

## **BUILDING INFORMATION MODELLING AND THE CULTURE OF CONSTRUCTION PROJECT TEAMS: A CASE STUDY**

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### **Abstract**

*The collaborative use of Information and Communication Technology (ICT) and Building Information Modelling (BIM) across a temporary project organisation (TPO) may represent the future of construction project delivery through greater design coordination, reduced conflict, efficiency savings, and a valuable information stream for use throughout the operational life of a building. However the success of BIM in a TPO is dependent upon participant firms that share compatible technologies, business processes and cultures, led by people who hold attitudes and display behaviours conducive to collaboration. Their collective interaction thereafter defines the culture of the TPO, more often than not resulting in differentiation, or fragmentation: true integration is the exception. This paper presents preliminary findings from a case study of a TPO, identifying differentiated cultures within the project, and explains their causes. It suggests that careful selection of trading partners and focused attention to the establishment of a TPO may mitigate many of these negative outcomes.*

**Keywords:** ICT, BIM, TPO, culture

### **INTRODUCTION**

Building Information Models capture the characteristics and relationships between the parts and assemblies of a building in database form, enabling them to be visualised and their behaviour tracked over time under different operating conditions. Weisberg (2000) highlights the potential this technology has to trigger significant changes in the development, design and building process, yet it has still to gain widespread acceptance in the architectural, engineering and construction (AEC) sector, lagging behind other major industries producing 3D products.

ICT provides a range of technological solutions which have the potential to standardise and streamline business processes throughout the design, construction and operational phases of a building. BIM functionality combined with improved business process alignment between trading partners should lead to increased uptake and integration across the AEC sector, providing adopters with increased profitability and value generation that ICT is said to present. However recent research indicates that psychological phenomena observed in individuals (Brewer, Gajendran & Beard, 2009) and across project teams (Gajendran & Brewer, 2009) can be just as important in determining the business outcomes of ICT/BIM adoption. Moreover, whereas literature suggests that ICT/BIM is generally a force for

integration of the TPO previous research (Brewer & Gajendran, 2010) indicates that this isn't necessarily the case, often leading to differentiation within the team, and even fragmentation. This study reports a meta-analysis of case study data of a TPO assembled to complete an iconic civic building in Australasia, focussing on the involvement of a specialist subcontractor to design and construct the engineered façade. This project was deemed suitable for this study as it utilised BIM, web-based information sharing, and a raft of other ICT. The case study data were initially collected as part of a research project funded by the Co-operative Research Centre for Construction Innovation (CRC-CI), and reanalysed using protocols developed subsequently, resulting in it being subjected to multiple forms of qualitative analysis.

## **LITERATURE REVIEW**

It has sometimes been suggested that the low level of innovation is a consequence of a lack of conviction on the part of decision makers in the industry of the benefits - economic return - arising from its use. Classical economic theory indicates that this is a logical consequence of a rational cost benefit analysis undertaken by potential innovators, resulting in widespread rejection of its efficacy, and indeed on one level this appears irrefutable. However, such business decisions are made by humans, often on the basis of incomplete knowledge of the "facts", influenced by prior experience and also frequently emotion, in a boundedly rational way (Simon, 1991). Business decisions made on the basis of bounded rationality are rarely optimal, instead resulting in "satisficing" solutions, outcomes that can be described as being "good enough".

A better understanding of the influences that shape the attitudes of potential innovators and adopters of innovation, and particularly the attitudinal traits (Venkatesh, Morris, Davis, & Davis, 2003) of strategic decision makers who sanction and dictate their deployment within construction firms and construction project organisations would help innovation levels in the construction industry. However, the human dimension has been largely overlooked by construction industry researchers and policy-makers. At present, no research has been undertaken to comprehensively map the attitudinal profile of innovators in the construction industry.

