Understanding BIM's impact on professional work practices using activity theory

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Recent critiques of the BIM literature describe it as largely devoid of critical theoretical perspectives and theorisation capable of explaining the nature of change in work practices in a holistic manner. In response, the authors argue from a theoretical standpoint, that implementing BIM within professional work practices (as activity systems) induces their evolution through dysfunctions created within the systems and their resolution. Cases of professional organisations in South Africa that have implemented BIM within their organisation and in multi-organisational projects, helped to develop new theoretical insights into how professional work practices evolve using activity theory-based re-description of the data. Changes in professional work practices were analysed sequentially within the framework, confirming theoretical propositions and revealing the dynamics between and within the interconnected system of actors, their object, tools, rules guiding work, roles they assume, and the stakeholders. Essentially, the findings imply that the implementation of BIM significantly changes work practices within organisations, but gradually and over time. This supports an evolutionary, rather than a radical or revolutionary, view of BIM-induced change. This theoretical perspective could explain future dimensions of change in professional work practices involving BIM, and indeed similar work mediating tools.

Keywords: building information modelling, work practices, social context, technological change, collective work, activity theory.

Introduction

In spite of developments in BIM research and practice, there remain impediments to modelling sufficient information to support seamless collaboration and information exchange (Berard & Karlshoej, 2012). Indeed, achieving the full benefits often associated with BIM, requires stakeholders to undergo an extensive change in management process. Many authors have alluded to this, or made claims about the changes induced within organisational and project team work practices; that is, BIM's demand for change in current ways of working in the industry on the one hand, and its capability to change the construction industry on the other. The literature is therefore rife with specific and broad claims and assertions about the impact of BIM in the construction industry. They allude to BIM-induced changes being both inter- and intra-organisational (Cavka, Staub-French, & Pottinger, 2015); CAD informed practices need to be replaced with BIM practices (Kaner, Sacks, Kassian, & Quitt, 2008); new workflows, practices and roles are required and emerging (Gheisari & Irizarry, 2016; Holzer, 2015); and changes to team organisation, procurement, and contracts are required (Burt & Purver, 2014), amongst others. Broad assertions have also been made, such as that BIM brings about a changed way of thinking for construction industry professionals (Xu, Feng, & Li, 2014), and implementing BIM requires significant changes in virtually all aspects of the construction business process (Arayici *et al.*, 2013). Many of these claims are plausible and also common-sense, even while they have been criticised as largely lacking a grounding in robust theory.

Fox's (2014) critique of such claims holds that many of them are fallacious and unsupported by evidence, while some of the findings in the literature do not explicate actual change; instead, they mainly present BIM enablement of work practices and vague descriptions of change. Indeed, much of the BIM literature is characterised by vague descriptions of BIM-induced change. This is largely due to the tacit nature of routinised work practices. As new forms of operations are repeated, they gradually become routine and hidden.

A gap in the literature is evident in the dearth of critical theoretical perspectives and theorisation capable of holistically exposing the real nature of change in work practices. This is particularly related to Çıdık, Boyd and Thurairajah's (2017) assertion in their study of change within digital interdisciplinary collaboration. They affirmed that much of the current critical literature on BIM and organisational change has largely been descriptive, providing explanations of actual changes and the reasoning behind them, while failing to theorise the dynamics that cause change to happen – a view that is strongly shared and leant on. Therefore, the aim here is to develop theoretical insight into the path and pattern of BIM impact on organisational and team work practices using activity theory as a lens, and for elucidating what is otherwise tacit knowledge.

This responds to the call for a new stream of critical BIM literature to provide nuanced theoretical understandings of BIM-induced changes in construction-related work practices (Dainty, Leiringer, Fernie, & Harty, 2017). In particular, activity theory is well suited to 'describe how human activity and the setting in which it is situated co-evolve over time and change the nature of future activities while participants deal with new barriers and possibilities' (Yamagata-Lynch, 2010, p. 11).

Firstly, an overview of the use of meso- and macro-level social theory in the BIM research literature is provided, which reveals its sparing use in the last decade – this even though many of the important challenges to the implementation of BIM in the construction industry are social. Next, a theoretical framework based on activity theory is developed, which provides a unique theoretical account and novel conceptualisation of BIM's impact on professional work practices, and an understanding of evolutionary change dynamics within organisational and project team activities. These, therefore, lay the theoretical foundations for the research design and analysis of change in professional work practices, viewed through the lens of activity theory. The sections that follow present the research methodology, methods and analysis of cases of professional organisations that have implemented BIM within them, and on multidisciplinary projects after which the empirical findings and their interpretations were analysed within the chosen theoretical framework. Furthermore, the concluding section summarises important findings and their implications, which have significance to theory on the understanding of BIM-induced change, as either evolutionary or revolutionary. It also details some significant implications for future research in the construction industry, particularly in the face of rapid advances in construction-related technological and non-technological innovation.

The impact of implementing BIM

Within the information systems (IS) literature, it is well established that implementing IS induces changes in work practices (Martinsons & Cheung, 2001; Rintala & Suolanen, 2005). In their work, Rintala and Suolanen (2005) acknowledged that technology is known to have significant impacts on aspects of organisations' work. Davidson and Chiasson (2005) also raised some important questions (previously posed by Johnston and Vitale (1988)) about Information Systems' impact on organisational structure and strategy, and inter-organisational Information Systems' potential impact on industry structure. In their work, Johnston and Vitale (1988) emphasised the need to recognise that the electronic link between several organisations, accounts for much of the changes in their relationship.

Some of the related work, for example by Vaast and Watsham (2005), examined how practices impacted by Information Systems change at the micro/individual relationship level. They approached an understanding of Information Systems induced change, in the context of consonance and dissonance. Vaast and Watsham (2005) argue that IS- or IT-induced change, may be explained by the dynamics through which agents modify their actions and representations to re-establish consonance when they perceive a dissonance. They defined representations as the way in which actors act in different work contexts. Furthermore, they suggested the need to examine representations that shape agents' understanding of their work and technology – and the consonance or dissonance they may experience – to fully understand how IS/IT may induce changes in work practices. Vaast and Watsham (2005) further assert that new actions that result in changed practices must be recurrent, socially shared, and one may argue further, socially acceptable. These are particularly necessary for legitimizing new work practices.

In the BIM literature, Sebastian (2011) asserts that effective multidisciplinary collaboration through BIM, requires changing the roles for all project stakeholders, new contractual relationships, re-organised collaborative processes, and a shift in the mind-set of parties on both the demand and supply sides of the construction business process. The author went on to highlight the gap in practical knowledge in how to manage stakeholders, in order to efficiently collaborate with their changing roles. As changing construction work practices relate to complementary changes in contractual relationships, it is noteworthy that the existing standard forms of contractual engagement may also fall short of supporting collaboration through BIM.

Furthermore, according to Hartmann *et al.* (2012), little is known about the possibilities of adapting BIM technologies to aid existing organizational work processes – a gap they sought to fill through empirical research based on two case studies of practical BIM implementation in construction projects. They found that while implementers of BIM hold initial beliefs that the implementation would require a change in the work process for estimating, this perception changed as they became more aware of the possibility of adapting the technology to their work processes. Nevertheless, Hartmann *et al.* (2012) also acknowledge that despite the evidence supporting their view, the specific dynamics in organisational settings might necessitate a radical shift in existing and established work processes, to successfully implement BIM. In conclusion, they suggested that future research should investigate the emergence of organisational change around BIM-based tools at different levels within an organisation, by applying multi-level organisational research methods.

In their study, Arayici *et al.* (2012) recognised that in order to achieve the full benefits often associated with BIM, stakeholders need to go through a comprehensive change management process, which is likely to require external assistance. Holzer (2015), in similarity to the earlier work of Sebastian (2011) also affirmed that new roles are emerging to maximise efficiency within BIM workflows, such as BIM content creators, BIM model manager (project level), BIM manager (office/organisation level), and BIM coordinators (multidisciplinary projects).

The work of Olatunji (2011), likewise related to Sebastian's (2011), highlighted the need for organisations in the industry to understand the nature of BIM induced change, and develop effective ways of coping with it. Similarly, Foster (2011)'s work on BIM makes a contribution to the debate around BIM's impact on industry business processes. As with several other authors, Foster (2011) acknowledges the blurring divides between design and construction in integrated practice with BIM. Moreover, BIM brings the possibility of inducing fundamental changes in the project delivering process. Importantly, Foster (2011) noted that new business models have not been developed to suit the use of BIM, and that its implementation requires a change in risk allocation among project stakeholders. New contractual arrangements will ultimately dictate which project stakeholder bears which risks.

