, and their design involvement comes from practical problem-solving in the field. This suggests that BIM roles within contractor organisations have more freedom to develop and are less likely to follow historic CAD-based delivery patterns. The proliferation of roles around BIM implementation may be seen as a reflection of these different professional approaches and the need for processes to allow the different participants to contribute to the model development as they are capable, while still maintaining explicit and co-ordinated project structures.

3.3 Role competition

Professionals are often very sensitive to changes in their roles, and assert traditional modes of interaction in order to maintain their position. Conversely, they can actively promote change to extend and secure their own status and area of interest (Suddaby and Viale 2011). Both of these patterns are visible in case studies of BIM implementation. Sebastian (2011, p185) describes some of the role competition that emerges with the development of the new role of BIM manager: “The project manager questions the scope of the mandate of the model manager, as the model manager is also contracted directly by the client. The architect wants to remain in charge of the design performance. He is also anxious that his design creativity would be reduced or limited if detailed information is required since the early design phase.” At the same time, Sebastian (2011, p185) identifies the driver for change from the architects’ perspective as “a new awareness among the architects of the urgency to cope with the BIM knowledge in order to keep their role both as the creative brain as well as the conductor of the design processes.” Porwal and Hewage (2013) also noted that the role of the structural engineer was greatly reduced by the BIM process, as the structural detailers became much more involved in the design process, leading to role competition in this area as well.

Some of the gamesmanship that may take place around use and management of models also demonstrates an element of role competition. The desire of individuals to protect the parameters and practices of their traditional role is challenged by the transparency that BIM, particularly social BIM, introduces into project communications. Linderoth (2010, p69) identified that in traditional projects it is typical for some consultants to “hide behind their drawings” and resist providing detailed information until others have done so, allowing the late deliverers to benefit from the problem solving process undertaken by the rest of the team, while avoiding the extra effort required to be involved in that process. While this maneuvering may provide the best outcome for that individual, it is likely to have a negative impact on other individual roles, and on project outcomes. The introduction of BIM can highlight such manipulation of the process, as the contribution of each project participant is evident in the coordinated model.

3.4 Working practices

In many cases BIM introduces a change in working practices, both within an organisation in solo implementation, or more particularly across organisations in a project-level social BIM implementation. One such change is the trend for collaborative teams to work alongside others involved in the development of the project design and BIM model. The level of interaction is managed differently on different projects, however, and is not necessarily required by any particular level of BIM implementation; for example Leite et al. (2011) describe co-ordination meetings on a project where the contractor operated within a solo BIM framework and only received 2D information from other project participants, while Merschbrock (2012) describes similar project meetings in a social BIM implementation where the full team came together twice a week to use the BIM model to negotiate project development. Greater interaction comes from co-location into temporary project groupings so that project participants are effectively on-call for negotiation and problem solving throughout the process. Khanzode et al. (2008) describe a case study with a silo implementation where developers of the mechanical, electrical and plumbing (MEP) systems were co-located for the duration of the project, although they were not connected to the same extent with other project participants. Similarly Porwal and Hewage (2013) documented an integrated design team, where only the designers were co-located, although they noted that ideally this grouping would include the contractors’ design representatives. Several case studies identified by Ghassemi and Becerik-Gerber (2011) used co-located teams for some or all of the projects’ duration. The concept of the “Big Room”, with all participants working together in a single space for a significant part of the project is a tenet of Integrated Project Delivery (IPD) (Cohen 2010, Ghassemi and Becerik-Gerber 2011), but is increasingly becoming associated with BIM projects more generally. Depending on the extent of the co-location, closer relationships and understandings develop between team members, with traditional role boundaries becoming less distinct, and separations between responsibilities and areas of expertise diminished, as a result of proximity and familiarity.

Davies and Harty (2013) present a case study where BIM was an integral site management tool through the use of tablet computers for access to the project model and associated documentation. As a result, working practices changed, to allow “streamlining day-to-day work and allowing construction managers to be on site where '*they should be.*' " (p22) In this case the ability of the manager to perform the role effectively was enhanced by the improved level of information that became available on site as required, reducing the need to be tied to the office. Although this may be seen as a function of the tablet technology used, it is also a result of the BIM integration into the construction process that provided "the 3D information as an exploitable resource that can be used to support site operations" (p22), and demonstrates a BIM-related working practice that had a significant impact on the construction manager's role.