Describing the attitudinal traits or attitudinal profile of a particular population is a technique that is familiar to both market and academic researchers, across multiple fields and disciplines. However in each case the starting point has to be a pre-existing framework of reference such as Ajzen's (1991) model, or multidimensional attitude profiling (Gann & Salter, 2000). This approach underpins the mapping of the attitudinal domain within which ICT/BIM decision-makers for TPOs operate (Brewer, 2009; Brewer & Beard, 2009). Implicit in this is the understanding that a collection of decision-makers within a single TPO will necessarily develop a group culture, be that positive or negative.

Organisational culture has been variously described as a "strong prescription for success" (Martin, Frost & O'Neill, 2004) and "an interpretation for better understanding" (Willmot, 2000). However in both cases the concept of "cultural analysis" has been mooted as an appropriate mechanism to allow its investigation.

Culture is an emergent feature of a group, which springs from the underlying assumptions and beliefs of its members about what they share in common, how the world operates and

consequently, how they should relate to it. This shapes their attitudes and often their consequent behaviour.

Schein (2004) defines culture as:

*...a pattern of shared basic assumptions [beliefs] that was learned by a group as it solved its problems of external adoption and internal integration, that has worked well enough to be considered valid and, therefore, to be thought to new members as the correct way to perceive, think, and feel in relating to those problems. (p 17)*

Group culture can manifest itself overtly through rituals and other behaviours, although often the most enduring cultural traits are embedded in the underlying beliefs held by its members (Schein, 2004; Rousseau, 1990). These beliefs can take one of two forms: espoused, and actual.

Espoused or claimed (beliefs) are usually those attributes that people want to be seen to possess, or believe they should demonstrate. By contrast actual beliefs are those made manifest through their unconscious behaviour. Literature (Schein, 2004) suggests that attempting to understand culture through surface level manifestations alone (e.g. overt behaviour) is unreliable. Schein (2004) recommends surfacing deeper psychological manifestations such as underlying assumptions or beliefs as a more reliable approach. Thereafter it is possible to observe “inconsistencies” or “conflicts” between overt behaviours indicative of claimed beliefs, and underlying beliefs.

The learning or transmission of cultural assumptions or beliefs from one person to another within a group is the way in which group cultures form, whether they form spontaneously (e.g. when a group is thrown together unexpectedly) or by design (e.g. through recruitment of like-minded staff). Various metaphors have been developed to explain the cultural development of groups, likening it to engineered control mechanisms (Archer, 2004), infection (Geertz, 1966), or evolution (Sperber, 1996): where the spread or promotion of cultural traits is not actively initiated or managed there has to be an alternative, naturalistic facilitation process, as in the latter two instances. In the context of this paper the development of project team culture and the cultural influence of the industry beyond the focal project are of central importance.

Many authorities regard the integration of ICT/BIM into construction industry supply chain activities as both desirable and imperative (e.g. Department of Trade and Industry, 2001). This runs counter to its cultural norms and project-centric structure. A conceptual model of the TPO is therefore useful to analyse cultural influences on ICT use in this context (Brewer, Gajendran, & Chen, 2006). Derived from concepts originated by the Industrial Networks School of supply chain management (Ford, 1997; Hakansson & Johanson, 1992) it notes that each organisation within the project consists of a network of interacting actors, resources, and activities, all of which are necessary in order for it to function. Crucially this is extended to include the project, which itself becomes an actant. The model therefore posits that a TPO accretes around a project rather than an individual actor (e.g. the client).

There are a number of ways in which TPOs can be influenced by each other, and that these are not always contractual. Indeed they may not be formally recognised at all, rather being the product of a network of informal contacts and communications (Wasserman & Faust, 1994). It follows that whilst the adoption of ICT might facilitate the communication of ideas and information within a TPO this is only one of a number of possible communication

channels (Gajendran & Brewer, 2007). In the context of the current research it is clear that the characteristics of a TPO have the capacity to impinge upon the formation of culture in relation to the adoption and use of ICT/BIM within a project setting, both in a positive and a negative way.