Putting the foregoing into context, studies have begun to stimulate new research questions about the 'technocratic optimism' that often dominates the current debates around BIM as a tool and its implementation (Dainty *et al.* 2017). Dainty *et al*. (2017) scrutinised the enthusiasm around BIM and assertions about BIM's revolutionary impact on construction industry practices. In Fox's (2014) critique of claims about BIM's impacts as revolutionary, some important arguments were put forward. These include, that BIM descriptions are often characterised by hype, and that descriptions of BIM as exceptionally radical and uniquely socio-technical, are naïve. Rather, these descriptions were reframed to indicate that BIM is quite like other technologies within other industries, and that many others involve complex interactions between technology (or tools), actors, and their socio-cultural work contexts.

Miettinen and Paavola (2014), in their position paper, also offered an analysis of the 'rhetorical-promotional' dimension of BIM implementation, arguing that BIM implementation promises need to be complemented by more realistic views, through applying relevant conceptual tools from social science literature. They further criticised the tendency to transform the visions and expectations of BIM potentials, into a depiction of future reality, oftentimes without due regard for the conditions and constraints that may hinder their realisation – although it is argued here that the expected change also happens to benefit from said constraints, and how they are dealt with as shown in the next section.

Theoretical perspectives

Theory use in the BIM literature

Conceptual frameworks ensue from theory in such a way that they guide the research process, from conception through to analysis and sense making. Social theories afford researchers the tools to conceptualise and understand humans and their actions within the relevant socio-cultural and socio-technical contexts (Willis *et al*., 2007). It is necessary, therefore, to seek theoretical understanding of phenomena of interest in research endeavours. BIM research has hitherto been mostly a-theoretical, despite having proliferated in the last decade. While there have been some applications of theory, this has largely been limited to a particular set of theories which have been nevertheless applied sparingly. Out of 1,040 reviewed journal and conference papers on BIM published between the years and including 2005 until 2016, 64 were found to have either employed the use of meso- to macro-level theory or mentioned their influence on the research approach.

It can be surmised, therefore, that BIM research has developed over the years without much application of relevant theory. Furthermore, upon closer examination of research where some element of theory was found, it became clear that many only explained their use of theory sparingly, with very few having applied theory visibly in formulating their research design and making analytical decisions. The most common theories applied in BIM research are those relating to the diffusion of innovation and technology adoption (Davies & Harty, 2013; Gledson, 2016; Wu, Wen, Chen, & Hsu, 2016). This is expected, as many of the critical BIM research issues have remained connected to awareness, user perceptions and benefits accruable from adoption, among other things.

Some of these theories address different aspects of BIM implementation issues, but do not holistically show how the different elements of the implementation are linked and interact within the sociocultural context. It is therefore interesting to note that some authors are beginning to explore the strength of psychosocial theory to explain the dynamics of BIM implementation and induced change. For instance, Doloi, Varghese and Raphael (2015) employed social network theory examining BIM project impediments to identify the stakes of actors in multifunctional and organisational dynamics. Clearly, of specific interest to this research are studies that have employed theory in the area of computer-supported collaborative work (CSCW) and human-computer interaction (HCI) research. Miettinen and Paavola (2014), for example, proposed an evolutionary approach to BIM implementation research that draws from cultural-historical activity theory (CHAT) and organisational studies. Similarly, Korpela, Miettinen, Salmikivi and Ihalainen (2015) applied CHAT in the study of challenges and potentials for utilising BIM in facilities management.

Without appropriate use of theory, it is difficult to achieve conceptual clarity concerning what to study, within which boundaries, how to study it, and how to make sense of research findings. Accepting the premise that BIM adoption is a complex social activity (Cao, Li, & Wang, 2014), the application of theory in research design and theorisation is indispensable. Therefore, activity theory was employed here to provide novel insights into BIM induced change in professional work practices. The next section justifies this choice of theory.

Activity theory as a lens for conceptualising BIM change impact

Engeström and Miettinen (1999) opined that a theoretical account of the constituent elements of complex systems, is an essential precursor to analysing their relationship(s). Activity theory is relevant for examining and understanding object-oriented and motive-driven collective work. Furthermore, to suitably conceptualise the nature of project teams' collaborative work in the delivery process, it is useful to employ activity theory (Akintola, Senthilkumar, & Root, 2015). The usefulness of activity theory lies in its ability to aid the understanding of tool-mediated human interactions (Kaptelinin & Nardi, 2006). Such tools may be intangible (e.g., knowledge) or tangible (e.g., information technology tools) (Crawford & Hasan, 2006; Kaptelinin & Nardi, 2006). Additionally, the theory enables the analysis of emerging patterns of human activity in terms of changing processes (Crawford & Hasan, 2006). It has also been proposed as a means for making sense of how people act together, with the assistance of tools and in complex, dynamic environments (Crawford & Hasan, 2006).

Furthermore, activity theory provides theoretical explanations for the dynamics within an activity system's elements (Crawford & Hasan, 2006; Engeström, 1999; Kaptelinin & Nardi, 2006). As in Figure 1, a work activity system comprises individual actors, tools that facilitate their work, rules to guide how they work, the purpose to which members of the workplace community direct their actions, and the distribution of responsibilities between actors within the system (Engeström, 2000). Hence, the description of an activity system as a system of collaborative human practices (Engeström, 2000).

Importantly, activity theory posits that dysfunctions between elements of an activity system are the causes of change and development (Engeström, 1999). These dysfunctions, in turn, create 'need states' in which change, and development of the system can be accounted for (Engeström, 2000). To bolster this, Engeström (2000) in the treatise that put the theory forward for analysing and redesigning work, further stressed the non-static nature of activity systems, in that they are in perpetual evolution and internally contradictory. Contradictions in the system offer possibilities for developmental transformations in the creation of needs for change, and to cater for missed targets or expectations not being met

(Engeström, 2000; Hassan & Banna, 2010; Holt & Morris, 1993; Kaptelinin & Nardi, 2006). This assertion is essential to the cultural-historical analysis of work practices, bringing to bear the 'need states' created by manifested contradictions.

While the introduction of new tools (e.g., BIM) into an activity system (e.g., bounded within an organisation or project team) may proffer solutions to certain problems in human work, they introduce a new set of dysfunctions that require analysis within the socio-cultural context (Engeström, 2000). More importantly, when a need cannot be met within an existing activity system, a 'need state' is created. The author further pointed out that the theory is suited to engaging the system as it is emerging, and the primary purpose is to guide the system through various stages of dealing with the dysfunctions. This enables the actors or stakeholders to develop new solutions to address challenges that are experienced. As drivers for change, there are four types of contradictions. These are primary (within each element of the activity), secondary (between constituent elements of the activity), tertiary (between the activity itself and a culturally more advanced form of the activity), and quaternary (between the central activity and adjacent activities) (Engeström, 1987).

There is, therefore, a strong case for exploring activity theory in analysing technology-induced change. This is supported in the work of Engeström and Escalante (1996), who showed that activity systems analysis could be used to describe collective activities involved in the development and implementation of technological innovations; as well as to analyse the effect of human interaction on the implementation (Yamagata-Lynch, 2010). Closely related is Mwanza's (2002) study, which was designed to analyse work practices in relation to identifying design requirements for computer-assisted learning. This was an ethnographic study that used Engeström's (2000) activity systems model (see adaptation in Figure 1) to map how existing work-related practices fit into each element of the model. [Insert Figure 1 here].

Activity theory, therefore, provides a framework for guiding a system through the process of transformation, while at the same time dealing with emergent contradictions and disturbances within and between elements of the system (Holt & Morris, 1993; Kaptelinin & Nardi, 2006). The focus of this study is on analysing the changing patterns of professional work practices as impacted by the use of new tools (BIM). This enables the unique opportunity to apply activity theory to elicit and contextualise the evolution of collaborative professional practices, due to dysfunctions created by contradictions in the system. This approach also affords methodological developments in an area of research mostly lacking the application of psycho-social theory.

A theory is only as useful and practical as to how its key propositions and assumptions inform a study. As an argument for the theoretical choice made, activity theory is specific in its focus, being a theory for understanding the evolutionary dynamics of human endeavour. Moreover, it is clear in its explanation of fundamental concepts, assumptions and propositions about transformations, or change within and between elements of an activity system. Further, there is a considerable body of knowledge on the theory. Activity theory, therefore, affords a holistic understanding of the phenomena of interest, i.e., change in patterns of professional work practices.

