# Influences on the adoption of BPM/BIM: an Australian perspective

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ABSTRACT: BPM/BIM offer the possibility of faster, more accurate collaborative working thereby offering a solution to many current construction industry challenges, yet their usage remains frustratingly limited. It follows that there are likely be a number of influences and the aim of this research was therefore to identify those that could be considered relevant to the Australian construction industry. It first modeled candidate inhibitors identified from the literature, applying this to a single 'critical case' study project. Interviews undertaken with six key stakeholders were triangulated with two industry experts. Coding and abstraction of the data largely confirmed the efficacy of the model, which was subsequently found to be congruent with Brewer's model of Innovation & Attitude (Brewer 2008) after qualitative meta-analysis was conducted.

## 1 INTRODUCTION

Building Product Models (BPM) (Eastman 1999) and latterly Building Information Models (BIM) are forms of technology that capture the form, behaviour and relationships between the parts and assemblies of a building, thereby providing a rich representation of the building's design data. Despite them offering the promise of significant changes in how developers, designers, consultants and contractors manage the entire building process. (Weisberg 2000), the technology has thus far failed to gain widespread acceptance. This is despite a conviction of the inevitability of widespread BPM/BIM adoption, driven by their multiple benefits. The architectural, engineering and construction (AEC) sector is currently the only major industry producing 3D products that is not using some form of product model. Eastman (1999) regards this as further proof that the widespread use of BPM/BIM is overdue in the sector.

The literature has identified a myriad of benefits that such implementation could bring (Betts, Cher et al. 1991); (Fisher and Shen 1992); (NPWC 1993); (Aouad, Alshawi et al. 1996); (Mohamed 1996); (Shen 1996); (Froese, Rankin et al. 1997); (Shafagi and Betts 1997); (Walker and Betts 1997); (DPWS 1998); (Howard, Kiviniemi et al. 1998); (Stewart, Beswick et al. 1998); (Atkin 1999); (Betts 1999); (Walker 2000). These are countered by a plethora of explanations as to why this technology (and ICT in general) have failed to gain widespread acceptance within the AEC sector.

However, by merely identifying individual influences the current research fails to contextualise them. Only by modeling them holistically can an overall understanding of the interrelationship between the influences be achieved.

Given its relative novelty in the industry the use of BPM/BIM can still be considered an innovation for the majority those considering its use. The decision to innovate comes with the assessment of risk and reward, and an expectation of creating sustainable competitive advantage (Porter 1985).It follows that the influences on adoption find their practical expression in the decision of whether or not to adopt BPM/BIM..

Business decision-makers often believe that they make choices on the basis of rational evaluation of alternatives and consequences. However this is erroneous. Simon (1991) has shown that there are a myriad of less-than-rational influences at play in the making of business decisions, and it follows that decisions relating to BPM/BIM use may well be the manifestation of boundedly rational decision-making, wherein the influences on BPM/BIM have played a major, though not necessarily exclusive part.

Brewer's model of Innovation & Attitude (Brewer 2008) was developed in the first instance to understand the influences affecting the behaviour of decision-makers considering the innovative use of ICT across temporary project organisations (TPOs) in the construction industry. The acme of this behaviour would be the decision to integrate ICT across the main participants in the TPO, with its expression in the adoption of web based communication portals and/or BPM/BIM.

The model (Brewer 2008) maps a range of exogenous and endogenous influences on the decision maker, and it conceptually follows that there should be considerable alignment between the influences on BPM/BIM adoption and those parts of the Innovation & Attitude model that are technology-specific.

This paper therefore reports firstly on the development of a model of influences on BPM/BIM adoption, and secondly it's triangulation. This is achieved in two ways: firstly using independent expert feedback on the model; then secondly using qualitative, content analysis-based meta-analysis of the interview data. Brewer's model of Innovation & Attitude (Brewer 2008) is used to supply the concept codes that drive the content analysis.

## 2 BPM/BIM

3-D modeling, based upon the capabilities of CAD systems, has its ultimate expression in the building product model (BPM). Eastman (1999) defined the BPM as:

*"A digital information structure of the objects making up a building that captures the form, behaviour and relations of the parts and assemblies within the building. A building product model therefore potentially provides a richer representation of a building than any set of drawings could and can be implemented in multiple ways, including raw computer files or in a database format."*

The appeal of the BPM is its ability to provide a single repository for all of the information that is generated, transmitted and interpreted during the course of a project. In this way the information can be captured and updated through the building's life cycle from inception through operation to deconstruction (Emmitt and Grose 2003).