Brewer (2009) develops model of innovation and attitude to explain the influences affecting the behaviour of decision-makers considering the innovative use of ICT across TPOs in the construction industry. Using Ajzen's Theory of Planned Behaviour (1991) as the point of departure it acknowledges that the ideal decision ought to be to integrate ICT throughout the primary participant organisations in a particular TPO, with its ultimate expression in the adoption of web based communication plus online access to BIM information. A meta-analysis of case study data (Brewer, Gajendran & Beard, 2009) confirmed the model's applicability for analysing the decision-making of key individuals operating within BIM-centric contexts.

The collective attitudes and behaviours of a group of people in large part serve to define their group culture (Schein, 2004). Culture has the ability to influence all areas and activities within organisations, and whilst these are usually thought of as being an individual firm, club or institution, cultural concepts can equally be applied to project teams. It has been observed that the culture of a construction project influences its level and quality of ICT uptake and integration.

Previous research identified the Critical Success Factors (CSFs) for integration of ICT as being: Organisational Commitment; Organisational Attitude to Communication; Rights and Duties of Organisations (in relation to ICT-mediated communications); Investment Drive, and; Risks related to ICT Usage (Brewer & Gajendran, 2006). Subsequent cultural analysis of these revealed that the cultural values espoused by the industry were analogous to the desired cultural values for an optimised project environment, which in turn ought to facilitate ICT integration. Unfortunately in practice it has been found that very few real life project cultures fully reflect these cultural ideals, resulting in a wide disparity between the levels of ICT integration experienced by participants in different projects and at different levels within the project supply chain.

It follows that a comparison of the actual culture of a project with the espoused values of the individual participants provides a basis upon which to identify the issues that lead to sub-optimal levels of ICT integration. The Cultural Analysis Framework for ICT integration proposed by Gajendran & Brewer (2007) maps the actual cultural characteristics of the environment into which ICT is deployed, comparing it to the cultural stereotypes first identified in their CSF study (Brewer & Gajendran, 2006).

## **RESEARCH METHOD**

The underlying principle for this research is exploratory, intended to develop theory. However Brewer and Gajendran (2010) established both the theoretical adjacency of attitudes, behaviour, and culture, and the practical fusion of these concepts in the presence of concurrent principles and codes. These were found in independently conducted interview-based studies of the same people, relating to a common project. In preparation for this study comparisons were made of the coding for themes developed during the authors' doctoral work when applied to case study data developed by each other. Over 85% of the thematic codes developed during their doctoral work (Brewer,2009; Gajendran, 2010) could be

usefully applied to each other's interview data, and since this had been confirmed in a subsequent case study (Brewer and Gajendran, 2010) a rigorous re-analysis protocol was developed to enable the study of attitude, behaviour, and team culture based on a single set of case study interviews and supporting data.

#### *Data re-analysis protocol*

Interview transcripts originally developed for the CRC-CI project were subjected to multiple pass qualitative analyses. Each stage was designed to elicit deeper levels of understanding of the data whilst concurrently providing a concise and consistent description of the phenomena thus revealed.

The first pass of each transcript generated a memo, which was written as a "sense-making" exercise that captured the researchers understanding of it. No prior assumptions were made as to the ideas that were likely to be found.

The second pass at the data confined itself to interrogating the memos themselves in order to identify recurring themes. Any ideas considered of interest or relevance were coded by the researchers to generate a code list. This list was cross-referenced to those codes originally developed in Brewer and Gajendran (2010) in order to ensure wherever possible a consistency of terminology: where this was not possible new codes were added, thereby adding to the overall library of codes related to the topic.

The third pass of the data reviewed both the original transcripts and the memos associated with them in order to assign detailed "meaning" to relevant passages.

The final process was therefore one of abstraction, designed to explain the codes and their appearance in the transcripts with reference to both the attitude and behaviour matrix (after Brewer, 2009 - see Table 1), and the cultural analysis matrix (after Gajendran, 2010 – see Table 2).