Activity theory propositions and assumptions are the basis for the conceptual model in Figure 2. It shows that implementing BIM within pre-BIM organisational and project team activity contexts, produces constraints and contradictions which, when resolved, present opportunities for the activities' evolution. The aim of this article is not, therefore, to echo BIM challenges already evident in the literature in its findings, but rather within real-life cases identify specific constraints and contradictions that trigger changes in the pattern of professional work practices, using activity theory as a lens and methodological approach to map out patterns of change [Insert Figure 2 here]. Thus, the pertinent questions of interest are:

- What are the constituent elements of organisational and project team context activities?
- What are the conflicts and contradictions created within existing professional work practices as a result of implementing BIM?
- How are the conflicts and contradictions within these systems being resolved?
- How have professional work practices changed as a result of the introduction of new tools (BIM) into the activity systems?

These questions are based on the activity theory position that all forms of human practices are the products of 'historical development', which perpetually reforms and triggers the development of said practice. Furthermore, that individual and collaborative human work activities are mediated and shaped by tools (Kaptelinin & Nardi, 2006). This theoretical perspective is not entirely new in the BIM literature. Korpela *et al.* (2015) applied it to study a library project case in Finland, to uncover the challenges and potentials for using BIM in facilities management. Although, the authors reported their reliance on activity theory and the concept of activity systems for their theoretical framework and analysis, it was observed that the study was not distinctly framed as one based on activity theory.

By contrast Mäki and Kerosuo (2015) focussed their research on the Rule and Tool elements of an activity system. They acknowledged that implementing BIM, as has been done here, can cause disturbances within work activity systems. While their study is clearly presented as being based on activity theory, a more explicit identification of contradictions and disturbances within clearly defined activity system contexts would have been beneficial. They, however, importantly affirmed that future research should examine other critical elements of BIM use, such as rule and role elements of an activity system.

Undoubtedly, other theoretical perspectives and frameworks are relevant to understanding BIM-induced change. Among others, structuration theory can help to formulate important research questions to investigate, while institutional theory can also provide valuable insight into different aspects of BIM implementation issues. For example, Cao, Li and Wang (2014) investigated isomorphic pressures influencing BIM adoption, while Akintola, Venkatachalam and Root (2017) studied legitimacy and changing power dynamics on BIM-enabled projects.

Since theoretical choices dictate choices of research methods, in the next section the methods chosen for this research are outlined in line with the adopted theoretical perspective.

Methods

BIM usage is not widespread in the study context of South Africa (Froise & Shakantu, 2014). In fact, Harris (2016, p. 2) revealed the 'industry's inherent traditionalism towards Building Information Modelling technologies, with many survey respondents preferring to follow trends rather than to take the lead. Many who have adopted a BIM technology strategy have done so in a silo approach.' The approach to sampling was, therefore, a nested strategy which consisted of two levels of purposive sampling (Patton, 2015, p. 305), since it was important to select cases of relatively advanced level of BIM implementation. This method is similar to the methods employed by authors like Engeström and Escalante (1996) and Yamagata-Lynch (2010) who apply activity theory in other contexts.

First, comparison-focused case sampling (Patton, 2015, p. 277) was undertaken. Through this, eight purposively selected cases of professional construction organisations that have implemented BIM within and on multidisciplinary projects, were studied. These included extreme deviant cases of relatively high success at implementing BIM and notable failures in implementing BIM (Patton, 2015; Wengraf, 2001, p. 102). Five of these cases were multidisciplinary organisations (i.e., including of architects, quantity surveyors, services engineers, and structural engineers) and three were architectural firms. In determining the number of cases for a study like this, Patton (2015) affirms that the determination of a suitable number of cases depends on the purpose of the enquiry and availability of such cases. A further trade-off is also required between depth and breadth of data collected and its analysis (Patton, 2015, p. 311).

Furthermore, in-depth interviews were conducted with purposively selected key informants (BIM Champions) from these cases (Marshall, 1996; Tremblay, 1957). The participants were selected based on personal skill, position within the organisation, knowledge about the subject of interest and possession of a wide range of views. The specific recruitment criteria were that the participant:

- Is responsible for maintaining and developing BIM implementation within the organisation and is therefore sufficiently experienced to provide in-depth accounts of various aspects of such implementations (as BIM Champions)
- Has participated in a construction project where the project team implemented BIM
- Is one of the following professionals – architect, project manager, quantity surveyor, mechanical services engineer, electrical services engineer or structural engineer

The nested sampling strategy is supported by Yin (2014, p. 92), in that while cases of organisations may be the object of interest, data may be collected about them through individual interviews to examine how such organisations work, and also how and why phenomena of interest are happening within the organisation.

To demonstrate credibility, studies based on activity theory should provide thick participant descriptions and establish the context of interest (Yamagata-

Lynch, 2010). For this reason, detailed profiles of the key informants are provided in Table 1, while the context is provided in the sections that follow. [Insert Table 1 here].

Data collection methods

The data was collected by audio recordings of conversations based on a pre-prepared semi-structured interview protocol. Probing questions were asked about participants' experiences on BIM-enabled projects as compared to non-BIM projects; as well as questions about how their organisations have been impacted since BIM was implemented. In particular, questioning was focused on how they carried out their functions, constraints experienced and specific changes that they had to make in their work practices. Furthermore, a sequence of taking field notes, transcribing audio and coding was followed in line with the recommendations of Saldaña (2013). The interviews each lasted an average of 45 minutes. Memos were written immediately after each interview to preserve contextual information/data, after which verbatim transcripts were produced. Analytical memos were also written while transcribing to keep records of theoretical reflection on the data. Further analysis was done by coding textual data into categories and sense-making.

Importantly, the method of theoretical re-description, in which empirical data is re-described using theoretical concepts, was employed. Through this method a particular phenomenon or event may be interpreted from a set of theoretical ideas or concepts, raising the level of theoretical engagement beyond the description of the empirical entities (Fletcher, 2017). The following analysis is therefore presented as a theoretical explanation and re-description of the data collected on the changing nature of organisational and project team work practices. It is based on the experiences of implementing BIM in these contexts by the participants.

Interviewing and interview data analysis can be highly structured and systematic, with allowance for moments in the research process where analysis and interpretation are data-led rather than existing theory-led (Wengraf, 2001). It is also possible to collect information for objective, subjective and discourse analysis in the course of questioning (Wengraf, 2001). Therefore, interview data can be used to elicit information in both structured and unstructured forms.

Nevertheless, a rational methodological alternative choice for this study might have been ethnography, since it is a study of work practices. Ethnographic observations for instance might have laid bare more of the hidden practices that may be difficult for key informant interview participants to articulate as was discovered in the process of data collection. However, conducting an ethnography posed challenges including gaining appropriate and continuous access, and more significantly, the difficulty in observing a whole project process as contract periods for the projects of interest are typically lengthy and unpredictable. Therefore, it is often not practical to gain a whole project view even through this method.

Credibility and trustworthiness

The method adopted allows issues of considerable complexity to be studied in detail and depth (Saunders, Lewis, & Thornhill, 2012). The research design is therefore consistent with that which is typically employed in activity theory-based studies.

Generalisability

Rather than attempt to generalise findings over a population, in this case it is more appropriate to generalise to theory (Creswell, 2013). Furthermore, Saunders *et al.* (2012), supported by Patton (2015), affirm that generalisability in this type of design has to do with the significance to theoretical propositions and locating the findings in existing theory. While this may seem a limitation, Yamagata-Lynch (2010) affirms that studies based on activity theory help to gain and share understandings of complex human interactions in work settings, but are not conducted with the intention to generate generalizable results. Rather, they seek to provide important insights into the dynamics of activities through particularisation of the context and, thereafter, achieve the transferability of findings to other contexts through theoretical re-description. Therefore, the aim was to generalise to theory.

Other studies have used similar sample selection methods as has been employed in this study. Examples include the activity theory-based study by Yamagata-Lynch (2010), in which three cases of schools were studied from which within-case selection of individual participants was undertaken. This was also the case in a BIM-related study by Gledson (2016), which used single case sampling technique, while Shibeika and Harty (2015) also used a one-case design.

Analysis and discussion

In this section, an activity theory-based insight on BIM-induced change within the cases studied is presented. Secondly, an insight into the debate on whether the nature of BIM-induced change on professional work practices is revolutionary or evolutionary is provided, and a position is taken.

