

# 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.

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4 **25 Introduction**  
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6 In spite of developments in BIM research and practice, there remain impediments  
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8 to modelling sufficient information to support seamless collaboration and  
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10 information exchange (Berard & Karlshoej, 2012). Indeed, achieving the full  
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12 benefits often associated with BIM, requires stakeholders to undergo an extensive  
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14 change in management process. Many authors have alluded to this, or made  
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16 claims about the changes induced within organisational and project team work  
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18 practices; that is, BIM's demand for change in current ways of working in the  
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20 industry on the one hand, and its capability to change the construction industry on  
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22 the other. The literature is therefore rife with specific and broad claims and  
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24 assertions about the impact of BIM in the construction industry. They allude to  
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26 BIM-induced changes being both inter- and intra-organisational (Cavka, Staub-  
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28 French, & Pottinger, 2015); CAD informed practices need to be replaced with  
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30 BIM practices (Kaner, Sacks, Kassian, & Quitt, 2008); new workflows, practices  
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32 and roles are required and emerging (Gheisari & Irizarry, 2016; Holzer, 2015);  
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34 and changes to team organisation, procurement, and contracts are required (Burt  
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36 & Purver, 2014), amongst others. Broad assertions have also been made, such as  
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38 that BIM brings about a changed way of thinking for construction industry  
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40 professionals (Xu, Feng, & Li, 2014), and implementing BIM requires significant  
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42 changes in virtually all aspects of the construction business process (Arayici *et al.*,  
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44 2013). Many of these claims are plausible and also common-sense, even while  
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46 they have been criticised as largely lacking a grounding in robust theory.

47 Fox's (2014) critique of such claims holds that many of them are  
48 fallacious and unsupported by evidence, while some of the findings in the  
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4 49 literature do not explicate actual change; instead, they mainly present BIM  
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6 50 enablement of work practices and vague descriptions of change. Indeed, much of  
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8 51 the BIM literature is characterised by vague descriptions of BIM-induced change.  
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10 52 This is largely due to the tacit nature of routinised work practices. As new forms  
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12 53 of operations are repeated, they gradually become routine and hidden.

14 54 A gap in the literature is evident in the dearth of critical theoretical  
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16 55 perspectives and theorisation capable of holistically exposing the real nature of  
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18 56 change in work practices. This is particularly related to Çıdık, Boyd and  
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20 57 Thurairajah's (2017) assertion in their study of change within digital  
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22 58 interdisciplinary collaboration. They affirmed that much of the current critical  
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24 59 literature on BIM and organisational change has largely been descriptive,  
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26 60 providing explanations of actual changes and the reasoning behind them, while  
27  
28 61 failing to theorise the dynamics that cause change to happen – a view that is  
29  
30 62 strongly shared and leant on. Therefore, the aim here is to develop theoretical  
31  
32 63 insight into the path and pattern of BIM impact on organisational and team work  
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34 64 practices using activity theory as a lens, and for elucidating what is otherwise tacit  
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36 65 knowledge.

40 66 This responds to the call for a new stream of critical BIM literature to  
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42 67 provide nuanced theoretical understandings of BIM-induced changes in  
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44 68 construction-related work practices (Dainty, Leiringer, Fernie, & Harty, 2017). In  
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46 69 particular, activity theory is well suited to 'describe how human activity and the  
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48 70 setting in which it is situated co-evolve over time and change the nature of future  
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50 71 activities while participants deal with new barriers and possibilities' (Yamagata-  
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52 72 Lynch, 2010, p. 11).

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4 73 Firstly, an overview of the use of meso- and macro-level social theory in  
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6 74 the BIM research literature is provided, which reveals its sparing use in the last  
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8 75 decade – this even though many of the important challenges to the implementation  
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10 76 of BIM in the construction industry are social. Next, a theoretical framework  
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12 77 based on activity theory is developed, which provides a unique theoretical account  
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14 78 and novel conceptualisation of BIM’s impact on professional work practices, and  
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16 79 an understanding of evolutionary change dynamics within organisational and  
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18 80 project team activities. These, therefore, lay the theoretical foundations for the  
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20 81 research design and analysis of change in professional work practices, viewed  
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22 82 through the lens of activity theory. The sections that follow present the research  
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24 83 methodology, methods and analysis of cases of professional organisations that  
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26 84 have implemented BIM within them, and on multidisciplinary projects after which  
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28 85 the empirical findings and their interpretations were analysed within the chosen  
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30 86 theoretical framework. Furthermore, the concluding section summarises important  
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32 87 findings and their implications, which have significance to theory on the  
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34 88 understanding of BIM-induced change, as either evolutionary or revolutionary. It  
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36 89 also details some significant implications for future research in the construction  
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38 90 industry, particularly in the face of rapid advances in construction-related  
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40 91 technological and non-technological innovation.  
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## 46 **The impact of implementing BIM**

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48 93 Within the information systems (IS) literature, it is well established that  
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50 94 implementing IS induces changes in work practices (Martinsons & Cheung, 2001;  
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52 95 Rintala & Suolanen, 2005). In their work, Rintala and Suolanen (2005)  
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54 96 acknowledged that technology is known to have significant impacts on aspects of  
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4 97 organisations' work. Davidson and Chiasson (2005) also raised some important  
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6 98 questions (previously posed by Johnston and Vitale (1988)) about Information  
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8 99 Systems' impact on organisational structure and strategy, and inter-organisational  
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10 100 Information Systems' potential impact on industry structure. In their work,  
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12 101 Johnston and Vitale (1988) emphasised the need to recognise that the electronic  
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14 102 link between several organisations, accounts for much of the changes in their  
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16 103 relationship.

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19 104           Some of the related work, for example by Vaast and Watsham (2005),  
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21 105 examined how practices impacted by Information Systems change at the  
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23 106 micro/individual relationship level. They approached an understanding of  
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25 107 Information Systems induced change, in the context of consonance and  
26  
27 108 dissonance. Vaast and Watsham (2005) argue that IS- or IT-induced change, may  
28  
29 109 be explained by the dynamics through which agents modify their actions and  
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31 110 representations to re-establish consonance when they perceive a dissonance. They  
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33 111 defined representations as the way in which actors act in different work contexts.  
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35 112 Furthermore, they suggested the need to examine representations that shape  
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37 113 agents' understanding of their work and technology – and the consonance or  
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39 114 dissonance they may experience – to fully understand how IS/IT may induce  
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41 115 changes in work practices. Vaast and Watsham (2005) further assert that new  
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43 116 actions that result in changed practices must be recurrent, socially shared, and one  
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45 117 may argue further, socially acceptable. These are particularly necessary for  
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47 118 legitimizing new work practices.

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51 119           In the BIM literature, Sebastian (2011) asserts that effective  
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53 120 multidisciplinary collaboration through BIM, requires changing the roles for all  
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4 121 project stakeholders, new contractual relationships, re-organised collaborative  
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6 122 processes, and a shift in the mind-set of parties on both the demand and supply  
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8 123 sides of the construction business process. The author went on to highlight the gap  
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10 124 in practical knowledge in how to manage stakeholders, in order to efficiently  
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12 125 collaborate with their changing roles. As changing construction work practices  
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14 126 relate to complementary changes in contractual relationships, it is noteworthy that  
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16 127 the existing standard forms of contractual engagement may also fall short of  
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18 128 supporting collaboration through BIM.

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21 129 Furthermore, according to Hartmann *et al.* (2012), little is known about the  
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23 130 possibilities of adapting BIM technologies to aid existing organizational work  
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25 131 processes – a gap they sought to fill through empirical research based on two case  
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27 132 studies of practical BIM implementation in construction projects. They found that  
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29 133 while implementers of BIM hold initial beliefs that the implementation would  
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31 134 require a change in the work process for estimating, this perception changed as  
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33 135 they became more aware of the possibility of adapting the technology to their  
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35 136 work processes. Nevertheless, Hartmann *et al.* (2012) also acknowledge that  
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37 137 despite the evidence supporting their view, the specific dynamics in organisational  
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39 138 settings might necessitate a radical shift in existing and established work  
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41 139 processes, to successfully implement BIM. In conclusion, they suggested that  
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43 140 future research should investigate the emergence of organisational change around  
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45 141 BIM-based tools at different levels within an organisation, by applying multi-level  
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47 142 organisational research methods.

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51 143 In their study, Arayici *et al.* (2012) recognised that in order to achieve the  
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53 144 full benefits often associated with BIM, stakeholders need to go through a  
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4 145 comprehensive change management process, which is likely to require external  
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6 146 assistance. Holzer (2015), in similarity to the earlier work of Sebastian (2011) also  
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8 147 affirmed that new roles are emerging to maximise efficiency within BIM  
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10 148 workflows, such as BIM content creators, BIM model manager (project level),  
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12 149 BIM manager (office/organisation level), and BIM coordinators (multidisciplinary  
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15 150 projects).

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17 151 The work of Olatunji (2011), likewise related to Sebastian's (2011),  
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19 152 highlighted the need for organisations in the industry to understand the nature of  
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21 153 BIM induced change, and develop effective ways of coping with it. Similarly,  
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23 154 Foster (2011)'s work on BIM makes a contribution to the debate around BIM's  
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25 155 impact on industry business processes. As with several other authors, Foster  
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27 156 (2011) acknowledges the blurring divides between design and construction in  
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29 157 integrated practice with BIM. Moreover, BIM brings the possibility of inducing  
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31 158 fundamental changes in the project delivering process. Importantly, Foster (2011)  
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33 159 noted that new business models have not been developed to suit the use of BIM,  
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35 160 and that its implementation requires a change in risk allocation among project  
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37 161 stakeholders. New contractual arrangements will ultimately dictate which project  
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39 162 stakeholder bears which risks.