The stepwise evolution of 3-D CAD models into object models (Marini 2002), building product models (Eastman 1999), and lately building information models (Autodesk 2007; Raisbeck 2007) has been accompanied by evolving modeling standards, the most widely accepted of which are known as industry foundation classes (International Alliance for Interoperability 2007). These enable the attributes of virtual objects to be catalogued in a database associated with the building design in which they have been used. Whilst these attributes were initially restricted to the "as designed/specified" domain, they have subsequently been expanded to include attributes such as degradation over time, maintenance requirements, energy use characteristics, and so on. This has made it possible to automate the process of modeling a building over time (Huijbregts, Norris et al. 2001), thereby allowing rapid and pragmatic evaluation of design alternatives throughout the building's life-cycle (Ciroth and Becker 2006).

Clients as key members of temporary project organisations may recognise the value of adopting these technologies in relation to their building information needs during its operational phase, particularly as they pay for its generation. However the commercial risks associated with the technology's adoption are often more persuasive considerations for the other members of the temporary project organisation when deciding whether to adopt.

The implications of the foregoing can be summarised in the following way. Firstly, since the introduction of computing to construction-specific applications it has become increasingly possible develop and store details of construction projects in a centralised fashion, be it central to an individual firm or to the TPO. Secondly, increasing technological capability has resulted in the potential to re-design working practices in such a way as to go some way to achieving Egan (1998) and post-Egan objectives (e.g. NAO, 2001). The process of technical development in the field is far from complete, with the introduction of the Building Information Model (BIM) and Virtual Design and Construction (VDC) environments being the latest developments (Raisbeck, 2007), and this development is matched by the potential, if not actual process improvements that it enables. Finally, the attitude of a firm in a TPO towards engagement with these technologies will be determined partly by its perceptions of the risks involved and partly by the attitudes of other participants.

## 3 LITERATURE REVIEW

Thematic identification 'involves the identification of prominent or recurrent themes in the literature, and summarising the findings of different studies under thematic headings.' (Dixon-Woods, Agarwal et al. 2005, page 45)

In the case of this research and its exploratory nature, thematic identification of the literature is to be undertaken so as to identify themes relating to the influences affecting the implementation of BPM/BIM.

From the analysis of the literature, 14 overall themes have been identified, with each of these themes being comprised of a number of influences.

The themes have been grouped in this way to holistically describe the influences affecting the implementation of BPM/BIM. They achieve this by bringing together influences from a large number of sources including books, journals, government bodies, trade journals and internet-based references. The following paragraphs explore each of the themes, and their associated sub-issues in turn.

A number of the influences identified relate to an ambiguity in relation to responsibility. The influences that have been linked to this theme include the fear of information overload, due to a perceived failure to determine participants' responsibilities (Arnold, Cooper et al. 1996) and therefore an ambiguity as to their workload requirements; the fear of criticism over design decisions, with an increase in the number of participants potentially assessing a decision (Eastman 1999) and the potential for responsibilities over design decisions being raised; a perceived restrictive design, with the design process needing to abide by another structure (Aouad, Ormerod et al. 2000) and the possible ambiguity between the design professionals; and, finally, the potential for confusion over the risk and reward distribution structure for a project, with it potentially being unclear as to who is taking ownership of the risks associated with the project and therefore who should receive the related rewards (Loosemore 1998).

Complacency is a theme comprised of a number of issues, including the industry's resistance to change (Mohamed and Tucker 1996) with the industry displaying a resistance to changing its current position; the task specific development of current systems, with current technologies within the construction industry being developed around current tasks (Eastman 1999), rather than exploring the actual industry requirements; incremental changes within the industry (Eastman 1999) with the need for change not being realised; and, finally, the reluctance of users to use new technologies or techniques. (Milis and Mercken 2003).

The coordination of a project and the technologies used within that project form another theme common to a number of the influences, including the possibility that the task is too big for one company to change, with a large number of organisations needing to work together (Eastman 1999) and therefore coordinate in order implement the technology for a project. This also leads to the potential for an uncoordinated uptake of new technologies, which may result from the failure to identify a common goal for the project (Hillebrant and Cannon 1990); (Atkin and Pothecary 1994). Finally, a failure to take users into account, relates to this theme, with the users needing to be considered in the coordination efforts for a project (Milis and Mercken 2003).