The authors therefore present a concise description and explanation of collaborative professional work change patterns, when such work is impacted by the introduction of BIM. To this end, systemic constraints and contradictions within professionals' work activities, as in the data, are employed to engage the activity systems as they evolve. The methods espoused in the synthesis of different approaches to activity systems analysis, are used as a foundation and drawing from Yamagata-Lynch (2010). Furthermore, this section presents an interpretive analysis of the research findings using activity theory, which shows, based on the data analysed, BIM-induced change to be evolutionary (gradual), rather than of a radical or revolutionary nature.

Analysing data based on activity theory often requires a visual diagram of the conceptual framework, to reveal how each element of the activity systems has been operationalised in the specific context under study. It also shows how the data has been made sense of theoretically, to clearly highlight where primary and secondary contradictions that trigger change exist on one hand, and how one level of activity (organisational context) links to the other (project context). This method closely follows the recommendations of Yamagata-Lynch (2010) and Engeström (2000).

Additionally, the units of analysis are the organisational context activity system (OCAS) and project team activity system (PTAS). Therefore, the analysis essentially traces the change in work practices, selecting the time when new technology was required as the point of reference. First, depictions of the OCAS and PTAS, upon which the analysis is carried out, are put forward (see Figure 3 and Figure 4); this is then followed by an analysis of changes in the pattern of these activity systems over time through the introduction of new tools (BIM), as elucidated in the following sections.

[Insert Figure 3 here]

[Insert Figure 4 here]

Organisation context activity system analysis of BIM-induced change

The key motivation for introducing new tools (BIM) within organisations, and by extension construction project teams, stems from the challenges relating to delivering construction projects within the constraints of time, quality and cost, while still maintaining profitability (Crotty, 2012). This was evidenced, for instance, within ORG2 in which BIM adoption was directed by their senior leadership to reduce organisaitonal costs; while also helping to compete favourably with other organisations providing similar services and, by extension, maintain or improve their profit margin. Furthermore, within two of the cases studied, ORG4 and ORG8, BIM was adopted as a means to help in meeting client's demands regarding perforemance (particularly cost reduction) and increased productivity, respectively. This can be interpreted on one hand, as a Rule *(budget, time requirement, quality requirement)* vs Object *(high performing project, organisational profitability)* contradiction in the activity system at the project level, as shown in Figure 5 (a). [Insert Figure 5 here].

The introduction of BIM also originates from efforts within organisations to improve their delivery of project expectations and outcomes. On the organisational front, the motivations for implementing new technology and associated applications, goes beyond merely meeting clients' demands to achieving competitiveness among peers, as depicted in Figure 6 (b) and Figure 6 (c) (as reported by Informants Q1-11) – and also considering their goals of cost efficiency while improving profitability. In other words, organisations are constrained by the need to achieve their objectives within the limits of organisational resources, while striving for competitiveness with their peers. This is a Rule *(organisation's resources/budget)* vs Object *(provision of professional services)* vs Community *(competition with other organisations)* contradiction. [Insert Figure 6 here]. To resolve the above contradictions, BIM is introduced as a new tool, both in its form as a technology and also as a process.

Nevertheless, the introduction of new tools within organisations has been found to create a new set of primary contradictions, these being between the new tool(s) and existing tangible and intangible tools (otherwise termed non-interoperability), as depicted in Figure 7 (d). [Insert Figure 7 here]. First, for existing tangible tools, there are some contradictions brought about by the introduction of BIM. Tool *(BIM)* vs Tool *(existing CAD systems)* contradictions are experienced in the sub-optimal levels of interoperability between existing and new tools and systems. This challenge is typified in the quote below from Informant Q3:

> On the technology side, the challenge first and foremost is localisation, the output from the BIM needs to conform to like all industry standards, and it

> doesn't. So, we've got all kinds of workflow work-arounds just to deal with a simple thing such as geographical coordinates. We're not going to change what the authorities want to see, we have to adapt the BIM to suit and that's where we find we're meeting dead ends all the time. So, the answer lies in third party application development, we've got an in-house programmer sitting in there, [and] we've got third party external programming teams from whom we acquire the add-ons to plug the holes in the software, and we also then leverage knowledge from our colleagues in the more advanced countries. (Informant Q3)

Organisations often must contend with the dilemma of either implementing both together while gradually migrating to new tools, or else go the BIM route for all their work from the outset – this is not always an easy decision. Nevertheless, the findings show that a phased adoption and implementation strategy tends to be successful (Informants Q1, 6 &11). Informant Q1 stated that:

> One of the biggest challenges was...because the software is so different [and] because the mind-set is so different, it drives a completely different workflow. So, it's not something you do and then six months later we're fully BIM. You may have to recognise [that] it's going to take time, and unless you make, sort of smaller targets, right? You're going to feel very frustrated… (Informant 1)

This supports an evolutionary change perspective. It also ties into the experiences of conflicts between knowledge requirements for using the new BIM tools, and established/existing professional knowledge and skills of organisations' staff; that is, in the understanding that cognitive abilities and knowledge are tools, albeit intangible in nature. Knowledge and skills as mental tools contribute to the mediation of the relationship between the Subjects *(staff)* and their Object *(endeavour to which their efforts are directed)*. Coping with the ‘need state’ created by a mismatch of new knowledge requirements and existing knowledge, requires a lot of training and development; as well as organisational knowledge management to ensure skills and knowledge are transferred between staff and also retained for sustenance (Informants Q1-11).

The third Tool vs Tool contradiction relates to the reported high cost of procuring the new BIM tools (software and associated applications). While the new tool is important for achieving organisations’ objectives, it is also a strain on financial resources. For instance, Informant Q11 affirmed that:

> You need to get the right skills set, you need to get people who are properly skilled. I mean even in our company we have [in the past] struggled to find the right pool of people. It's money as well, it's expensive, I mean you talk about licences ... as a company we are luckily able to afford the [initial] training, the on-going training, afford the licences, when you talk about a person joining your firm [newly]... just to get that person working, never mind his salary. We have to invest in that person [technological infrastructure], to be able to produce the [required] work for us. It’s expensive, licencing is expensive. (Informant Q11)

This is a Tool *(financial resources)* vs Tool *(BIM infrastructure cost)* contradiction a shown in Figure 8.

[Insert Figure 8 here].

With the introduction of BIM, the findings show that new BIM roles have emerged. This is often because transitioning to new technology is difficult for the organisations, and new roles need to be created to facilitate the process from within organisations. This was reported by Informants Q1-7, 9 & 11, who have created BIM management or coordination roles within their organisations. The double-binds that come to the fore at this point, relate to either training existing staff to take up new/modified responsibilities or employing staff experienced in implementing BIM. These are Tool *(emergent roles and competencies)* vs Role *(Role definition & distribution)* contradictions (Figure 8 (e)). The findings further show that the latter is the dominant route taken. Indeed, out of eight cases of organisations, six have taken this route. For instance, according to Informant Q2:

> Our organisation has appointed a formal BIM manager for the African region within ORG1, who is overseeing a lot of BIM workflows and systems and making sure that these things are being implemented. And then within every office we've got a coordinator or a person who has that as part of their...not formal job description yet, but we've got someone who has been identified, and is handling that aspect of the works, ...we're working towards actually making that part of their formal job description as well. So, you do need that, because it is a complex system and it needs monitoring as we're learning more and more about the system. So, you need one point where it gets coordinated. (Informant Q2)

Subsequently, roles are redistributed between existing staff and those that take a new BIM role within the organisation (reported by Informants Q1, 2, 3, 4, 6, 7, 9 & 11 as being the case within their organisations). Inferring from this, the situation may lead to role conflict; that is, Role *(existing roles/role takers)* vs Role *(new roles/new role takers)* contradictions, as in Figure 8 (f). It may also create tensions within the system regarding power and authority structures, hierarchies and co-constructed forms of interactions among others in a Role vs Rule contradiction (Figure 8 (g)). However, this was not reported at the organisational level in the data collected.

Interpreting the data further, with the introduction of new BIM roles and the creation of new areas of professional competence (as tools), comes the need to modify existing rules within organisations. It is important to note that financial resources are tools for organisations, whereas the budget are rules that guide and/or constrain their operation. Therefore, it is essential to highlight the need to resolve the challenge in deciding between hiring new staff or training existing staff, against the constraints of organisational resources and budget (Tool *(resources)* vs Subject *(new staff hire)* vs Rules *(budget)*).