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42 163 Putting the foregoing into context, studies have begun to stimulate new  
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44 164 research questions about the 'technocratic optimism' that often dominates the  
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46 165 current debates around BIM as a tool and its implementation (Dainty *et al.* 2017).  
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48 166 Dainty *et al.* (2017) scrutinised the enthusiasm around BIM and assertions about  
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50 167 BIM's revolutionary impact on construction industry practices. In Fox's (2014)  
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52 168 critique of claims about BIM's impacts as revolutionary, some important  
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4 169 arguments were put forward. These include, that BIM descriptions are often  
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6 170 characterised by hype, and that descriptions of BIM as exceptionally radical and  
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8 171 uniquely socio-technical, are naïve. Rather, these descriptions were reframed to  
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10 172 indicate that BIM is quite like other technologies within other industries, and that  
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12 173 many others involve complex interactions between technology (or tools), actors,  
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14 174 and their socio-cultural work contexts.

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17 175 Miettinen and Paavola (2014), in their position paper, also offered an  
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19 176 analysis of the ‘rhetorical-promotional’ dimension of BIM implementation,  
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21 177 arguing that BIM implementation promises need to be complemented by more  
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23 178 realistic views, through applying relevant conceptual tools from social science  
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25 179 literature. They further criticised the tendency to transform the visions and  
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27 180 expectations of BIM potentials, into a depiction of future reality, oftentimes  
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29 181 without due regard for the conditions and constraints that may hinder their  
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31 182 realisation – although it is argued here that the expected change also happens to  
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33 183 benefit from said constraints, and how they are dealt with as shown in the next  
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35 184 section.

## 36 37 38 39 40 185 **Theoretical perspectives**

### 41 42 43 186 *Theory use in the BIM literature*

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46 187 Conceptual frameworks ensue from theory in such a way that they guide the  
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48 188 research process, from conception through to analysis and sense making. Social  
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50 189 theories afford researchers the tools to conceptualise and understand humans and  
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52 190 their actions within the relevant socio-cultural and socio-technical contexts (Willis  
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55 191 *et al.*, 2007). It is necessary, therefore, to seek theoretical understanding of  
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4 192 phenomena of interest in research endeavours. BIM research has hitherto been  
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6 193 mostly a-theoretical, despite having proliferated in the last decade. While there  
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8 194 have been some applications of theory, this has largely been limited to a particular  
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10 195 set of theories which have been nevertheless applied sparingly. Out of 1,040  
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12 196 reviewed journal and conference papers on BIM published between the years and  
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14 197 including 2005 until 2016, 64 were found to have either employed the use of  
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16 198 meso- to macro-level theory or mentioned their influence on the research  
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19 199 approach.

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21 200 It can be surmised, therefore, that BIM research has developed over the  
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23 201 years without much application of relevant theory. Furthermore, upon closer  
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25 202 examination of research where some element of theory was found, it became clear  
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27 203 that many only explained their use of theory sparingly, with very few having  
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29 204 applied theory visibly in formulating their research design and making analytical  
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31 205 decisions. The most common theories applied in BIM research are those relating  
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33 206 to the diffusion of innovation and technology adoption (Davies & Harty, 2013;  
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35 207 Gledson, 2016; Wu, Wen, Chen, & Hsu, 2016). This is expected, as many of the  
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37 208 critical BIM research issues have remained connected to awareness, user  
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40 209 perceptions and benefits accruable from adoption, among other things.

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43 210 Some of these theories address different aspects of BIM implementation  
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45 211 issues, but do not holistically show how the different elements of the  
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47 212 implementation are linked and interact within the sociocultural context. It is  
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49 213 therefore interesting to note that some authors are beginning to explore the  
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51 214 strength of psychosocial theory to explain the dynamics of BIM implementation  
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53 215 and induced change. For instance, Doloi, Varghese and Raphael (2015) employed  
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4 216 social network theory examining BIM project impediments to identify the stakes  
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6 217 of actors in multifunctional and organisational dynamics. Clearly, of specific  
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8 218 interest to this research are studies that have employed theory in the area of  
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10 219 computer-supported collaborative work (CSCW) and human-computer interaction  
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12 220 (HCI) research. Miettinen and Paavola (2014), for example, proposed an  
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14 221 evolutionary approach to BIM implementation research that draws from cultural-  
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16 222 historical activity theory (CHAT) and organisational studies. Similarly, Korpela,  
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18 223 Miettinen, Salmikivi and Ihalainen (2015) applied CHAT in the study of  
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20 224 challenges and potentials for utilising BIM in facilities management.  
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23 225 Without appropriate use of theory, it is difficult to achieve conceptual  
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25 226 clarity concerning what to study, within which boundaries, how to study it, and  
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27 227 how to make sense of research findings. Accepting the premise that BIM adoption  
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29 228 is a complex social activity (Cao, Li, & Wang, 2014), the application of theory in  
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31 229 research design and theorisation is indispensable. Therefore, activity theory was  
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33 230 employed here to provide novel insights into BIM induced change in professional  
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35 231 work practices. The next section justifies this choice of theory.  
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40 232 *Activity theory as a lens for conceptualising BIM change impact*

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42 233 Engeström and Miettinen (1999) opined that a theoretical account of the  
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44 234 constituent elements of complex systems, is an essential precursor to analysing  
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46 235 their relationship(s). Activity theory is relevant for examining and understanding  
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48 236 object-oriented and motive-driven collective work. Furthermore, to suitably  
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50 237 conceptualise the nature of project teams' collaborative work in the delivery  
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52 238 process, it is useful to employ activity theory (Akintola, Senthilkumar, & Root,  
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54 239 2015). The usefulness of activity theory lies in its ability to aid the understanding  
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4 240 of tool-mediated human interactions (Kaptelinin & Nardi, 2006). Such tools may  
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6 241 be intangible (e.g., knowledge) or tangible (e.g., information technology tools)  
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8 242 (Crawford & Hasan, 2006; Kaptelinin & Nardi, 2006). Additionally, the theory  
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10 243 enables the analysis of emerging patterns of human activity in terms of changing  
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12 244 processes (Crawford & Hasan, 2006). It has also been proposed as a means for  
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14 245 making sense of how people act together, with the assistance of tools and in  
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16 246 complex, dynamic environments (Crawford & Hasan, 2006).

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19 247 Furthermore, activity theory provides theoretical explanations for the  
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21 248 dynamics within an activity system's elements (Crawford & Hasan, 2006;  
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23 249 Engeström, 1999; Kaptelinin & Nardi, 2006). As in Figure 1, a work activity  
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25 250 system comprises individual actors, tools that facilitate their work, rules to guide  
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27 251 how they work, the purpose to which members of the workplace community  
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29 252 direct their actions, and the distribution of responsibilities between actors within  
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31 253 the system (Engeström, 2000). Hence, the description of an activity system as a  
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33 254 system of collaborative human practices (Engeström, 2000).

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36 255 Importantly, activity theory posits that dysfunctions between elements of  
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38 256 an activity system are the causes of change and development (Engeström, 1999).  
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40 257 These dysfunctions, in turn, create 'need states' in which change, and  
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42 258 development of the system can be accounted for (Engeström, 2000). To bolster  
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44 259 this, Engeström (2000) in the treatise that put the theory forward for analysing and  
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46 260 redesigning work, further stressed the non-static nature of activity systems, in that  
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48 261 they are in perpetual evolution and internally contradictory. Contradictions in the  
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50 262 system offer possibilities for developmental transformations in the creation of  
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52 263 needs for change, and to cater for missed targets or expectations not being met  
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4 264 (Engeström, 2000; Hassan & Banna, 2010; Holt & Morris, 1993; Kaptelinin &  
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6 265 Nardi, 2006). This assertion is essential to the cultural-historical analysis of work  
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8 266 practices, bringing to bear the ‘need states’ created by manifested contradictions.  
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10 267 While the introduction of new tools (e.g., BIM) into an activity system  
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12 268 (e.g., bounded within an organisation or project team) may proffer solutions to  
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14 269 certain problems in human work, they introduce a new set of dysfunctions that  
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16 270 require analysis within the socio-cultural context (Engeström, 2000). More  
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18 271 importantly, when a need cannot be met within an existing activity system, a  
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20 272 ‘need state’ is created. The author further pointed out that the theory is suited to  
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22 273 engaging the system as it is emerging, and the primary purpose is to guide the  
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24 274 system through various stages of dealing with the dysfunctions. This enables the  
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26 275 actors or stakeholders to develop new solutions to address challenges that are  
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28 276 experienced. As drivers for change, there are four types of contradictions. These  
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30 277 are primary (within each element of the activity), secondary (between constituent  
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32 278 elements of the activity), tertiary (between the activity itself and a culturally more  
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34 279 advanced form of the activity), and quaternary (between the central activity and  
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36 280 adjacent activities) (Engeström, 1987).  
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40 281 There is, therefore, a strong case for exploring activity theory in analysing  
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42 282 technology-induced change. This is supported in the work of Engeström and  
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44 283 Escalante (1996), who showed that activity systems analysis could be used to  
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46 284 describe collective activities involved in the development and implementation of  
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48 285 technological innovations; as well as to analyse the effect of human interaction on  
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50 286 the implementation (Yamagata-Lynch, 2010). Closely related is Mwanza’s (2002)  
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52 287 study, which was designed to analyse work practices in relation to identifying  
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4 288 design requirements for computer-assisted learning. This was an ethnographic  
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6 289 study that used Engeström's (2000) activity systems model (see adaptation in  
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8 290 Figure 1) to map how existing work-related practices fit into each element of the  
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10 291 model. [Insert Figure 1 here].

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12 292 Activity theory, therefore, provides a framework for guiding a system  
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14 293 through the process of transformation, while at the same time dealing with  
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16 294 emergent contradictions and disturbances within and between elements of the  
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18 295 system (Holt & Morris, 1993; Kaptelinin & Nardi, 2006). The focus of this study  
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20 296 is on analysing the changing patterns of professional work practices as impacted  
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22 297 by the use of new tools (BIM). This enables the unique opportunity to apply  
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24 298 activity theory to elicit and contextualise the evolution of collaborative  
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26 299 professional practices, due to dysfunctions created by contradictions in the  
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28 300 system. This approach also affords methodological developments in an area of  
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30 301 research mostly lacking the application of psycho-social theory.