#### *Case study protocol*

The case study was completed over several months during the construction phase of the project, and collected interview data, questionnaire data, participant-derived supply chain maps, and other peripheral data offered by the participants. Five representatives from primary stakeholders in the TPO (head contractor, client's in-house project manager, architect, steel fabricator, client's façade consultant) and three representatives from the façade supply chain (specialist subcontractor, steel fabricator, glass supplier) were interviewed. At the interview each was asked about both their firm's stance in relation to the five critical success factors for ICT integration (Brewer & Gajendran, 2006) and their own personal attitude towards them.

The interview was augmented by their completion of a questionnaire that had also been distributed by post as part of a national survey. The interviewees were also helped to sketch a diagram of the TPO supply chain as viewed from their perspective, indicating both the nature of the relationships with their trading partners, and the nature of the ICT mediated interactions with each of them.

## CASE STUDY

The case study project came about subsequent to a design competition where the winning architect prepared sketch plans. These were approved by the client (city council), and were then used to prepare the documentation and cost plans. The key feature of the project was the front facade, known as the ‘‘Sculpture Wall’’, which consisted of an extensive glass curtain wall, curved in three planes. Subsequent to an audit of domestic facade engineering expertise and in accordance with the client’s wish to minimise contractual risk (i.e. pass on risks/costs associated with design and construction flaws and delays), an overseas facade engineer was appointed as consultant to the client, who then recommended a suitable specialist subcontractor.

The design package was put out to tender ahead of the main contract for the building. Although slightly dearer than the lowest bid, the specialist subcontractor’s bid was accepted. There followed a round table meeting to resolve any remaining difficulties at which the specialist subcontractor pointed out that the steel content of the design was 50% higher than they would have expected. They subsequently tabled an alternative design that used cast aluminium elements and over the next seven months this was collaboratively refined to produce significant improvements at lower cost, with most components being sourced in Asia.

The use of diverse ICT was evident in various parts of the TPO at different stages of the project. Various participants professed to have building product model (BPM)/BIM compatible software and the capability to use it collaboratively, though in reality this did not extend beyond the production of 3D CAD models with limited attached attributes. There was no formalised ICT-mediated communication structure for the TPO, though emailed document distribution was the norm, especially during the early stages of the project. Figure 1 illustrates the structural relationships between the various TPO participants.