Further, the introduction of new BIM tools can also generate conflict between the demands for implementing them within existing organisational practice procedures as both tools and rules – plans and protocols are tools when they are employed to guide practice but are rules when they are a means to ensure compliance by organisations' staff. This conflict necessitates the dedication of teams of staff to create new practice guidelines and protocols to suit the implementation of BIM within the organisational setting. This was particularly evident within ORG1, 2, 3, 4 and 7, where such guidelines had to be created to support BIM implementation. These (new guidelines and standards) become new tools as well as rules within the activity system. Nevertheless, the participants' responses on their implementation experiences, suggested that certain aspects of the new technology adoption and implementation, may conflict with established professional guidelines and also organisational norms and culture. For example, document submission guidelines and format to the relevant authorities.

Having taken the systemic constraints and contradictions identified from the data into account, an evolved organisational context activity system is presented in Figure 9. [Insert Figure 9 here].

In essence, the activity system evolves through the choices that organisations make in resolving a series of conflicts and contradictions, brought about by the introduction of BIM and related applications. The authors theorize that the implementation of BIM significantly changes work practices within organisations, but gradually, and over time. This supports an evolutionary view of BIM-induced change rather than a radical or revolutionary view of change and is argued from Miller's (1982) definition of evolutionary (incremental) change as piecemeal and gradual. In this text, evolutionary change is delineated from revolutionary change as that involving a 'few elements [that] change either in a minor or major way; and revolutionary when major or minor changes of many elements in a system within a brief interval radically transform many elements of the system's structure'. Clearly, although the foregoing analysis depicts a change in several elements of the activity system, analysis of the data collected from the cases studied suggests that changes to elements of the activity systems structure were gradually made over a significant amount of time, typically more than ten years (Informant Q6 & 11).

Project context activity system analysis of BIM-induced change

The project team activity system (PTAS) is multidisciplinary and can also be either multi- or mono-organisational. The analysis provided here depicts a collaborative multi-disciplinary and multi-organisational project activity system setting. As has been shown in the analysis above, changing patterns of professional activity begins within individual organisations. Therefore, the successes or failures of collaborating organisations in dealing with their challenges, may be transferred to the project team context.

Collaborating organisations' knowledge and skills, as well as their discipline-specific work tools, become tools for the project team activity, as depicted in Figure 10. [Insert Figure 10 here].

Some organisational-level rules are also inevitably transferred in part to project level rules. For instance, in their account of one project on which BIM was implemented extensively, ORG3, an architectural design firm and project team leader, impressed upon other project team members to produce information that conforms to their own pre-prepared BIM guidelines and protocols (thereby modifying rules). Furthermore, and rather inevitably, some other organisational work production tools became project team context activity tools, by the project team leader requiring them to be used. Equally, some of the modifications made in the rules guiding organisational work were also transferred to project level activity rules. In effect, *ab initio*, the project team activity system is already changed. Nevertheless, the fact that methods for implementing BIM and level of proficiency among collaborators vary, raises new contradictions within the tool element of the PTAS.

That is, the contradiction between Tool *(organisation 1 tools & knowledge resource(s))* vs Tool *(organisation n… tools & knowledge resource(s))*, as in Figure 11 (h). For instance Informant Q4 stated that 'from an architect's point of view, we get very frustrated with external Architects who are working on different software, and that's a point of conflict, because [we've] got to remodel stuff on this side, because they just mess it up on the other side'. To resolve these new contradictions, several changes take place. [Insert Figure 11 here].

The first way of responding to these contradictions is to create new BIM coordination/management roles (within the project team structure), Informant Q6 articulated it as follows:

> How can we collectively be on the same page so that when you do transfer data between one consultant and the other, one professional to another, that you don't end up with these problems of having to re-do work? So you're appointed as a BIM manager or BIM coordinator for that project specifically and in your company's capacity assisting all the other disciplines associated with it. See, yeah, that's where you find yourself and you do call quite a big shot there. (Informant Q6)

Typically, creating new BIM coordination roles within the project team necessitates the redefinition and redistribution of roles to accommodate the new role. It can also create Role vs Role contradictions; that is, between existing professionals and newly-introduced BIM knowledge experts who take up the new roles for information coordination, in cases where BIM coordination is not an expansion of an existing consultant's role. Role conflict is likely in this circumstance but, since the project team is itself a self-organising entity, such conflicts are resolved fairly easily, particularly where the architect or lead designer takes up the BIM coordination role (Informant Q7). Also according to Informant Q6, when separate BIM coordinators are included in teams, 'you do get resistance as it were, but, the resistance is overcome through acknowledging that this role is there for a purpose'. This is even more so if the new role takers can demonstrate superior knowledge to command the necessary power and authority to act and direct others to act (supported by Informants Q3, 4 & 7).

Interpreting the data further, the rules that guide work for the project team are also transformed through the resolution of contradictions. With the redistribution of roles as a result of the inclusion of new BIM role takers (Figure 12 (j)), project team rules are modified to suit the new demands arising from the incompatibility of new roles with existing pre-BIM Rules *(contracts, and guidance documents etc.)*, as depicted in Figure 12 (k). [Insert Figure 12 here]

Modifications to contractual provisions, project organisation structure and delivery procedures are made to facilitate BIM implementation on an ad hoc basis, project by project (Informant Q11 and Q3). Nevertheless, it can be inferred that with increased use, efforts may be made towards institutionalising new rules and practices by the Community *(government, professional bodies and client organisations)*, to resolve the continued conflict in the system resulting from information asymmetry in South Africa. This is so, since no generally accepted countrywide standards and guidelines have been developed for use in the country.

It is theorized, as in the OCAS analysis, that the implementation of BIM significantly changes work practices within organisations gradually and over time, supporting an evolutionary view of BIM-induced change – rather than a radical or revolutionary view of change. The evolved project team activity is shown in Figure 13. [Insert Figure 13 here].

Furthermore, the OCAS and PTAS analyses show that the changes experienced are regarding how professional work is done, rather than what work is done or why work is done. This is interpreted from the activity theory position that activities are not monolithic, but hierarchical in structure. This structure is organised in three levels beginning with the activity at the top or highest level of abstraction and directed at motives (Kaptelinin & Nardi 2006). The next in the structure are actions which are the sequence of steps taken, not directly related to the activity's motive, but ultimately help to achieve the motive. Actions are directed towards goals can also be decomposed into a lower level of abstraction called operations. Operations are routine processes and provide an avenue for actions to adjust to specific work situations and are automatic or routine (Kaptelinin & Nardi 2006).

The activity as a whole may, therefore, be said to be directed at the essence or reason why it's taking place while the actions and operations are representative of what work is done to achieve the motive and how that may be achieved in specific work contexts. In this analysis, the changes reported from the cases of organisations indicated changes in the how work is done to achieve the principal motive of construction or building, but do not change the 'essence' of the activity. While changes can be observed in, for example, the speed and sequence of work within the organisation, tools used, staff reward systems and redefined roles, the essence of the activities defined by their object and outcome remain largely the same even though the methods have evolved.

These findings extend the theoretical literature on BIM implementation impacts on work practices. More precisely, they extend the works of Miettinen and Paavola (2014) in their position paper which propounded an evolutionary view of BIM-induced change using cultural historical activity theory; and Mäki and Kerouso's (2015) work in which they focused on only the rule and tool elements of an activity system. Importantly, some aspects of the findings relate to Çıdık *et al.*'s (2017) work in which they developed a concept of 'ordering in disguise', conceptualised a description of the indirect nature of digital integrations' prompting of what work is done and how, through constraints and prompting of individual courses of actions. Their position, from the observation that practitioners within their daily work do not observe explicit changes in their work practices, is supported in this study by the recognition of the tacit nature of knowledge about changes in work practices, due to routinisation. Clearly, their work advances theory, but here a different approach is taken that construes the organisation and team as separate and interlinked units of analysis.

Interestingly, Poirier, Forgues and Staub-French (2017) who developed an analytical framework through a meta-analysis of different data sources in their study of the impact of BIM on collaboration, theorized that identified event patterns may be conditioned by an interlink of context, structures, processes, artefacts, and agents. Alternative holistic and more formal theoretical explanations of these interrelationships are possible through an activity theory framework, as has been shown in this paper.

Furthermore, in Miettinen and Paavola's (2014) work, they imply that BIM adoption requires learning and modification to meet local conditions, which often result in redesigning the technology. While the analysis presented here confirms this, it could be argued further that the evolutionary perspective provided through cultural historical activity theory also implies that, since activity systems are constantly evolving, the tools that are used to perform work (BIM and others) would continue to shape and be shaped by other constituent elements of the activities to which they are relevant.