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32 302 A theory is only as useful and practical as to how its key propositions and  
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34 303 assumptions inform a study. As an argument for the theoretical choice made,  
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36 304 activity theory is specific in its focus, being a theory for understanding the  
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38 305 evolutionary dynamics of human endeavour. Moreover, it is clear in its  
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40 306 explanation of fundamental concepts, assumptions and propositions about  
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42 307 transformations, or change within and between elements of an activity system.  
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44 308 Further, there is a considerable body of knowledge on the theory. Activity theory,  
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46 309 therefore, affords a holistic understanding of the phenomena of interest, i.e.,  
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48 310 change in patterns of professional work practices.  
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4 311 Activity theory propositions and assumptions are the basis for the  
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6 312 conceptual model in Figure 2. It shows that implementing BIM within pre-BIM  
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8 313 organisational and project team activity contexts, produces constraints and  
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10 314 contradictions which, when resolved, present opportunities for the activities'  
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12 315 evolution. The aim of this article is not, therefore, to echo BIM challenges already  
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14 316 evident in the literature in its findings, but rather within real-life cases identify  
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16 317 specific constraints and contradictions that trigger changes in the pattern of  
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18 318 professional work practices, using activity theory as a lens and methodological  
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20 319 approach to map out patterns of change [Insert Figure 2 here]. Thus, the pertinent  
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22 320 questions of interest are:

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26 321 • What are the constituent elements of organisational and project team  
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28 322 context activities?  
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31 323 • What are the conflicts and contradictions created within existing  
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33 324 professional work practices as a result of implementing BIM?  
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35 325 • How are the conflicts and contradictions within these systems being  
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37 326 resolved?  
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39 327 • How have professional work practices changed as a result of the  
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41 328 introduction of new tools (BIM) into the activity systems?  
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45 329 These questions are based on the activity theory position that all forms of  
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47 330 human practices are the products of 'historical development', which perpetually  
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49 331 reforms and triggers the development of said practice. Furthermore, that  
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51 332 individual and collaborative human work activities are mediated and shaped by  
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53 333 tools (Kaptelinin & Nardi, 2006). This theoretical perspective is not entirely new  
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4 334 in the BIM literature. Korpela *et al.* (2015) applied it to study a library project  
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6 335 case in Finland, to uncover the challenges and potentials for using BIM in  
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8 336 facilities management. Although, the authors reported their reliance on activity  
9  
10 337 theory and the concept of activity systems for their theoretical framework and  
11  
12 338 analysis, it was observed that the study was not distinctly framed as one based on  
13  
14 339 activity theory.

15  
16  
17 340 By contrast Mäki and Kerosuo (2015) focussed their research on the Rule  
18  
19 341 and Tool elements of an activity system. They acknowledged that implementing  
20  
21 342 BIM, as has been done here, can cause disturbances within work activity systems.  
22  
23 343 While their study is clearly presented as being based on activity theory, a more  
24  
25 344 explicit identification of contradictions and disturbances within clearly defined  
26  
27 345 activity system contexts would have been beneficial. They, however, importantly  
28  
29 346 affirmed that future research should examine other critical elements of BIM use,  
30  
31 347 such as rule and role elements of an activity system.

32  
33  
34 348 Undoubtedly, other theoretical perspectives and frameworks are relevant  
35  
36 349 to understanding BIM-induced change. Among others, structuration theory can  
37  
38 350 help to formulate important research questions to investigate, while institutional  
39  
40 351 theory can also provide valuable insight into different aspects of BIM  
41  
42 352 implementation issues. For example, Cao, Li and Wang (2014) investigated  
43  
44 353 isomorphic pressures influencing BIM adoption, while Akintola, Venkatachalam  
45  
46 354 and Root (2017) studied legitimacy and changing power dynamics on BIM-  
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48 355 enabled projects.  
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4 356 Since theoretical choices dictate choices of research methods, in the next  
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6 357 section the methods chosen for this research are outlined in line with the adopted  
7  
8 358 theoretical perspective.

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11  
12 359 **Methods**

13  
14 360 BIM usage is not widespread in the study context of South Africa (Froise &  
15  
16 361 Shakantu, 2014). In fact, Harris (2016, p. 2) revealed the ‘industry’s inherent  
17  
18 362 traditionalism towards Building Information Modelling technologies, with many  
19  
20 363 survey respondents preferring to follow trends rather than to take the lead. Many  
21  
22 364 who have adopted a BIM technology strategy have done so in a silo approach.’  
23  
24 365 The approach to sampling was, therefore, a nested strategy which consisted of two  
25  
26 366 levels of purposive sampling (Patton, 2015, p. 305), since it was important to  
27  
28 367 select cases of relatively advanced level of BIM implementation. This method is  
29  
30 368 similar to the methods employed by authors like Engeström and Escalante (1996)  
31  
32 369 and Yamagata-Lynch (2010) who apply activity theory in other contexts.

33  
34  
35 370 First, comparison-focused case sampling (Patton, 2015, p. 277) was  
36  
37 371 undertaken. Through this, eight purposively selected cases of professional  
38  
39 372 construction organisations that have implemented BIM within and on  
40  
41 373 multidisciplinary projects, were studied. These included extreme deviant cases of  
42  
43 374 relatively high success at implementing BIM and notable failures in implementing  
44  
45 375 BIM (Patton, 2015; Wengraf, 2001, p. 102). Five of these cases were  
46  
47 376 multidisciplinary organisations (i.e., including of architects, quantity surveyors,  
48  
49 377 services engineers, and structural engineers) and three were architectural firms. In  
50  
51 378 determining the number of cases for a study like this, Patton (2015) affirms that  
52  
53 379 the determination of a suitable number of cases depends on the purpose of the  
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4 380 enquiry and availability of such cases. A further trade-off is also required between  
5  
6 381 depth and breadth of data collected and its analysis (Patton, 2015, p. 311).

7  
8 382 Furthermore, in-depth interviews were conducted with purposively  
9  
10 383 selected key informants (BIM Champions) from these cases (Marshall, 1996;  
11  
12 384 Tremblay, 1957). The participants were selected based on personal skill, position  
13  
14 385 within the organisation, knowledge about the subject of interest and possession of  
15  
16 386 a wide range of views. The specific recruitment criteria were that the participant:

- 17  
18  
19  
20 387 • Is responsible for maintaining and developing BIM implementation within  
21  
22 388 the organisation and is therefore sufficiently experienced to provide in-  
23  
24 389 depth accounts of various aspects of such implementations (as BIM  
25  
26 390 Champions)
- 27  
28 391 • Has participated in a construction project where the project team  
29  
30 392 implemented BIM
- 31  
32 393 • Is one of the following professionals – architect, project manager, quantity  
33  
34 394 surveyor, mechanical services engineer, electrical services engineer or  
35  
36 395 structural engineer

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39  
40 396 The nested sampling strategy is supported by Yin (2014, p. 92), in that  
41  
42 397 while cases of organisations may be the object of interest, data may be collected  
43  
44 398 about them through individual interviews to examine how such organisations  
45  
46 399 work, and also how and why phenomena of interest are happening within the  
47  
48 400 organisation.

49  
50  
51 401 To demonstrate credibility, studies based on activity theory should provide  
52  
53 402 thick participant descriptions and establish the context of interest (Yamagata-

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3  
4 403 Lynch, 2010). For this reason, detailed profiles of the key informants are provided  
5  
6 404 in Table 1, while the context is provided in the sections that follow. [Insert Table  
7  
8 405 1 here].  
9

10  
11  
12 406 *Data collection methods*  
13

14 407 The data was collected by audio recordings of conversations based on a pre-  
15  
16 408 prepared semi-structured interview protocol. Probing questions were asked about  
17  
18 409 participants' experiences on BIM-enabled projects as compared to non-BIM  
19  
20 410 projects; as well as questions about how their organisations have been impacted  
21  
22 411 since BIM was implemented. In particular, questioning was focused on how they  
23  
24 412 carried out their functions, constraints experienced and specific changes that they  
25  
26 413 had to make in their work practices. Furthermore, a sequence of taking field notes,  
27  
28 414 transcribing audio and coding was followed in line with the recommendations of  
29  
30 415 Saldaña (2013). The interviews each lasted an average of 45 minutes. Memos  
31  
32 416 were written immediately after each interview to preserve contextual  
33  
34 417 information/data, after which verbatim transcripts were produced. Analytical  
35  
36 418 memos were also written while transcribing to keep records of theoretical  
37  
38 419 reflection on the data. Further analysis was done by coding textual data into  
39  
40 420 categories and sense-making.  
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44 421 Importantly, the method of theoretical re-description, in which empirical  
45  
46 422 data is re-described using theoretical concepts, was employed. Through this  
47  
48 423 method a particular phenomenon or event may be interpreted from a set of  
49  
50 424 theoretical ideas or concepts, raising the level of theoretical engagement beyond  
51  
52 425 the description of the empirical entities (Fletcher, 2017). The following analysis is  
53  
54 426 therefore presented as a theoretical explanation and re-description of the data  
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4 427 collected on the changing nature of organisational and project team work  
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6 428 practices. It is based on the experiences of implementing BIM in these contexts by  
7  
8 429 the participants.  
9

10 430 Interviewing and interview data analysis can be highly structured and  
11  
12 431 systematic, with allowance for moments in the research process where analysis  
13  
14 432 and interpretation are data-led rather than existing theory-led (Wengraf, 2001). It  
15  
16 433 is also possible to collect information for objective, subjective and discourse  
17  
18 434 analysis in the course of questioning (Wengraf, 2001). Therefore, interview data  
19  
20  
21 435 can be used to elicit information in both structured and unstructured forms.  
22

23 436 Nevertheless, a rational methodological alternative choice for this study  
24  
25 437 might have been ethnography, since it is a study of work practices. Ethnographic  
26  
27 438 observations for instance might have laid bare more of the hidden practices that  
28  
29 439 may be difficult for key informant interview participants to articulate as was  
30  
31  
32 440 discovered in the process of data collection. However, conducting an ethnography  
33  
34 441 posed challenges including gaining appropriate and continuous access, and more  
35  
36 442 significantly, the difficulty in observing a whole project process as contract  
37  
38 443 periods for the projects of interest are typically lengthy and unpredictable.  
39  
40 444 Therefore, it is often not practical to gain a whole project view even through this  
41  
42  
43 445 method.  
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#### 46 ***Credibility and trustworthiness***