3.5 Procurement and contractual arrangements

As previously alluded to, the procurement process and contractual arrangements of a project have considerable impact on the way in which BIM is implemented, and the resulting relationships and roles amongst the parties. The traditional design-bid-build arrangement is perhaps the most restrictive, and maintains the established roles and structures with the least potential for change. Under this project framework, BIM is more likely to be used in solo or silo implementations, as there is no incentive or support for more collaborative engagement.

Many examples of successful use of social BIM emphasise the need for alternative procurement approaches or contract structures. Where the design and construction stages are separated, social BIM tends to operate within the design stage only, unless the project procurement and organisation structure is explicitly established to facilitate full collaboration involving contractors as well as designers. More progressive arrangements facilitate or mandate collaboration, and open up scope for greater integration of the design and construction roles. BIM case studies presenting projects in which partnering, design-build, design-assist, guaranteed maximum price, early contractor involvement (ECI), integrated project delivery (IPD), and pain share/gain share mechanisms in their various forms all indicate that these approaches are associated with an increased level of collaboration. This generally manifests as greater contractor and sub-contractor involvement in the design phase of the project. The designers' involvement in the construction stage of the project appears to be relatively unchanged, leading to questions around erosion of traditional roles and loss of control, particularly from the architect's perspective (Cohen et al. 2005).

The emerging project role of a third-party BIM specialist can be used to assist different project partners with BIM implementation and modeling processes. While the use of such a person or team has the potential to bridge traditional role divisions or project stages, case studies to date suggest that it is most commonly seen in collaborative project frameworks, and not in design-bid-build. The need for construction input and expertise into the developing design model is the same for an independent BIM specialist as for an in-house BIM team, and so the division imposed by the design-bid-build approach limits their usefulness in the project.

4. CONCLUSIONS AND FUTURE WORK

This literature review reveals that many of the changes we are observing, particularly around new and emerging roles, result from the creation of skills gaps introduced by new technology that needs operators. Based on current documented case studies, the three types of BIM adoption approach categorized here suggest that different skills gaps arise depending on the approach taken within each project or organisation.

In solo implementation, interaction between parties is limited. Designers and contractors maintain their traditional role divisions and BIM takes the role previously filled by CAD or manual drafting, being predominantly for production of documentation. Additional roles or skill sets are required within each party in the project team to enable projects to obtain the additional benefits accruing from 3D visualisation, schedule modelling or other simulation processes that BIM offers.

Silo BIM requires a somewhat greater degree of interaction, and accordingly has a greater impact on traditional working patterns and roles. Exchange of model data within discipline or organisational groupings requires management and co-ordination, as well as the operational skills seen in the solo adoption approach.

In social implementations, BIM managers or specialists also act as monitors and co-ordinators, and take on more of a process role. The independent BIM implementer or third-party BIM team is an emerging role in the industry that combines the technical and co-ordination skills required of solo and silo BIM with a broader process management role within the social BIM project framework. Fully integrated use of social BIM starts to further erode the boundaries between the designers' and constructors' roles, as the design and construction phases become increasingly integrated. The virtual construction process allows an exploration of constructability that influences the design, and involves the construction team in the design process. It is less certain that it leads the design team to take a similar involvement in the construction process, however, and the shift appears to suggest greater emphasis on the contractor's role and associated skill set, while reducing that of the consultant.

Further exploration of the necessary skill sets and expected responsibilities in each of these approaches is required. All three adoption types entail significant role development based on the technical skills required to make use of BIM technology. Historically, however, technology-focused roles have been largely transient, and are absorbed by other professions or become obsolete as professionals become more attuned to the software tools and the tools become more developed, focused and easy to use. Other, potentially more significant, changes are the result of industry practitioners responding and adapting as increasing BIM adoption reveals more productive ways of working and thinking about the roles, responsibilities and place of the various professions within the changing AEC industry.

It is important to distinguish between role changes driven by the skill needs and technical requirements of BIM, and those developing from changes to working practices and environments that are enabled by BIM. In terms of future research, it is perhaps the latter that will help reveal how to maximize long-term industry benefits from technological innovation.

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