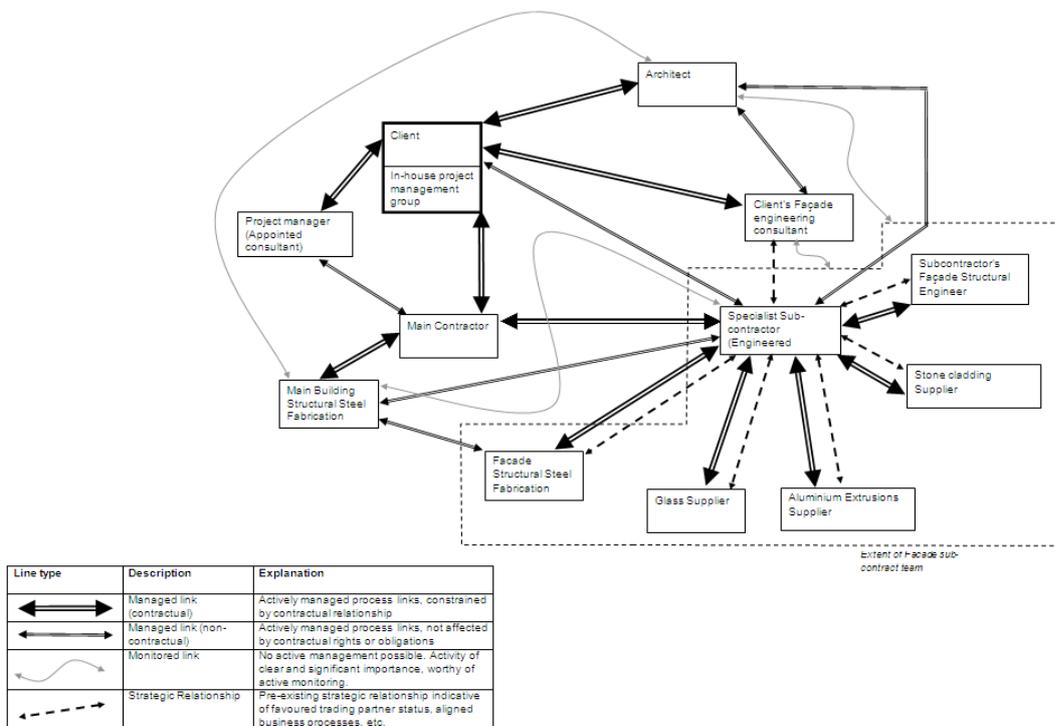


Figure 1. Supply chain map for the case study project.

## **RESULTS AND DISCUSSION**

The following sections summarise the outcomes derived from the various analyses/re-analysis of multiple data obtained during the case study. In doing so they reveal the espoused values of the various participants, their true attitudes and beliefs in relation to the use of ICT in the current project, linking them to their subsequent decisions and conduct in the project environment, further linking them to the creation and subsequent development of the project team culture.

When interrogated through the application of a standard questionnaire, originally developed for use in the CRC-CI project (Gajendran, Brewer & Chen, 2005) all of the project participants' responses were found to be within one standard deviation of the sector norms. As a consequence the project participants could be thought of as being a representative sample of industry thought and practice, sharing the espoused attitudes of their colleagues in the industry. Their hopes and concerns in relation to the collaborative use of ICT within project teams therefore centred on issues associated with Organisational Commitment; Organisational Attitude to Communication; Rights and Duties of Organisations (in relation to ICT-mediated communications); Investment Drive, and; Risks related to ICT Usage (Brewer & Gajendran, 2006).

Brewer (2009) revealed that the development of attitudes and subsequent decision-making behaviour in relation to ICT-based innovation was in fact more complex, and reflected a range of boundedly rational influences. These could be summarised in the form of a map, within which the individual attitudinal profile of decision-maker could be located. The attitude and behaviour matrix developed in Brewer & Gajendran (2010) has been populated with data analysis from the study and is shown in Table 1.

Further analysis of the data reveals the aggregated impact that all of the participants' decision-making and conduct within the project team have had on the overall project team culture. The cultural analysis matrix first developed in Gajendran & Brewer (2007) has been used and populated in order to summarise these effects (see table 2). This indicates that out of a potential 17 espoused aspects of ICT integration within the project, only 3 had been integrated on the case study project, with 10 being differentiated and the remaining 4 being fragmented (see table 2, column 3). By contrast the same analysis performed on the specialist subcontractor's own supply chain revealed a very different story, with all but three of the espoused conditions for ICT integration being put into practice, these being inappropriate for a supply chain of that nature (see table 2, column 4).

In many respects this case study is a tale of two supply chains, one associated with the procurement of the building, the other entirely related to the specialist subcontractor. The contrast between the two could not be more stark, with the former being conventionally convened to deliver the bulk of the project, whilst the latter appearing to be bound together strategically in a non-exclusive set of relationships (Blankenburg Holm, Eriksson & Johanson, 1999). It is perhaps telling that the business entre between the two was facilitated by the client's facade engineering consultant, who also had a strategic relationship with the specialist facade subcontractor.

The significance of the strategic relationships in this TPO relate in the first instance to the way in which the specialist facade subcontractor had invested time and resources in establishing stable supply chain relationships with all of its suppliers, particularly in terms of its use of ICT (Blankenburg Holm et al, 1999). This extended to temporarily embedding staff

members in its suppliers firms in a training capacity, to ensure that their use of the available technologies meshed seamlessly with its own. Whilst conventional wisdom seems to indicate that "championing" of ICT innovation is principally the domain of the "informed client" (e.g. NSW Government, 2002) in this case the championing "client" was itself a supplier to the project client, who made no such demands.