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49 447 The method adopted allows issues of considerable complexity to be studied in  
50  
51 448 detail and depth (Saunders, Lewis, & Thornhill, 2012). The research design is  
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54 449 therefore consistent with that which is typically employed in activity theory-based  
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4 450 studies.  
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7 451 **Generalisability**  
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9  
10 452 Rather than attempt to generalise findings over a population, in this case it is more  
11  
12 453 appropriate to generalise to theory (Creswell, 2013). Furthermore, Saunders *et al.*  
13  
14 454 (2012), supported by Patton (2015), affirm that generalisability in this type of  
15  
16 455 design has to do with the significance to theoretical propositions and locating the  
17  
18 456 findings in existing theory. While this may seem a limitation, Yamagata-Lynch  
19  
20 457 (2010) affirms that studies based on activity theory help to gain and share  
21  
22 458 understandings of complex human interactions in work settings, but are not  
23  
24 459 conducted with the intention to generate generalizable results. Rather, they seek to  
25  
26 460 provide important insights into the dynamics of activities through particularisation  
27  
28 461 of the context and, thereafter, achieve the transferability of findings to other  
29  
30 462 contexts through theoretical re-description. Therefore, the aim was to generalise to  
31  
32 463 theory.  
33

34  
35 464 Other studies have used similar sample selection methods as has been  
36  
37 465 employed in this study. Examples include the activity theory-based study by  
38  
39 466 Yamagata-Lynch (2010), in which three cases of schools were studied from which  
40  
41 467 within-case selection of individual participants was undertaken. This was also the  
42  
43 468 case in a BIM-related study by Gledson (2016), which used single case sampling  
44  
45 469 technique, while Shibeika and Harty (2015) also used a one-case design.  
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50 470 **Analysis and discussion**  
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53 471 In this section, an activity theory-based insight on BIM-induced change within the  
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4 472 cases studied is presented. Secondly, an insight into the debate on whether the  
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6 473 nature of BIM-induced change on professional work practices is revolutionary or  
7  
8 474 evolutionary is provided, and a position is taken.  
9

10 475 The authors therefore present a concise description and explanation of  
11  
12 476 collaborative professional work change patterns, when such work is impacted by  
13  
14 477 the introduction of BIM. To this end, systemic constraints and contradictions  
15  
16 478 within professionals' work activities, as in the data, are employed to engage the  
17  
18 479 activity systems as they evolve. The methods espoused in the synthesis of  
19  
20 480 different approaches to activity systems analysis, are used as a foundation and  
21  
22 481 drawing from Yamagata-Lynch (2010). Furthermore, this section presents an  
23  
24 482 interpretive analysis of the research findings using activity theory, which shows,  
25  
26 483 based on the data analysed, BIM-induced change to be evolutionary (gradual),  
27  
28 484 rather than of a radical or revolutionary nature.  
29  
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31 485 Analysing data based on activity theory often requires a visual diagram of  
32  
33 486 the conceptual framework, to reveal how each element of the activity systems has  
34  
35 487 been operationalised in the specific context under study. It also shows how the  
36  
37 488 data has been made sense of theoretically, to clearly highlight where primary and  
38  
39 489 secondary contradictions that trigger change exist on one hand, and how one level  
40  
41 490 of activity (organisational context) links to the other (project context). This  
42  
43 491 method closely follows the recommendations of Yamagata-Lynch (2010) and  
44  
45 492 Engeström (2000).  
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49 493 Additionally, the units of analysis are the organisational context activity  
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51 494 system (OCAS) and project team activity system (PTAS). Therefore, the analysis  
52  
53 495 essentially traces the change in work practices, selecting the time when new  
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4 496 technology was required as the point of reference. First, depictions of the OCAS  
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6 497 and PTAS, upon which the analysis is carried out, are put forward (see Figure 3  
7  
8 498 and Figure 4); this is then followed by an analysis of changes in the pattern of  
9  
10 499 these activity systems over time through the introduction of new tools (BIM), as  
11  
12 500 elucidated in the following sections.

13  
14  
15 501 [Insert Figure 3 here]

16  
17  
18 502 [Insert Figure 4 here]

19  
20  
21  
22 503 ***Organisation context activity system analysis of BIM-induced change***

23  
24  
25 504 The key motivation for introducing new tools (BIM) within organisations, and by  
26  
27 505 extension construction project teams, stems from the challenges relating to  
28  
29 506 delivering construction projects within the constraints of time, quality and cost,  
30  
31 507 while still maintaining profitability (Crotty, 2012). This was evidenced, for  
32  
33 508 instance, within ORG2 in which BIM adoption was directed by their senior  
34  
35 509 leadership to reduce organisational costs; while also helping to compete  
36  
37 510 favourably with other organisations providing similar services and, by extension,  
38  
39 511 maintain or improve their profit margin. Furthermore, within two of the cases  
40  
41 512 studied, ORG4 and ORG8, BIM was adopted as a means to help in meeting  
42  
43 513 client's demands regarding performance (particularly cost reduction) and  
44  
45 514 increased productivity, respectively. This can be interpreted on one hand, as a  
46  
47 515 Rule (*budget, time requirement, quality requirement*) vs Object (*high performing*  
48  
49 516 *project, organisational profitability*) contradiction in the activity system at the  
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51 517 project level, as shown in Figure 5 (a). [Insert Figure 5 here].  
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4 518 The introduction of BIM also originates from efforts within organisations  
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6 519 to improve their delivery of project expectations and outcomes. On the  
7  
8 520 organisational front, the motivations for implementing new technology and  
9  
10 521 associated applications, goes beyond merely meeting clients' demands to  
11  
12 522 achieving competitiveness among peers, as depicted in Figure 6 (b) and Figure 6  
13  
14 523 (c) (as reported by Informants Q1-11) – and also considering their goals of cost  
15  
16 524 efficiency while improving profitability. In other words, organisations are  
17  
18 525 constrained by the need to achieve their objectives within the limits of  
19  
20 526 organisational resources, while striving for competitiveness with their peers. This  
21  
22 527 is a Rule (*organisation's resources/budget*) vs Object (*provision of professional*  
23  
24 528 *services*) vs Community (*competition with other organisations*) contradiction.  
25  
26  
27 529 [Insert Figure 6 here]. To resolve the above contradictions, BIM is introduced as a  
28  
29 530 new tool, both in its form as a technology and also as a process.  
30  
31

32 531 Nevertheless, the introduction of new tools within organisations has been  
33  
34 532 found to create a new set of primary contradictions, these being between the new  
35  
36 533 tool(s) and existing tangible and intangible tools (otherwise termed non-  
37  
38 534 interoperability), as depicted in Figure 7 (d). [Insert Figure 7 here]. First, for  
39  
40 535 existing tangible tools, there are some contradictions brought about by the  
41  
42 536 introduction of BIM. Tool (*BIM*) vs Tool (*existing CAD systems*) contradictions  
43  
44 537 are experienced in the sub-optimal levels of interoperability between existing and  
45  
46 538 new tools and systems. This challenge is typified in the quote below from  
47  
48 539 Informant Q3:  
49  
50

51 540 On the technology side, the challenge first and foremost is localisation, the  
52  
53 541 output from the BIM needs to conform to like all industry standards, and it  
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4 542 doesn't. So, we've got all kinds of workflow work-arounds just to deal with  
5  
6 543 a simple thing such as geographical coordinates. We're not going to  
7  
8 544 change what the authorities want to see, we have to adapt the BIM to suit  
9  
10 545 and that's where we find we're meeting dead ends all the time. So, the  
11  
12 546 answer lies in third party application development, we've got an in-house  
13  
14 547 programmer sitting in there, [and] we've got third party external  
15  
16 548 programming teams from whom we acquire the add-ons to plug the holes  
17  
18 549 in the software, and we also then leverage knowledge from our colleagues  
19  
20  
21 550 in the more advanced countries. (Informant Q3)

22  
23 551 Organisations often must contend with the dilemma of either implementing both  
24  
25 552 together while gradually migrating to new tools, or else go the BIM route for all  
26  
27 553 their work from the outset – this is not always an easy decision. Nevertheless, the  
28  
29 554 findings show that a phased adoption and implementation strategy tends to be  
30  
31 555 successful (Informants Q1, 6 & 11). Informant Q1 stated that:

32  
33  
34 556 One of the biggest challenges was...because the software is so different  
35  
36 557 [and] because the mind-set is so different, it drives a completely different  
37  
38 558 workflow. So, it's not something you do and then six months later we're  
39  
40 559 fully BIM. You may have to recognise [that] it's going to take time, and  
41  
42 560 unless you make, sort of smaller targets, right? You're going to feel very  
43  
44 561 frustrated... (Informant 1)

45  
46  
47 562 This supports an evolutionary change perspective. It also ties into the experiences  
48  
49 563 of conflicts between knowledge requirements for using the new BIM tools, and  
50  
51 564 established/existing professional knowledge and skills of organisations' staff; that  
52  
53 565 is, in the understanding that cognitive abilities and knowledge are tools, albeit  
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4 566 intangible in nature. Knowledge and skills as mental tools contribute to the  
5  
6 567 mediation of the relationship between the Subjects (*staff*) and their Object  
7  
8 568 (*endeavour to which their efforts are directed*). Coping with the ‘need state’  
9  
10 569 created by a mismatch of new knowledge requirements and existing knowledge,  
11  
12 570 requires a lot of training and development; as well as organisational knowledge  
13  
14 571 management to ensure skills and knowledge are transferred between staff and also  
15  
16 572 retained for sustenance (Informants Q1-11).