The explanations and conceptualisations presented in this work offer nuanced explanations of changes in work practices and the reasoning behind them, while also theorising on the dynamics that cause the change to happen. This feeds off criticisms of the existing literature in their failure to achieve this by Miettinen and Paavola (2014), Fox (2014), Dainty *et al.* (2017) and Çıdık *et al.* (2017) in particular. However, the theoretical perspective chosen, and research design do have limitations, which are highlighted below.

Conclusions

Activity systems are non-static and constantly evolving. However, the analysis presented in this article depicts the pattern of change due to the introduction of new technology (BIM tool/process and related applications), as was evident in the experiences of implementers in specific case contexts. The analysis demonstrated the impact of implementing BIM on construction professional work practices, indicating conceptually that organisational-level evolution precedes that of project teams.

The findings describe construction professional work activity as it evolves from a pre-BIM implementation state, to show how the dynamics of change within the different contexts of collaborating organisations can bring about change in the project context activity. These were analysed using a cultural historical activity theory perspective to show how professional work evolves into newer forms. Principally, an evolutionary view of BIM-induced change rather than a radical or revolutionary view of change in work practices is supported in this study as the implementation of BIM significantly changes work practices within organisations, but gradually and over time.

The potential of activity systems analysis in describing collaborative activity between construction project stakeholders was also shown, while conceptually highlighting the links between the organisational context activity system and project context activity system. It also theoretically demonstrates the influence of organisational evolution due to BIM on project team activity or the work practices that comprise it.

While the findings have important practical implications, attention should particularly be given to their theoretical significance. For practice, the findings help to better understand the dependencies between the different elements of professionals' work activity(ies), and the connectedness of their individual and collective actions within organisations and project teams. Furthermore, since one of the main purposes of cultural historical activity theory is to assist in the design of computer supported collaborative work, the findings imply that the design of organisational and team rules and roles based on BIM, needs to be flexible to accommodate the non-static nature of work activity systems.

Theoretically, the findings emphasise the nature of knowledge as a tool (albeit intangible) in work settings, which is capable of mediating or shaping the relationship between the actors and their object. In fact, it reinforces the dual nature of individually- or organisationally-held knowledge as tools and rules. The possibility of studying primary and secondary, tertiary and ternary contradictions in different contexts and within different levels of abstractions of activities, has also become evident based on the theoretical and conceptual framework presented here.

The evolutionary perspective and principle of mediation provided through activity theory, importantly imply that since activity systems are constantly evolving, the tools that are used to perform work (BIM and others) will continue to shape and be shaped by other constituent elements of the activity systems, to which they are relevant and embedded. Furthermore, the findings particularly extend the theoretical literature, in part as an alternative approach to understanding change in work practices, and also in its introduction of new perspectives for the analysis of technologically induced change. Considering the concept of mediation in particular, the possibility of analysing, for instance, how the interrelationships between actors' (subjects) and stakeholders (community) can be shaped by rules has been presented.

One feature of the descriptions of BIM within the activity theory framework is its emphatic characterisation as a tool, even though associated plans and procedures may fit in as either tools that mediate actions or as rules guiding work. Although, not supported with empirical evidence, using activity theory brings to the fore the idea that as a tool such as BIM evolves through its previous forms (CAD for instance), it carries along with it historical attributes or aspects of the transformation of the activity's or activities, for which it has been used and is being used through that evolutionary process (Kaptelinin & Nardi 2006).

Furthermore, the data has been clearly defined and interpreted in activity theory terms to show a 'historical' analysis of events, traced from the organisational contexts activity system to the project context activity system. This method brought to the fore many details of complex work systems as activity systems that are otherwise tacit in nature. Finally, the theoretical and conceptual framework provided by activity theory has also enabled a different methodology for depicting, organising and analysing data about human interaction in work settings that have yet to be provided by others approaches.

Limitations

It is important to acknowledge the limitations of activity theory as a theoretical perspective, although it facilitates a holistic understanding of work and its development. Activity theory is more descriptive than explanatory, although excellent texts like Kaptelinin and Nardi's (2006) provide good insight into its capabilities in explaining work development. Additionally, activity systems are normally evolving. This analysis has, therefore, not accounted for, nor is it practicable to account for the usual evolutionary tendencies of human work activities irrespective of the induced change in the system.

Areas for further research

The conceptual framework is broad in its scope of possible applications. Future work could explore its potentials for analysing the dynamics of work of a different nature and context in the construction industry. Therefore, beyond its application in this study and in similar studies, activity theory methods could also enable the description and understanding of how individual and collaborative professionals work, might coevolve within their sociocultural settings with new technical systems such as BIM to create new forms of such activities; while constraints and enablement in the system are dealt with and accommodated. It would be beneficial in future research to also begin to consider, for example, the mediating effects of rules in the relationship between actors and the community of practice, or even that of roles in the relationship between the actors and their object.

As the nature of work practices evolve, an important question is how much of an impact could it have on individual and organisational image on the one hand, and self-identity on the other? In this regard, one of the more interesting applications of psychosocial theoretical perspectives to the BIM implementation and management area of research, is the study of resistance to change in light of BIM's capability to alter, or challenge professionals' identities as competent workers. Nach and Lejeune (2015) argue that such challenges to identity could hinder widespread adoption. Looking ahead, however, a much deeper conceptualisation is needed of how professions or disciplines may, without conscious effort, be changing in image and identity both at the individual and organisational levels. This would make it possible to investigate how such changes in identity might influence the definition, demarcation and distribution of roles in the future.

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Table 1. Profile of key informants drawn from the cases

Figure 1. Depiction of an activity system showing the relationship between elements (adapted from Engeström (2000))

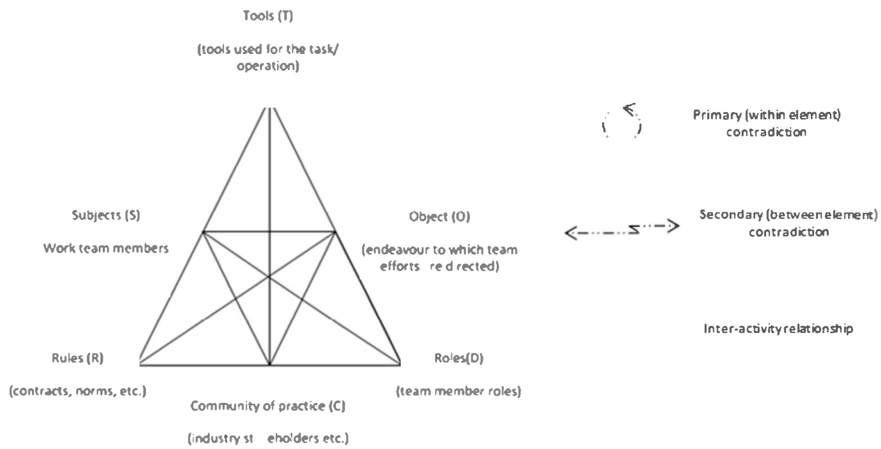


Figure 1. Depiction of an activity system showing the relationship between elements (adapted from Engeström (2000))

199x149mm (96 x 96 DPI)

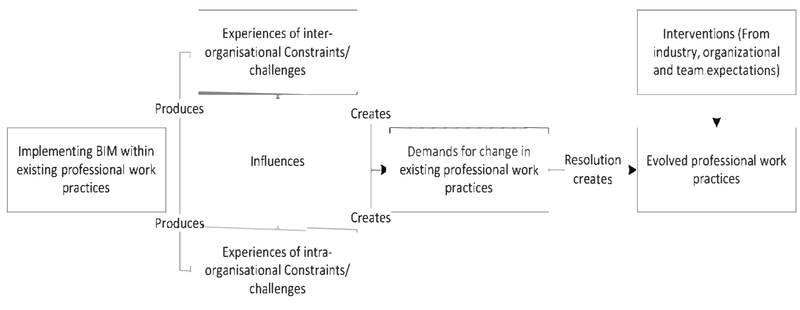


Figure 2. Conceptual model

199x149mm (300 x 300 DPI)