Domain	Technological			Human			Business process			Personal		
Participant	Intra	Inter	Term	Intra	Inter	Term	Intra	Inter	Term	Intra	Inter	Term
Client/In-house Project Manager	Commitment to basic ICT infrastructure for common business uses	Little expectation of boundary-spanning ICT but	Long term commitment to intra-organization integration	Commitment to ongoing staff development Built env. applications low on list of priorities			Tends to be bureaucratic				Appreciative of collaborative ICT use on current project	
Architect	ICT is a mechanism for error reduction in design.		High costs associated with model generation must be sold to client as		Best to tone down ego when collaborating online. Trust is essential when sharing IP.		Envisages the advent of full virtual prototyping, reflecting the business practices of other industries.	ICT not regarded as a prerequisite during selection of trading partners, however flexibility is required	Essentially an evolutionary process. AEC sector something of a laggard.			
Main Contractor	Commitment to the automation of internal business processes	Disinterested /mistrusting			Tends to cynicism			ICT not regarded as a prerequisite during selection of trading partners			Doesn't believe inter-firm ICT will play a major role during his career	
Client's Façade Engineer	Central to function of business	Regards limited inter-firm interaction as inevitable during the design phase	Long-term, unable to control/limit pace of development					ICT not regarded as a prerequisite during selection of trading partners				
Main Building Fabricator	Commitment to the automation of internal business processes	Little evidence of engagement			Preference for F2F communication/paper esp. during construction phase							
Specialist Façade Subcontractor (SFS)	All staff capable of operating all systems and platforms used in-house	Preference given to trading partners who share similar platforms, but not prerequisite	Serious long term commitment to ICT. Significant portion of annual investment.		Commitment to supporting the training of trading partner staff in required technologies for ICT interaction			Commitment to supporting the training of trading partner staff in required business processes for ICT interaction	ICT compatibility essential prerequisite for doing business	Unwilling to support non-tech savvy staff.	Very aware of the potential for Catastrophe when relying on ICT – inter-personal dimension to be closely monitored	Long-term commitment
Façade Fabricator	Generally supplanting paper-based processes	Happy with interaction with SFS, less so with others in the main building contract	Long-term commitment to ICT for design and fabrication	Staff development to complement and support ICT investment	Able to meet client demand/ willing to adapt to changing client demands			Flexibility required when dealing with clients' requirement for ICT				Long-term commitment
Glass supplier	Undergoing major ICT reinvestment largely in response to client demand	Willing to align with SFS as price for doing business	Long-term commitment to ICT	Staff development to complement and support ICT investment	Willing to accept external input to assist in business process alignment with clients			Flexibility required when dealing with clients' requirement for ICT			Very adaptable, keen to exhibit best practice	Long-term commitment

**Table 1.** Attitude and behaviour matrix.

The contrasting supply chains were populated by individuals whose attitudes mirrored those who were driving the supply chains. On the one hand the client considered itself quite separate from the other participants. On the other hand the specialist facade subcontractor

insisted on high levels of involvement, even in areas of the project where it held no primary responsibility. Throughout the facade supply chain there was never any evidence of resistance to, or resentment of the imposition of specific ICT protocols from its client. All of those who were interviewed from this part of the project expressed appreciation for the streamlined way in which their supply chain relationship operated, leading to improved business outcomes for their respective firms. What cannot be determined from this study is the extent to which the collaborative nature of their relationship with the specialist facade subcontractor was mirrored in their dealings with their customers from other TPOs.