The contractual requirements of a project have been recognised as another common theme among the influences identified, and comprise the contractual nature of communications (Cheung, 2003), with a project's contract outlining the methods in which some project communications must be undertaken; and the bureaucracy requirements (Brandon, Betts et al. 1998) that exist as part of a project, including local and state government legislations and other legislated requirements for a project.

A number of the influences addressed relate directly to a disappointment with the implementation of technologies. The main reason for disappointment with technologies is unfulfilled expectations (McCreadie and Rice 1999), with many industry participants previously implementing technological systems that have not performed in the manner expected. Often this has been a direct result of the implementation of flawed systems (Kamara and Anumba 2001) with technology often being implemented for technology's sake rather than to improve the process.

Two of the influences identified from the literature review were seen as relating directly to the existing industry environment. These two influences were the organisational cultures (Higgin and Jessop 1965) that exist, with these forming the basis for the environment in which the industry operates; and the context establishment (Hightower and Sayeed 1996; Solomon 1997; McCreadie and Rice 1999) or lack of it that exists among many of the industry's professions.

Within the existing industry environment will also exist a number of the other influences that have been placed under other themes to assist with the ease of their identification during the research.

Two of the influences addressed in the literature relate directly to how a technology is evaluated. It was noted that a technology can be evaluated in two main ways, firstly, one based on cost influences (Milis and Mercken 2003), where the cost of a technology is explored including purchase and training costs; and secondly productivity assessment (Hinton and Kaye 1996); (Eastman 1999) where the tangible benefits of a technology's implementation are evaluated.

Both of these evaluation methods, if not used correctly, can result in a technology being wrongly seen in a negative light, which could reduce the potential for that technology's implementation.

Fear has been identified as another potential influence, firstly being linked to the possibility of conflicting interests among participants (Grunederg 1995) and the goals that they are trying to achieve in undertaking a project; the fear of change (Burkhardt and Brass 1990); (Hemmett 1996) and the possibility of going into the unknown; fragmentation and the coordination of other associated influences ; and the threats perceived by technologies (Low and Sloan 2001) and their ability to potentially make industry members redundant or of lesser value.

A number of the influences identified relate to the structure of the industry, including the traditional organisational structure that now dominates the industry (Mohamed 1996) and the level of organisational stability that exists because of this (Burkhardt and Brass 1990); the standard methods of communication that have been developed as part of this 'traditional' organisation structure (Eastman 1999); the reliance by professions on paper based systems (Emmitt and Grose 2003) that has developed as a result of these traditional ways of undertaking business; and, finally, the professional culture (Brownell, Pincus et al. 1997) that has developed among the various industry professions as a result of this traditional structure being developed over a number of years.

Two influences have been placed under the theme of increased structure. The first is a failure to allow for unintentional & unplanned communication (Buckland 1990), with information tending to be communicated through planned formal channels. The second is the possibility of increased reliance on formal communications resulting in a reduction in informal/relationship-building communications (Trenholm and Jensen 1995).

The ownership and control of project information is a recurrent theme. Two influences arise, the first being a fear of information-sharing, with concern being identified as to who should own and control the information and therefore what information should be shared. Secondly, intellectual property and control over information (Eden, Chen et al. 2000) with industry members concerned that the shared information may be used against them or that they may lose control and therefore not gain the benefits of the information's use.

The over-reliance on technologies for solutions is another theme. This theme comprises two main influences. Assumptions about access to information (Smith, Richetto et al. 1977) means there is often a difference between the actual information made available by a technology and that received by an individual. There is also a potential reliance on technology itself as a driver, on the assumption that a technology itself will result in beneficial changes. (Aouad, Kagioglou et al. 1999).

When exploring the influences for common themes two were identified as relating to the social environment in which the industry exists. The fist influence was trust (Roberts 2000) with the level of trust between participants directly affecting the project's social environment. The second influence within this theme was that of the social context, (Burkhardt and Brass 1990) that exists between the various participants. This can be thought of as approximating to the project culture.

The technical capability of an organisation is the final theme, which contains two main influences. The first is the lack of skills possessed by individuals and organisations (McCreadie and Rice 1999) with a technology only being as good as the people that are required to use it. The second influence concerns accessibility to hardware and software, with the participants within a given project requiring the technical capability both in skills and access to hardware and software in order to successfully implement a technology.

A detailed thematic review of the literature revealed 14 overarching themes within which a range of influences on the decision to engage with BPM/BIM could be situated. These are summarised in Table 1, and it is this framework of influences that is now used to inform the design and subsequent conduct of the primary research investigation.