17  
18  
19 573 The third Tool vs Tool contradiction relates to the reported high cost of  
20  
21 574 procuring the new BIM tools (software and associated applications). While the  
22  
23 575 new tool is important for achieving organisations’ objectives, it is also a strain on  
24  
25 576 financial resources. For instance, Informant Q11 affirmed that:

26  
27 577 You need to get the right skills set, you need to get people who are  
28  
29 578 properly skilled. I mean even in our company we have [in the past]  
30  
31 579 struggled to find the right pool of people. It's money as well, it's expensive,  
32  
33  
34 580 I mean you talk about licences ... as a company we are luckily able to  
35  
36 581 afford the [initial] training, the on-going training, afford the licences, when  
37  
38 582 you talk about a person joining your firm [newly]... just to get that person  
39  
40 583 working, never mind his salary. We have to invest in that person  
41  
42 584 [technological infrastructure], to be able to produce the [required] work for  
43  
44 585 us. It's expensive, licencing is expensive. (Informant Q11)

45  
46  
47 586 This is a Tool (*financial resources*) vs Tool (*BIM infrastructure cost*)  
48  
49 587 contradiction a shown in Figure 8.

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51 588 [Insert Figure 8 here].  
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4 589 With the introduction of BIM, the findings show that new BIM roles have  
5  
6 590 emerged. This is often because transitioning to new technology is difficult for the  
7  
8 591 organisations, and new roles need to be created to facilitate the process from  
9  
10 592 within organisations. This was reported by Informants Q1-7, 9 & 11, who have  
11  
12 593 created BIM management or coordination roles within their organisations. The  
13  
14 594 double-binds that come to the fore at this point, relate to either training existing  
15  
16 595 staff to take up new/modified responsibilities or employing staff experienced in  
17  
18 596 implementing BIM. These are Tool (*emergent roles and competencies*) vs Role  
19  
20 597 (*Role definition & distribution*) contradictions (Figure 8 (e)). The findings further  
21  
22 598 show that the latter is the dominant route taken. Indeed, out of eight cases of  
23  
24 599 organisations, six have taken this route. For instance, according to Informant Q2:

27  
28 600 Our organisation has appointed a formal BIM manager for the African  
29  
30 601 region within ORG1, who is overseeing a lot of BIM workflows and  
31  
32 602 systems and making sure that these things are being implemented. And  
33  
34 603 then within every office we've got a coordinator or a person who has that  
35  
36 604 as part of their...not formal job description yet, but we've got someone who  
37  
38 605 has been identified, and is handling that aspect of the works, ...we're  
39  
40 606 working towards actually making that part of their formal job description  
41  
42 607 as well. So, you do need that, because it is a complex system and it needs  
43  
44 608 monitoring as we're learning more and more about the system. So, you  
45  
46 609 need one point where it gets coordinated. (Informant Q2)

47  
48  
49 610 Subsequently, roles are redistributed between existing staff and those that  
50  
51 611 take a new BIM role within the organisation (reported by Informants Q1, 2, 3, 4,  
52  
53 612 6, 7, 9 & 11 as being the case within their organisations). Inferring from this, the  
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4 613 situation may lead to role conflict; that is, Role (*existing roles/role takers*) vs Role  
5  
6 614 (*new roles/new role takers*) contradictions, as in Figure 8 (f). It may also create  
7  
8 615 tensions within the system regarding power and authority structures, hierarchies  
9  
10 616 and co-constructed forms of interactions among others in a Role vs Rule  
11  
12 617 contradiction (Figure 8 (g)). However, this was not reported at the organisational  
13  
14 618 level in the data collected.

16  
17 619           Interpreting the data further, with the introduction of new BIM roles and  
18  
19 620 the creation of new areas of professional competence (as tools), comes the need to  
20  
21 621 modify existing rules within organisations. It is important to note that financial  
22  
23 622 resources are tools for organisations, whereas the budget are rules that guide  
24  
25 623 and/or constrain their operation. Therefore, it is essential to highlight the need to  
26  
27 624 resolve the challenge in deciding between hiring new staff or training existing  
28  
29 625 staff, against the constraints of organisational resources and budget (Tool  
30  
31 626 (*resources*) vs Subject (*new staff hire*) vs Rules (*budget*)).

33  
34 627           Further, the introduction of new BIM tools can also generate conflict  
35  
36 628 between the demands for implementing them within existing organisational  
37  
38 629 practice procedures as both tools and rules – plans and protocols are tools when  
39  
40 630 they are employed to guide practice but are rules when they are a means to ensure  
41  
42 631 compliance by organisations' staff. This conflict necessitates the dedication of  
43  
44 632 teams of staff to create new practice guidelines and protocols to suit the  
45  
46 633 implementation of BIM within the organisational setting. This was particularly  
47  
48 634 evident within ORG1, 2, 3, 4 and 7, where such guidelines had to be created to  
49  
50 635 support BIM implementation. These (new guidelines and standards) become new  
51  
52 636 tools as well as rules within the activity system. Nevertheless, the participants'

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4 637 responses on their implementation experiences, suggested that certain aspects of  
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6 638 the new technology adoption and implementation, may conflict with established  
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8 639 professional guidelines and also organisational norms and culture. For example,  
9  
10 640 document submission guidelines and format to the relevant authorities.

11  
12 641 Having taken the systemic constraints and contradictions identified from  
13  
14 642 the data into account, an evolved organisational context activity system is  
15  
16 643 presented in Figure 9. [Insert Figure 9 here].

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18  
19 644 In essence, the activity system evolves through the choices that  
20  
21 645 organisations make in resolving a series of conflicts and contradictions, brought  
22  
23 646 about by the introduction of BIM and related applications. The authors theorize  
24  
25 647 that the implementation of BIM significantly changes work practices within  
26  
27 648 organisations, but gradually, and over time. This supports an evolutionary view of  
28  
29 649 BIM-induced change rather than a radical or revolutionary view of change and is  
30  
31 650 argued from Miller's (1982) definition of evolutionary (incremental) change as  
32  
33 651 piecemeal and gradual. In this text, evolutionary change is delineated from  
34  
35 652 revolutionary change as that involving a 'few elements [that] change either in a  
36  
37 653 minor or major way; and revolutionary when major or minor changes of many  
38  
39 654 elements in a system within a brief interval radically transform many elements of  
40  
41 655 the system's structure'. Clearly, although the foregoing analysis depicts a change  
42  
43 656 in several elements of the activity system, analysis of the data collected from the  
44  
45 657 cases studied suggests that changes to elements of the activity systems structure  
46  
47 658 were gradually made over a significant amount of time, typically more than ten  
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49 659 years (Informant Q6 & 11).  
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4 660 ***Project context activity system analysis of BIM-induced change***  
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7 661 The project team activity system (PTAS) is multidisciplinary and can also be  
8  
9 662 either multi- or mono-organisational. The analysis provided here depicts a  
10  
11 663 collaborative multi-disciplinary and multi-organisational project activity system  
12  
13 664 setting. As has been shown in the analysis above, changing patterns of  
14  
15 665 professional activity begins within individual organisations. Therefore, the  
16  
17 666 successes or failures of collaborating organisations in dealing with their  
18  
19 667 challenges, may be transferred to the project team context.  
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22 668 Collaborating organisations' knowledge and skills, as well as their  
23  
24 669 discipline-specific work tools, become tools for the project team activity, as  
25  
26 670 depicted in Figure 10. [Insert Figure 10 here].  
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28  
29 671 Some organisational-level rules are also inevitably transferred in part to  
30  
31 672 project level rules. For instance, in their account of one project on which BIM was  
32  
33 673 implemented extensively, ORG3, an architectural design firm and project team  
34  
35 674 leader, impressed upon other project team members to produce information that  
36  
37 675 conforms to their own pre-prepared BIM guidelines and protocols (thereby  
38  
39 676 modifying rules). Furthermore, and rather inevitably, some other organisational  
40  
41 677 work production tools became project team context activity tools, by the project  
42  
43 678 team leader requiring them to be used. Equally, some of the modifications made  
44  
45 679 in the rules guiding organisational work were also transferred to project level  
46  
47 680 activity rules. In effect, *ab initio*, the project team activity system is already  
48  
49 681 changed. Nevertheless, the fact that methods for implementing BIM and level of  
50  
51 682 proficiency among collaborators vary, raises new contradictions within the tool  
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53 683 element of the PTAS.  
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4 684 That is, the contradiction between Tool (*organisation 1 tools & knowledge*  
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6 685 *resource(s)*) vs Tool (*organisation n... tools & knowledge resource(s)*), as in  
7  
8 686 Figure 11 (h). For instance Informant Q4 stated that ‘from an architect’s point of  
9  
10 687 view, we get very frustrated with external Architects who are working on different  
11  
12 688 software, and that’s a point of conflict, because [we’ve] got to remodel stuff on  
13  
14 689 this side, because they just mess it up on the other side’. To resolve these new  
15  
16 690 contradictions, several changes take place. [Insert Figure 11 here].  
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18