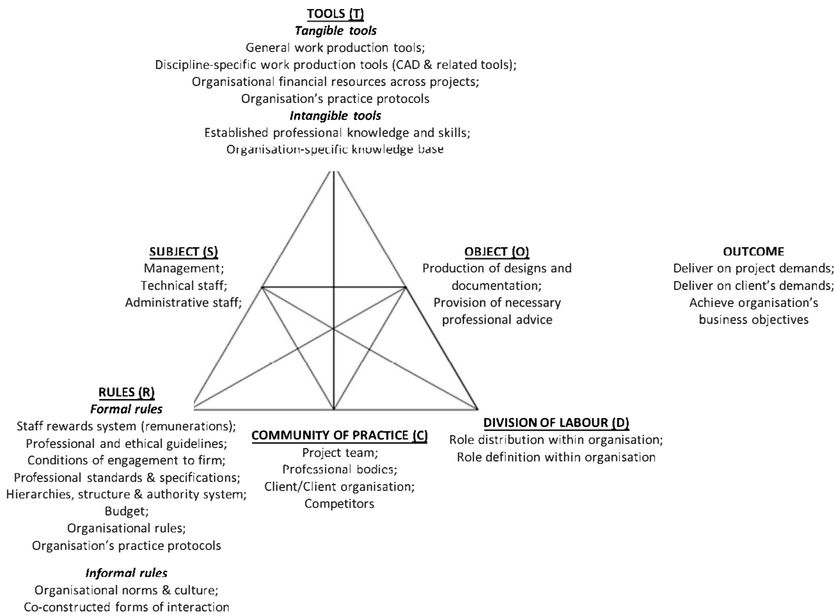


Figure 3. Organisational context activity system

199x149mm (300 x 300 DPI)

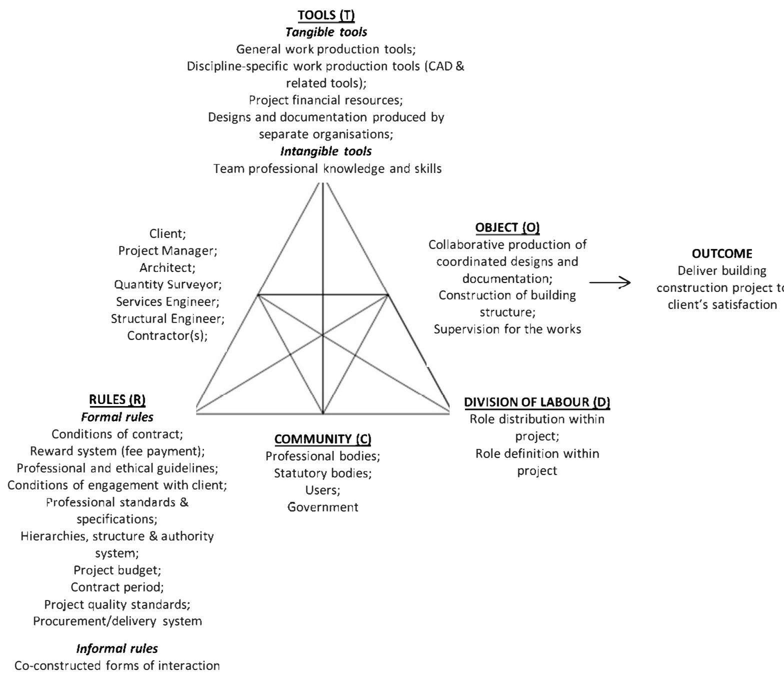


Figure 4. Project context activity system

199x149mm (300 x 300 DPI)

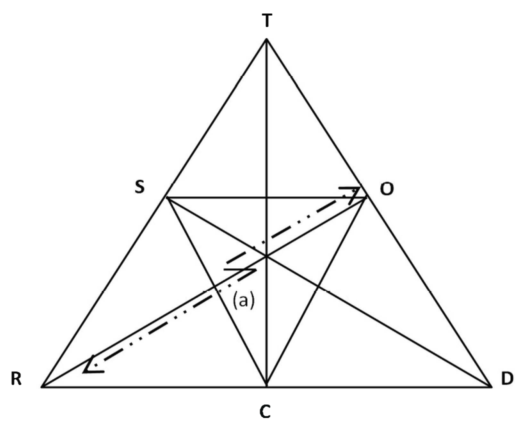


Figure 5. Rule vs Object contradiction necessitating the introduction of BIM at the organisational level (a)

199x149mm (300 x 300 DPI)

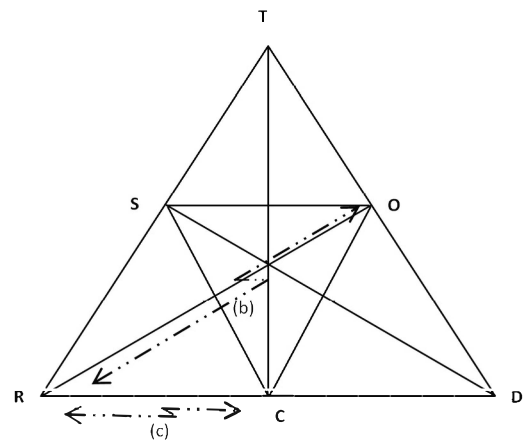


Figure 6. Rule vs Object; and Rule vs Community contradictions necessitating the introduction of BIM at the organisational level (b & c)

199x149mm (300 x 300 DPI)

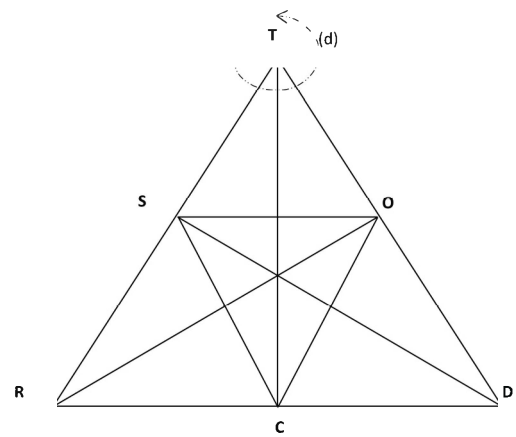


Figure 7. Tool vs Tool contradiction between newly-introduced tools and existing tangible and intangible tools (d)

199x149mm (300 x 300 DPI)

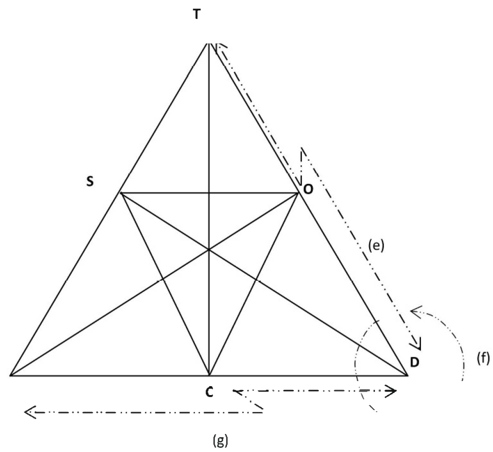


Figure 8. Tool vs Role (e); Role vs Role (f); and Role vs Rules (g) contradictions

199x149mm (300 x 300 DPI)

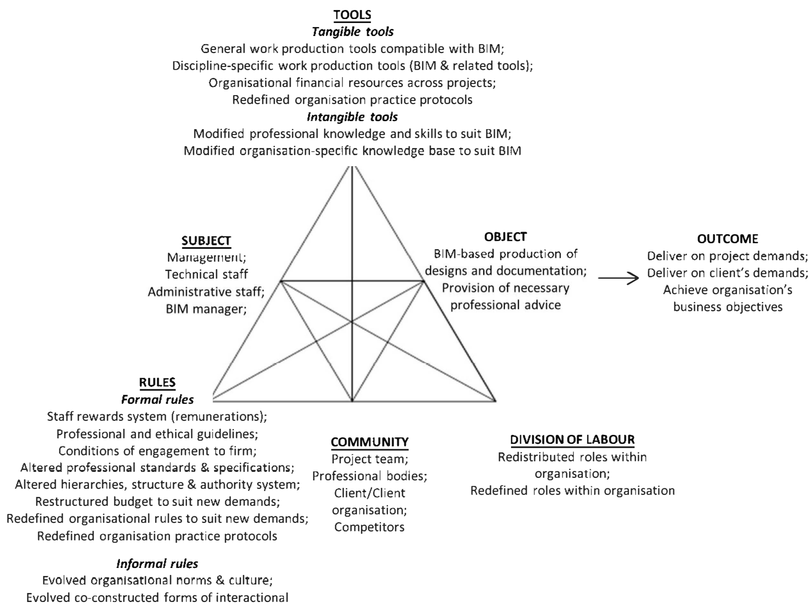


Figure 9. Evolved organisational context activity system upon impact by new technology (BIM)

199x149mm (300 x 300 DPI)