ICT Integration Trait	Organisational trait	Observed culture (TPO) In this case it was found to be:	Observed culture (SSC) In this case it was found to be:
<i>Successful ICT implementation requires the:</i>	<i>For a firm to successfully integrate ICT within a TPO:</i>		
The commitment of a firm's senior management.	Senior management should embrace ICT and commit to implement ICT in their organisation/when there is potential for ICT to support operations.	Differentiated	Integrated
The commitment of an organisation's employees	Employees need to commit to engage with ICT tools those support/enhance their personal work environment	Differentiated	Integrated
Transparency and trust among project team participants	Members of the team should develop trust and transparency within the project environment	Integrated	Integrated
The identification and sensitive handling of the ownership of the intellectual property generated during a project	Contractual arrangements should encompass safeguard on intellectual property rights.	Differentiated	Integrated
The project team members to acknowledge the sensitivity and confidentiality of other participants' information	Members are guided by explicit codes of practice and informally held ethics and moral values. The source of these value codes may come from the organisation's procedures, personal upbringing or by education.	Integrated	Integrated
A powerful ICT "champion" to support the technologically weaker organisations in project teams	Powerful member should support the weaker members through leadership, collaboration or as a result of their positional power.	Fragmented	Integrated
An organisation's continuous and conspicuous investment in staff development and training	Should continuously invest in their staff ICT development programs and training	Differentiated	Integrated
A "powerful organisation" within the team to impose ICT adoption	Could impose 'power positions' within the project to encourage appropriate level of ICT use in a project environment	Differentiated	Integrated
A "champion" to support all new technology that is to be used across a project team within a firm/Project.	Leadership structure should engage in giving proactive direction in the use of new ICT tools and techniques	Fragmented	Integrated
Standard conditions of contracts that specifically accommodate the issues raised by the use of ICT	Need to maintain contractual clarity in ICT employment through stipulating conditions of contract and adherence to the conditions. This also could be viewed as an industry regulators role.	Fragmented	Differentiated
An organisation to be prepared to engage in long-term collaborative relationships	Preparedness to engage long-term relationships with trading partners.	Differentiated	Integrated
Organisations to commit to ICT as a long-term strategic decision.	Commitment to engage in long term strategic relationships with trading partners to foster return on large ICT investments	Differentiated	Integrated
Organisations to commit to ICT as a project-based tactical decision.	Commitment to engage with ICT in project to project basis in short run in small ICT investments	Differentiated	N/A
The organisations to monitor competitor's ICT adoption.	Need monitor the competitors to gain potential competitive advantage	N/A	N/A
Addressing the fragmentation issues of the project team for improved performance of ICT-enabled operations.	Must engage in procurement methods that minimises fragmentation of project teams.	Fragmented	Differentiated
Organisations try to limit their use of multiple online systems promoted by different project participants.	This factor can be viewed purely as a technical (interoperability) issue, outside of cultural considerations. However, one can relate the espoused values to Item 12 above	Fragmented	Integrated
The security of information is vital in an ICT-enabled project environment.	This can also relate to the espoused values relating to the level of acceptance of ICT security	Differentiated	Integrated

**Table 2.** Cultural analysis matrix.

It is appropriate at this point to remember that the primary stated purpose of technological integration is to reduce the inherent information fragmentation commonly experienced in

industry (Nitithamyong & Skibniewski, 2004), and to look for clues as to why the presence of high-level new technology has apparently failed to achieve its objective in some parts of the industry, whilst proving very successful in others.

In most vital respects the construction project at the centre of this case study was typical of those found in the industry. Many of the key decision-makers who were active in the early stages of the project decided to stick with the tried and tested approaches to project procurement and consequent project team selection. None of these players had sufficient experience with high-level ICT to fully understand its potential or to drive its adoption/integration into the life of the project (NSW Government, 2002). It was therefore purely fortuitous that a project participant chosen because of the technological excellence of its product was in fact the one who eventually championed high-level ICT use across parts of the TPO.

In reality the penetration of high-level ICT/BIM from the specialist subcontractors supply chain into the TPO was quite limited. However the cultural impact of its champion was more profound. Several TPO participants spoke of a change in the culture of the project once the subcontractor became involved. They often cited its willingness to share commercially sensitive information and engage in additional, unrewarded work, thus facilitating speedy problem-solving and improved project performance. This openness and willingness was reported as being infectious, leading others including the head contractor and main building fabricator to reciprocate. No one suggested that this was an act of charity or altruism, but rather a welcome change to the normal expectation that problems in a project necessarily equated to delays, conflict and eventual increased costs. The role of ICT/BIM in facilitating this agreeable flow of information was widely regarded as being incidental, and indeed much of it occurred at a time when all parties had largely moved to an on-site presence, predominantly using paper-based drawings.