19 691 The first way of responding to these contradictions is to create new BIM  
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21 692 coordination/management roles (within the project team structure), Informant Q6  
22  
23 693 articulated it as follows:  
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25 694 How can we collectively be on the same page so that when you do transfer  
26  
27 695 data between one consultant and the other, one professional to another,  
28  
29 696 that you don’t end up with these problems of having to re-do work? So  
30  
31 697 you’re appointed as a BIM manager or BIM coordinator for that project  
32  
33 698 specifically and in your company’s capacity assisting all the other  
34  
35 699 disciplines associated with it. See, yeah, that’s where you find yourself and  
36  
37 700 you do call quite a big shot there. (Informant Q6)  
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40 701 Typically, creating new BIM coordination roles within the project team  
41  
42 702 necessitates the redefinition and redistribution of roles to accommodate the new  
43  
44 703 role. It can also create Role vs Role contradictions; that is, between existing  
45  
46 704 professionals and newly-introduced BIM knowledge experts who take up the new  
47  
48 705 roles for information coordination, in cases where BIM coordination is not an  
49  
50 706 expansion of an existing consultant’s role. Role conflict is likely in this  
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52 707 circumstance but, since the project team is itself a self-organising entity, such  
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4 708 conflicts are resolved fairly easily, particularly where the architect or lead  
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6 709 designer takes up the BIM coordination role (Informant Q7). Also according to  
7  
8 710 Informant Q6, when separate BIM coordinators are included in teams, ‘you do get  
9  
10 711 resistance as it were, but, the resistance is overcome through acknowledging that  
11  
12 712 this role is there for a purpose’. This is even more so if the new role takers can  
13  
14 713 demonstrate superior knowledge to command the necessary power and authority  
15  
16 714 to act and direct others to act (supported by Informants Q3, 4 & 7).  
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19 715           Interpreting the data further, the rules that guide work for the project team  
20  
21 716 are also transformed through the resolution of contradictions. With the  
22  
23 717 redistribution of roles as a result of the inclusion of new BIM role takers (Figure  
24  
25 718 12 (j)), project team rules are modified to suit the new demands arising from the  
26  
27 719 incompatibility of new roles with existing pre-BIM Rules (*contracts, and*  
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29 720 *guidance documents etc.*), as depicted in Figure 12 (k). [Insert Figure 12 here]  
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32 721           Modifications to contractual provisions, project organisation structure and  
33  
34 722 delivery procedures are made to facilitate BIM implementation on an ad hoc  
35  
36 723 basis, project by project (Informant Q11 and Q3). Nevertheless, it can be inferred  
37  
38 724 that with increased use, efforts may be made towards institutionalising new rules  
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40 725 and practices by the Community (*government, professional bodies and client*  
41  
42 726 *organisations*), to resolve the continued conflict in the system resulting from  
43  
44 727 information asymmetry in South Africa. This is so, since no generally accepted  
45  
46 728 countrywide standards and guidelines have been developed for use in the country.  
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49 729           It is theorized, as in the OCAS analysis, that the implementation of BIM  
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51 730 significantly changes work practices within organisations gradually and over time,  
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53 731 supporting an evolutionary view of BIM-induced change – rather than a radical or  
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4 732 revolutionary view of change. The evolved project team activity is shown in  
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6 733 Figure 13. [Insert Figure 13 here].  
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8 734 Furthermore, the OCAS and PTAS analyses show that the changes  
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10 735 experienced are regarding how professional work is done, rather than what work  
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12 736 is done or why work is done. This is interpreted from the activity theory position  
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14 737 that activities are not monolithic, but hierarchical in structure. This structure is  
15  
16 738 organised in three levels beginning with the activity at the top or highest level of  
17  
18 739 abstraction and directed at motives (Kaptelinin & Nardi 2006). The next in the  
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20 740 structure are actions which are the sequence of steps taken, not directly related to  
21  
22 741 the activity's motive, but ultimately help to achieve the motive. Actions are  
23  
24 742 directed towards goals can also be decomposed into a lower level of abstraction  
25  
26 743 called operations. Operations are routine processes and provide an avenue for  
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28 744 actions to adjust to specific work situations and are automatic or routine  
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32 745 (Kaptelinin & Nardi 2006).  
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34 746 The activity as a whole may, therefore, be said to be directed at the  
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36 747 essence or reason why it's taking place while the actions and operations are  
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38 748 representative of what work is done to achieve the motive and how that may be  
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40 749 achieved in specific work contexts. In this analysis, the changes reported from the  
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42 750 cases of organisations indicated changes in the how work is done to achieve the  
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44 751 principal motive of construction or building, but do not change the 'essence' of  
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46 752 the activity. While changes can be observed in, for example, the speed and  
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48 753 sequence of work within the organisation, tools used, staff reward systems and  
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50 754 redefined roles, the essence of the activities defined by their object and outcome  
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53 755 remain largely the same even though the methods have evolved.  
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4 756           These findings extend the theoretical literature on BIM implementation  
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6 757   impacts on work practices. More precisely, they extend the works of Miettinen  
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8 758   and Paavola (2014) in their position paper which propounded an evolutionary  
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10 759   view of BIM-induced change using cultural historical activity theory; and Mäki  
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12 760   and Kerouso's (2015) work in which they focused on only the rule and tool  
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14 761   elements of an activity system. Importantly, some aspects of the findings relate to  
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16 762   Çıdık *et al.*'s (2017) work in which they developed a concept of 'ordering in  
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18 763   disguise', conceptualised a description of the indirect nature of digital  
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20 764   integrations' prompting of what work is done and how, through constraints and  
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22 765   prompting of individual courses of actions. Their position, from the observation  
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24 766   that practitioners within their daily work do not observe explicit changes in their  
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26 767   work practices, is supported in this study by the recognition of the tacit nature of  
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28 768   knowledge about changes in work practices, due to routinisation. Clearly, their  
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30 769   work advances theory, but here a different approach is taken that construes the  
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32 770   organisation and team as separate and interlinked units of analysis.

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36 771           Interestingly, Poirier, Forgues and Staub-French (2017) who developed an  
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38 772   analytical framework through a meta-analysis of different data sources in their  
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40 773   study of the impact of BIM on collaboration, theorized that identified event  
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42 774   patterns may be conditioned by an interlink of context, structures, processes,  
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44 775   artefacts, and agents. Alternative holistic and more formal theoretical explanations  
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46 776   of these interrelationships are possible through an activity theory framework, as  
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48 777   has been shown in this paper.

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51 778           Furthermore, in Miettinen and Paavola's (2014) work, they imply that  
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53 779   BIM adoption requires learning and modification to meet local conditions, which  
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4 780 often result in redesigning the technology. While the analysis presented here  
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6 781 confirms this, it could be argued further that the evolutionary perspective provided  
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8 782 through cultural historical activity theory also implies that, since activity systems  
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10 783 are constantly evolving, the tools that are used to perform work (BIM and others)  
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12 784 would continue to shape and be shaped by other constituent elements of the  
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14 785 activities to which they are relevant.

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17 786 The explanations and conceptualisations presented in this work offer  
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19 787 nuanced explanations of changes in work practices and the reasoning behind  
20  
21 788 them, while also theorising on the dynamics that cause the change to happen. This  
22  
23 789 feeds off criticisms of the existing literature in their failure to achieve this by  
24  
25 790 Miettinen and Paavola (2014), Fox (2014), Dainty *et al.* (2017) and Çıdık *et al.*  
26  
27 791 (2017) in particular. However, the theoretical perspective chosen, and research  
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29 792 design do have limitations, which are highlighted below.

### 31 32 33 793 **Conclusions**

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36 794 Activity systems are non-static and constantly evolving. However, the analysis  
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38 795 presented in this article depicts the pattern of change due to the introduction of  
39  
40 796 new technology (BIM tool/process and related applications), as was evident in the  
41  
42 797 experiences of implementers in specific case contexts. The analysis demonstrated  
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44 798 the impact of implementing BIM on construction professional work practices,  
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46 799 indicating conceptually that organisational-level evolution precedes that of project  
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48 800 teams.

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51 801 The findings describe construction professional work activity as it evolves  
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53 802 from a pre-BIM implementation state, to show how the dynamics of change  
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4 803 within the different contexts of collaborating organisations can bring about change  
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6 804 in the project context activity. These were analysed using a cultural historical  
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8 805 activity theory perspective to show how professional work evolves into newer  
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10 806 forms. Principally, an evolutionary view of BIM-induced change rather than a  
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12 807 radical or revolutionary view of change in work practices is supported in this  
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14 808 study as the implementation of BIM significantly changes work practices within  
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16 809 organisations, but gradually and over time.

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19 810 The potential of activity systems analysis in describing collaborative  
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21 811 activity between construction project stakeholders was also shown, while  
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23 812 conceptually highlighting the links between the organisational context activity  
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25 813 system and project context activity system. It also theoretically demonstrates the  
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27 814 influence of organisational evolution due to BIM on project team activity or the  
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29 815 work practices that comprise it.

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32 816 While the findings have important practical implications, attention should  
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34 817 particularly be given to their theoretical significance. For practice, the findings  
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36 818 help to better understand the dependencies between the different elements of  
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38 819 professionals' work activity(ies), and the connectedness of their individual and  
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40 820 collective actions within organisations and project teams. Furthermore, since one  
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42 821 of the main purposes of cultural historical activity theory is to assist in the design  
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44 822 of computer supported collaborative work, the findings imply that the design of  
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46 823 organisational and team rules and roles based on BIM, needs to be flexible to  
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48 824 accommodate the non-static nature of work activity systems.

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51 825 Theoretically, the findings emphasise the nature of knowledge as a tool  
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53 826 (albeit intangible) in work settings, which is capable of mediating or shaping the  
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4 827 relationship between the actors and their object. In fact, it reinforces the dual  
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6 828 nature of individually- or organisationally-held knowledge as tools and rules. The  
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8 829 possibility of studying primary and secondary, tertiary and ternary contradictions  
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10 830 in different contexts and within different levels of abstractions of activities, has  
11  
12 831 also become evident based on the theoretical and conceptual framework presented  
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14 832 here.

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17 833 The evolutionary perspective and principle of mediation provided through  
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19 834 activity theory, importantly imply that since activity systems are constantly  
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21 835 evolving, the tools that are used to perform work (BIM and others) will continue  
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23 836 to shape and be shaped by other constituent elements of the activity systems, to  
24  
25 837 which they are relevant and embedded. Furthermore, the findings particularly  
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27 838 extend the theoretical literature, in part as an alternative approach to  
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29 839 understanding change in work practices, and also in its introduction of new  
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31 840 perspectives for the analysis of technologically induced change. Considering the  
32  
33 841 concept of mediation in particular, the possibility of analysing, for instance, how  
34  
35 842 the interrelationships between actors' (subjects) and stakeholders (community)  
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37 843 can be shaped by rules has been presented.