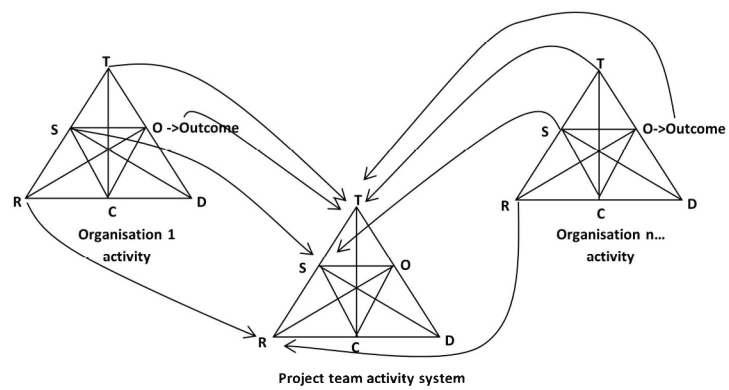
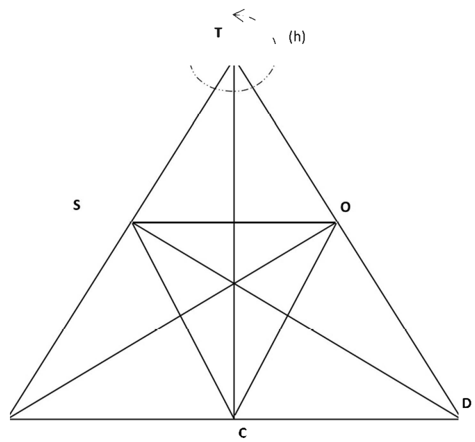


Figure 10. Systemic relationship between OCAS and PTAS

199x149mm (300 x 300 DPI)



199x149mm (300 x 300 DPI)

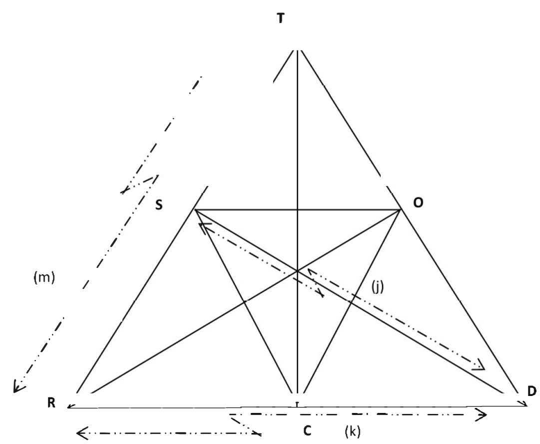


Figure 12. Subject vs Roles (j); Role vs Rule (k); Tool vs Rule (m) contradictions

199x149mm (300 x 300 DPI)

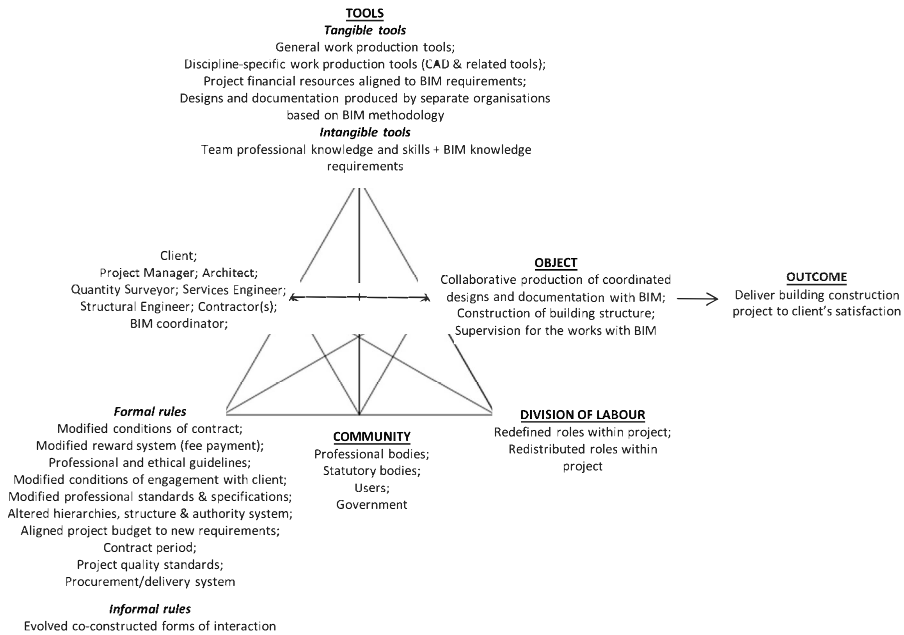


Figure 13. Evolved project context activity system upon impact by new technology

199x149mm (300 x 300 DPI)

Table 1. Profile of key informants drawn from the cases

CASES (ORG)	PARTICIPANT	PROFILE
ORG1	*Q2: ARCHITECT & BIM COORDINATOR*	The participant is a professional architect who was employed about three years ago with BIM expertise as a key criterion. Since joining the organisation, the participant has, in conjunction with colleagues, helped in formalising BIM adoption companywide. (It is a multidisciplinary organisation with multinational operations and the parent company in a Western country.)
ORG2	*Q3: CIVIL/ STRUCTURAL ENGINEER, VDC/BIM COORDINATOR, & DIRECTOR*	The participant is a regional director within the organisation (a multidisciplinary organisation with multinational scope of operations and the parent company in a developed country), with responsibility and experience in facilitating Virtual Design and Construction (VDC) sessions and BIM within the organisation. The organisation has taken on a decidedly formal approach to BIM implementation by borrowing from exemplary implementation cases in company branches in countries like the UK.
ORG3	*Q11: ARCHITECT & BIM COORDINATOR*	The participant has had experience in using BIM authoring tools for about 12 years, while the organisation (an architectural organisation with multinational scope of operations) has been using BIM authoring software for about a decade as one of the early adopters in the country. BIM experience was one of the key criteria for which the participant was employed. Further, Q11 has been at the forefront of developing a formal companywide approach to BIM implementation within the organisation with the express support of top management.
ORG4	*Q4: ARCHITECT, PROJECT MANAGER, & VDC/BIM COORDINATOR*	The participant is responsible for facilitating both BIM and VDC (virtual design and construction) coordination within the organisation (multidisciplinary and multinational scope of operations) and on multi-organisational projects. The participant, therefore, provided valuable insight and broad perspectives about implementing BIM.
	Q7: BIM MANAGER & ARCHITECT	Q7 was employed specifically to facilitate implementation of BIM by the organisation countrywide (a multidisciplinary organisation with multinational scope of operations and providing mainly engineering services) to match the global drive of the organisation to make BIM a key strategy for delivering on clients' demands using their international branches as exemplars.

CASES (ORG)	PARTICIPANT	PROFILE
ORG5	*Q1: BIM MANAGER*	The participant was employed about five years ago by the organisation (an architectural organisation with multinational operations), in a dedicated role to manage the day-to-day development of BIM and BIM content within the organisation, while also helping to keep the organisation abreast of BIM development internationally.
	Q9: ARCHITECT & DIRECTOR	Q9 is a professional architect and director of the organisation (an architectural organisation with multinational scope of operations). Having been using BIM authoring software for about eight years, the participant gained considerably high experience which enabled broad views, often from a managerial perspective.
ORG6	*Q10: CIVIL/STRUCTURAL ENGINEER & DIRECTOR*	Q10 is a director with Civil/Structural Engineering qualifications. The organisation (a multidisciplinary organisation with multinational scope of operations) had decided on implementing BIM as a formal strategy for delivering on projects about two and a half years before the interview. However, due to severe difficulties encountered, it decided to return to using CAD tools by January 2016 (see also Q5 Architect).
ORG6	*Q5: ARCHITECT*	This participant, although knowledgeable about issues around BIM and its implementation having been a user, joined the organisation (multidisciplinary and multinational scope of operations) shortly before they decided to discontinue BIM use by January 2016 (by January 2016 the organisation had gone back to using CAD for all projects).
OGR7	*Q8: ARCHITECT*	Q8 is a professional architect at an architectural organisation with only local operations. However, the organisation had decided to take the BIM route to delivering projects fairly recently. Being a relatively small-sized organisation compared to the rest, it had not taken any formal approach to adopting BIM.
ORG8	*Q6: BIM MANAGER & ARCHITECT*	Q6 was a Senior Architectural Technologist who also had extensive experience working for a BIM consulting firm in South Africa, from where experience was gained in setting up BIM within organisations and also coordinating BIM on multidisciplinary and multi-organisational projects. The participant had only recently joined the current organisation (architectural) to help facilitate on the job skills development around BIM and development of uniform organisational process and design templates. For these reasons, the participant provided very enlightening and unique perspectives.