A fundamentally different story emerged from the subcontractor's own supply chain where, after a period of experimentation prior to this project a set of fairly stable supply chain relationships had developed. These necessarily spanned international boundaries, were information intensive, and required all parties to invest heavily in them. Their longevity was based in equal measure upon two characteristics: firstly, the ability to deliver quality products, to the right price, at the right time (Blankenburg Holm et al, 1999), and; secondly to engage with the specialist subcontractor using high-level ICT, including BIM-compatible information exchange, in a manner which suited their purposes (Nitithamyong & Skibniewski, 2004). Informal contact with the specialist subcontractor a couple of years later has confirmed the centrality of these principles to their ongoing relationships with supply chain partners:

*You know, there are 6 billion people in the world, and it's surprising how difficult it is to find one of them who will reliably supply you with what you need on a regular basis..... When you find someone you can do business with, you cling onto them. They are pure gold. They become family.* (CEO, Specialist subcontractor).

The questions remain as to whether the specialist subcontractor's influence on cultural development of the TPO was real or coincidental, and whether the experience for others in the TPO produced a lasting change in their attitude to collaboration or whether it was a purely transient phenomenon. It is unlikely that such complex questions can be satisfactorily answered, and certainly not without a prohibitive amount of forward planning in the design of a longitudinal study that follows the case study participants into further projects. Nevertheless

it is reasonable to speculate that negative attitudes to a variety of issues pertaining to TPO relationships (and the behaviours they trigger) commonly encountered in the industry are in fact cultural artefacts, developed and/or learnt from others over a considerable period of time (Schein, 2004). Such traits are not easy to overcome and yet, as the specialist subcontractor and its trading partners demonstrate, the rewards for doing so can be both enduring and rewarding. It can therefore be further speculated that if the negative cultural traits endemic in the industry have endured because they produce profitable results then positive cultural traits have to produce demonstrably more profitable outcomes in order to supplant them.

Given the foregoing it is perverse that it cannot be assumed that successful ICT/BIM outcomes can, or should be equally attainable by all. In the past ICT/BIM enthusiasts have espoused the notion of ICT integration as a panacea for the industry's ills. In this they have been amply supported, or perhaps even inspired by successive industry reviews (e.g. Egan, 2002), which have promoted industry adoption of the technological and supply chain innovations commonly found in manufacturing. Such playing field-levelling, pain-share/gain-share perspective is inherently egalitarian, and yet modern approaches to the issue such as the American Institute of Architects Integrated Project Delivery system (AIA, 2007) appear to eschew this, preferring a pragmatic technological sectarianism. In accepting the reality of differing levels of technological capability, they also acknowledge differing levels of integration between trading partners, the lowest of which ensures little more than the exchange of CAD data.

## **CONCLUSIONS**

This case study has built upon earlier work by Brewer and Gajendran (2010), which established the theoretical overlap and practical links between the attitude and decision-making behaviour of key individuals within single firms and the resulting culture formed within TPOs. In doing so it has created a reliable methodological framework that can be used for future investigations of ICT/BIM integration within TPOs in the AEC sector.

This paper has presented an example of a highly integrated supply chain and a largely differentiated/fragmented TPO. Earlier studies (e.g. Brewer & Gajendran, 2010; Gajendran, 2009) have suggested that the latter is the industry norm.

These findings raise a number of important questions: Firstly, to what extent is it beneficial or even necessary to integrate the ICT/BIM used in a TPO across all its members? Secondly, what is the nature of the relationship between ICT/BIM integration in a TPO and its culture (i.e. does culture drive integration, does technology shape TPO culture, or is the relationship more complex)? Thirdly, how is ICT/BIM integration experienced and understood by diverse project participants?

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