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40 844 One feature of the descriptions of BIM within the activity theory  
41  
42 845 framework is its emphatic characterisation as a tool, even though associated plans  
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44 846 and procedures may fit in as either tools that mediate actions or as rules guiding  
45  
46 847 work. Although, not supported with empirical evidence, using activity theory  
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48 848 brings to the fore the idea that as a tool such as BIM evolves through its previous  
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50 849 forms (CAD for instance), it carries along with it historical attributes or aspects of  
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4 850 the transformation of the activity's or activities, for which it has been used and is  
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6 851 being used through that evolutionary process (Kaptelinin & Nardi 2006).  
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8 852 Furthermore, the data has been clearly defined and interpreted in activity  
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10 853 theory terms to show a 'historical' analysis of events, traced from the  
11  
12 854 organisational contexts activity system to the project context activity system. This  
13  
14 855 method brought to the fore many details of complex work systems as activity  
15  
16 856 systems that are otherwise tacit in nature. Finally, the theoretical and conceptual  
17  
18 857 framework provided by activity theory has also enabled a different methodology  
19  
20 858 for depicting, organising and analysing data about human interaction in work  
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22 859 settings that have yet to be provided by others approaches.  
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#### 26 27 860 *Limitations* 28

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30 861 It is important to acknowledge the limitations of activity theory as a theoretical  
31  
32 862 perspective, although it facilitates a holistic understanding of work and its  
33  
34 863 development. Activity theory is more descriptive than explanatory, although  
35  
36 864 excellent texts like Kaptelinin and Nardi's (2006) provide good insight into its  
37  
38 865 capabilities in explaining work development. Additionally, activity systems are  
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40 866 normally evolving. This analysis has, therefore, not accounted for, nor is it  
41  
42 867 practicable to account for the usual evolutionary tendencies of human work  
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44 868 activities irrespective of the induced change in the system.  
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#### 48 49 869 *Areas for further research* 50

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52 870 The conceptual framework is broad in its scope of possible applications. Future  
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54 871 work could explore its potentials for analysing the dynamics of work of a different  
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4 872 nature and context in the construction industry. Therefore, beyond its application  
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6 873 in this study and in similar studies, activity theory methods could also enable the  
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8 874 description and understanding of how individual and collaborative professionals  
9  
10 875 work, might coevolve within their sociocultural settings with new technical  
11  
12 876 systems such as BIM to create new forms of such activities; while constraints and  
13  
14 877 enablement in the system are dealt with and accommodated. It would be  
15  
16 878 beneficial in future research to also begin to consider, for example, the mediating  
17  
18 879 effects of rules in the relationship between actors and the community of practice,  
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20  
21 880 or even that of roles in the relationship between the actors and their object.  
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23 881 As the nature of work practices evolve, an important question is how much  
24  
25 882 of an impact could it have on individual and organisational image on the one  
26  
27 883 hand, and self-identity on the other? In this regard, one of the more interesting  
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29 884 applications of psychosocial theoretical perspectives to the BIM implementation  
30  
31 885 and management area of research, is the study of resistance to change in light of  
32  
33 886 BIM's capability to alter, or challenge professionals' identities as competent  
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35 887 workers. Nach and Lejeune (2015) argue that such challenges to identity could  
36  
37 888 hinder widespread adoption. Looking ahead, however, a much deeper  
38  
39 889 conceptualisation is needed of how professions or disciplines may, without  
40  
41 890 conscious effort, be changing in image and identity both at the individual and  
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43 891 organisational levels. This would make it possible to investigate how such  
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45 892 changes in identity might influence the definition, demarcation and distribution of  
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47 893 roles in the future.  
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48 1075 Table 1. Profile of key informants drawn from the cases  
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51 1076 Figure 1. Depiction of an activity system showing the relationship between  
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23 1085 Figure 7. Tool vs Tool contradiction between newly-introduced tools and existing  
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29 1087 Figure 8. Tool vs Role (e); Role vs Role (f); and Role vs Rules (g) contradictions  
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37 1090 Figure 10. Systemic relationship between OCAS and PTAS  
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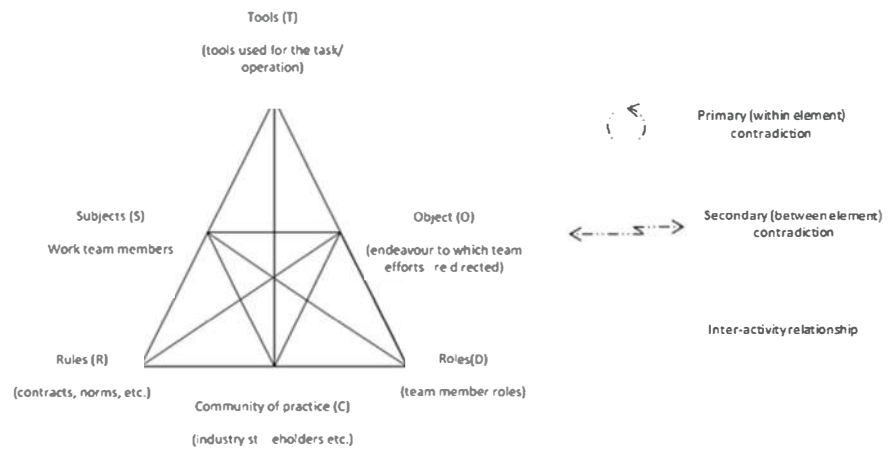


Figure 1. Depiction of an activity system showing the relationship between elements (adapted from Engeström (2000))

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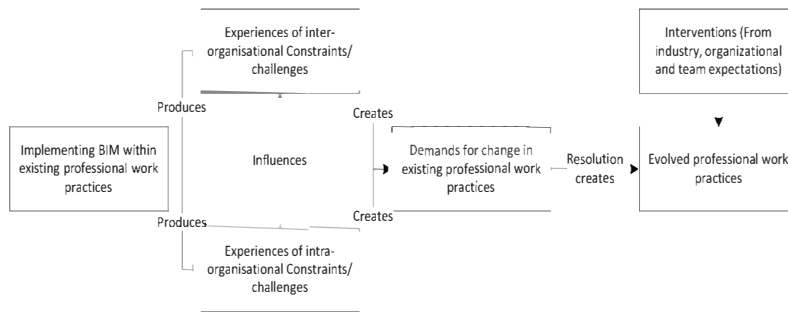


Figure 2. Conceptual model  
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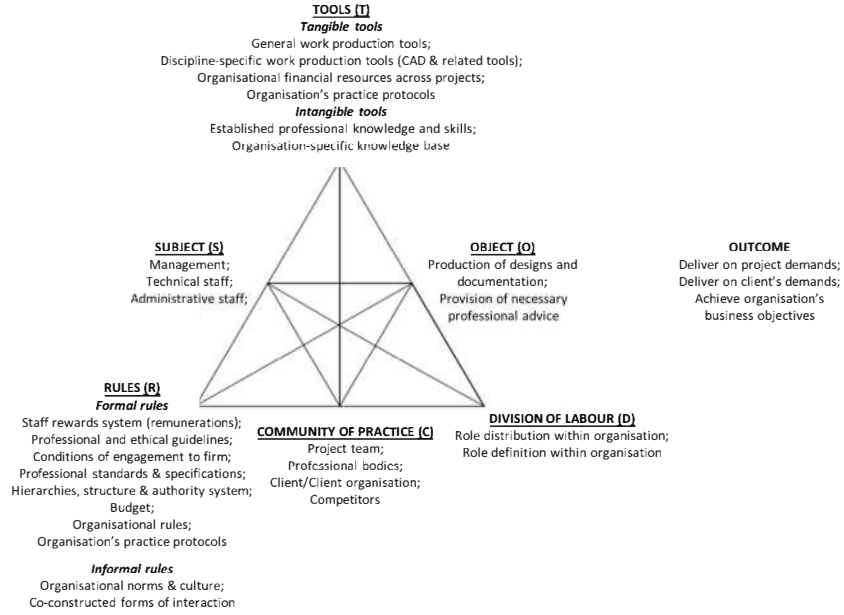


Figure 3. Organisational context activity system

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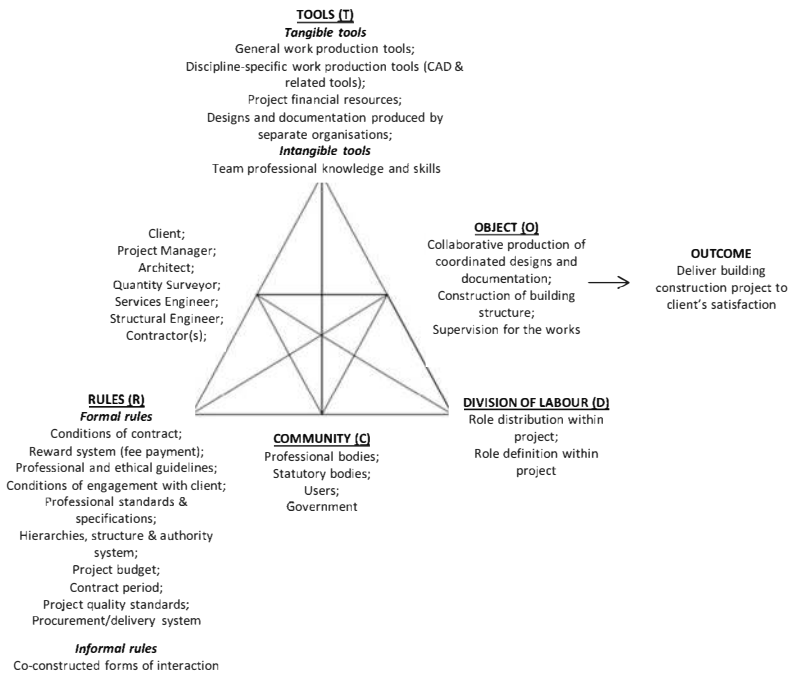


Figure 4. Project context activity system

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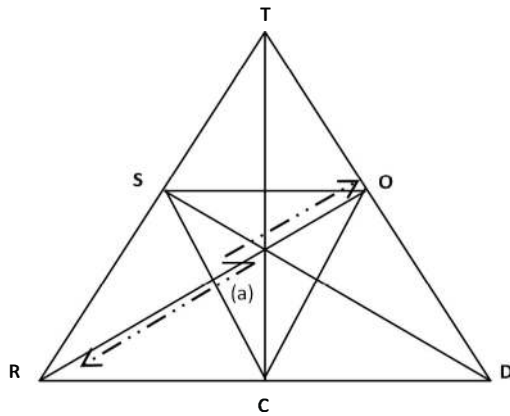


Figure 5. Rule vs Object contradiction necessitating the introduction of BIM at the organisational level (a)

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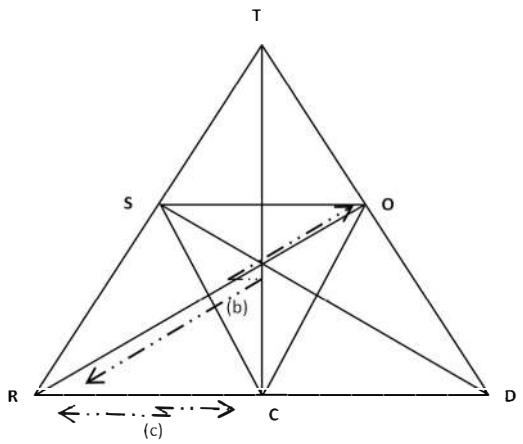


Figure 6. Rule vs Object; and Rule vs Community contradictions necessitating the introduction of BIM at the organisational level (b & c)

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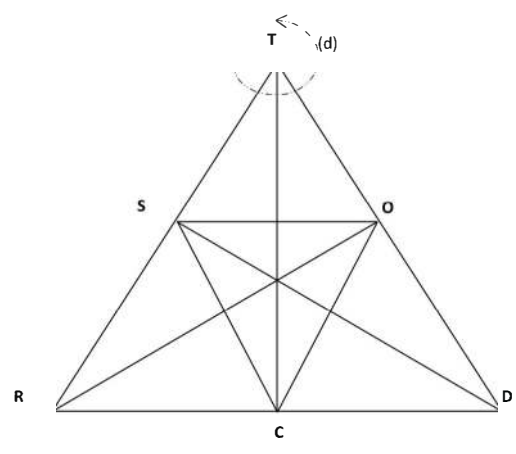


Figure 7. Tool vs Tool contradiction between newly-introduced tools and existing tangible and intangible tools (d)

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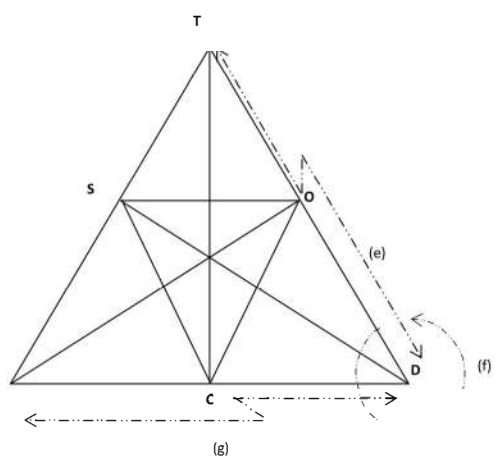


Figure 8. Tool vs Role (e); Role vs Role (f); and Role vs Rules (g) contradictions

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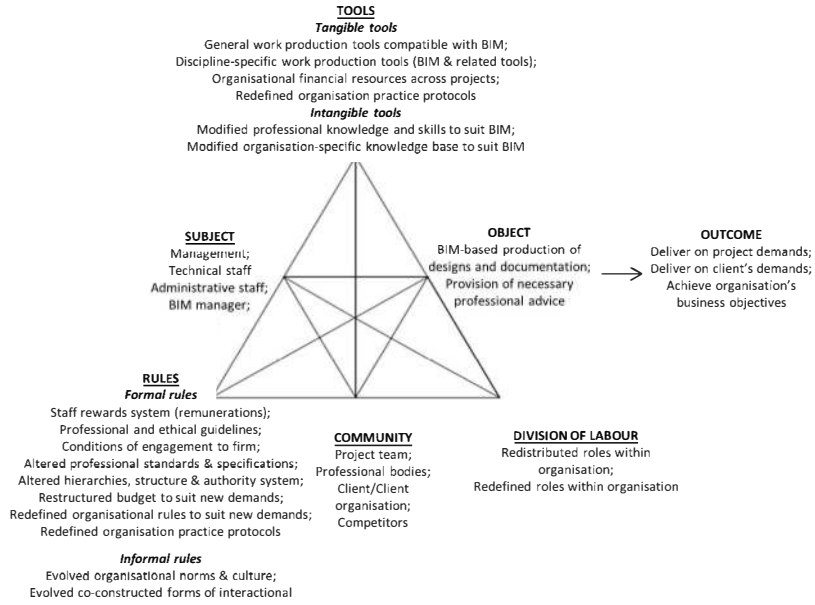


Figure 9. Evolved organisational context activity system upon impact by new technology (BIM)

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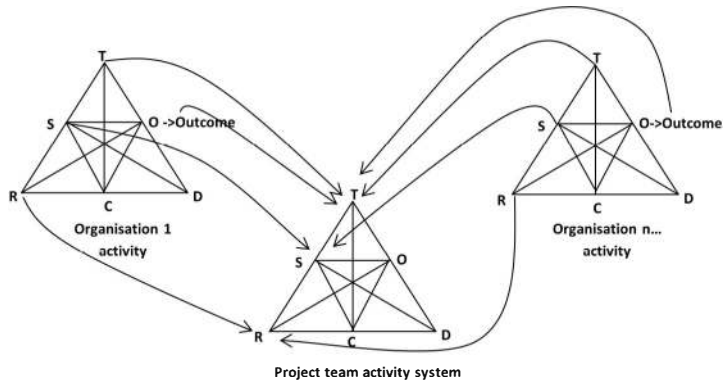
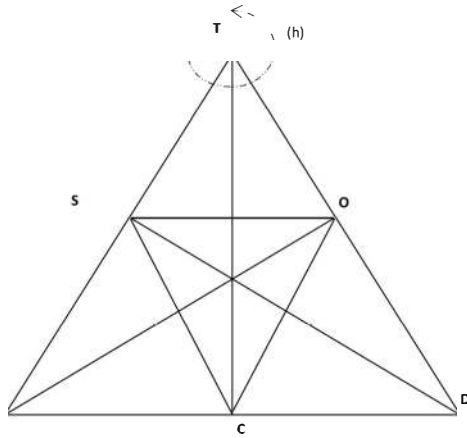


Figure 10. Systemic relationship between OCAS and PTAS

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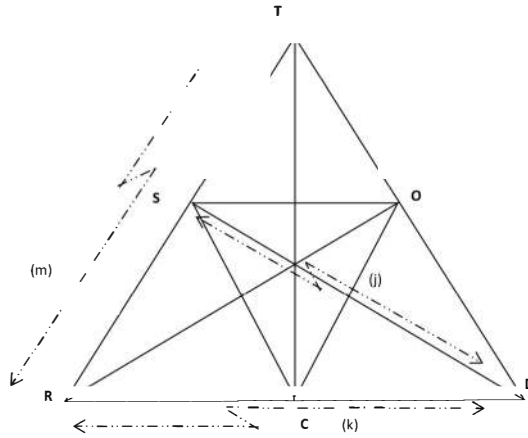


Figure 12. Subject vs Roles (j); Role vs Rule (k); Tool vs Rule (m) contradictions

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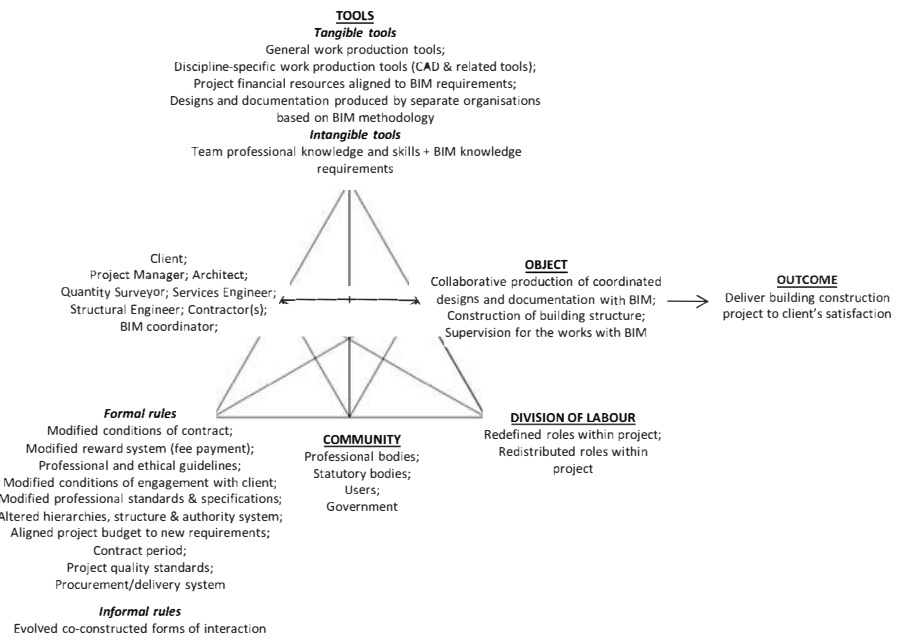


Figure 13. Evolved project context activity system upon impact by new technology

199x149mm (300 x 300 DPI)

Table 1. Profile of key informants drawn from the cases

CASES (ORG)	PARTICIPANT	PROFILE
ORG1	<i>Q2: ARCHITECT &amp; BIM COORDINATOR</i>	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 <u>parent company in a Western country.</u> )
ORG2	<i>Q3: CIVIL/ STRUCTURAL ENGINEER, VDC/BIM COORDINATOR, &amp; DIRECTOR</i>	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 <u>exemplary implementation cases in company branches in countries like the UK.</u>
ORG3	<i>Q11: ARCHITECT &amp; BIM COORDINATOR</i>	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 <u>top management.</u>
ORG4	<i>Q4: ARCHITECT, PROJECT MANAGER, &amp; VDC/BIM COORDINATOR</i>	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.
	<i>Q7: BIM MANAGER &amp; ARCHITECT</i>	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 <u>exemplars.</u>

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CASES (ORG)	PARTICIPANT	PROFILE
ORG5	<i>Q1: BIM MANAGER</i>	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.
ORG5	<i>Q9: ARCHITECT &amp; DIRECTOR</i>	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	<i>Q10: CIVIL/STRUCTURAL ENGINEER &amp; DIRECTOR</i>	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	<i>Q5: ARCHITECT</i>	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	<i>Q8: ARCHITECT</i>	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	<i>Q6: BIM MANAGER &amp; ARCHITECT</i>	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 <u>unique perspectives.</u>