Table 1. Theme and influence summary

| Theme | Influence |
|---|---|
| Ambiguity of Responsibility | Fear of information overload<br>Fear of criticism over design decisions<br>Perceived restrictive design<br>Risk & reward distribution |
| Complacency | Resistance to change<br>Task specific development of current systems<br>Incremental changes within industry<br>Reluctance of user |
| Coordination | Task too big for one company to change<br>Uncoordinated uptake of new technologies<br>Failure to take users into account |
| Contractual Requirements | Contractual nature of communications<br>Bureaucracy requirements |
| Disappointment with Technologies | Implementation of flawed systems<br>Unfulfilled expectations |
| Existing Industry Environment | Organisational cultures<br>Context establishment |
| Evaluation of Technologies | Cost Issues<br>Productivity Assessment |
| Fear | Conflicting Interests<br>Fear of Change<br>Fragmentation<br>Threats perceived by technologies |
| Industry Structure | Traditional organisational structure<br>Organisational stability<br>Standard methods of communication<br>Reliance by professions on paper based systems<br>Professional culture |
| Increased Structure | Failure to allow for unintentional & unplanned communication<br>Increased reliance on formal communications |
| Ownership & Control | Fear of information sharing<br>Intellectual property and control over information |
| Over Reliance on Technology for Solutions | Assumptions about access to information<br>Reliance on technology as a driver for construction |
| Social Environment | Trust<br>Social Context |
| Technical Capability | Lack of skills<br>Accessibility of hardware and software |

## 4 METHODOLOGY

This research was designed to be exploratory in nature, with the intention of generating new theoretical propositions for subsequent testing by further research projects. Given that at this time (2005) the use of BPM/BIM across a TPO was (and to a slightly lesser extent, still is) a rarity in Australia it was decided that a single, detailed case study containing a number of equally detailed embedded case studies of decision-makers in the members of the main case study TPO was appropriate.

Following general case study precepts (Silverman 1993; Silverman 2002; Yin 2003) this study made use variously of documents, archival records, interviews, direct observation, participant observation; and physical artifacts as sources of data. Using this data embedded cases were constructed for the six key TPO participant organisations, namely: client's representative; architect; builder; superintendent; structural engineer; and services engineer.

It is suggested by Yin (2003) that "a flaw in doing case studies is to conceive of statistical generalisation as the method of generalising the results of the case study." Given that this research has been undertaken on an exploratory basis and use has been made of a single case study, the mode of generalisation that can be applied in this instance is that of "analytic generalisation".

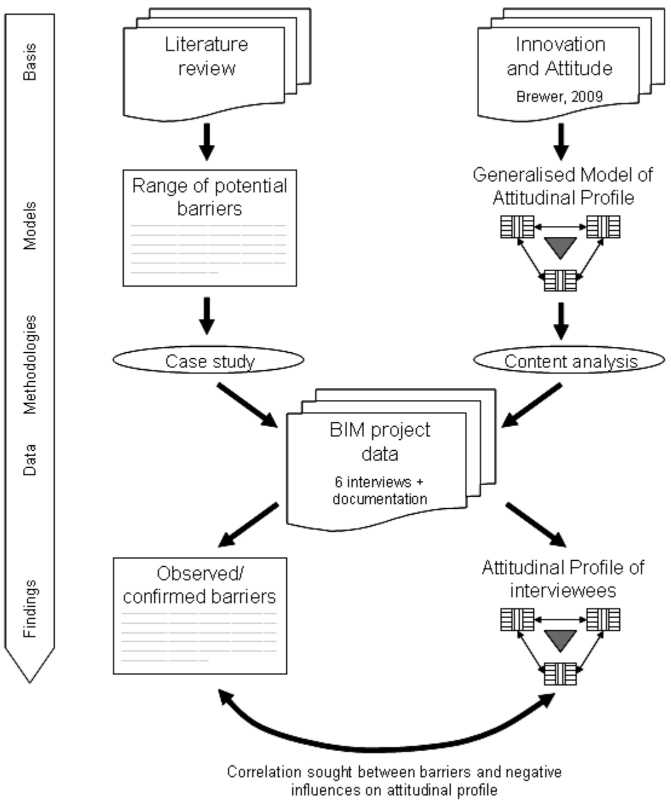


Figure 1. Research process

Analytic generalisation is based on a 'previously developed theory, with the theory being used as a template with which to compare the empirical results of the case study." (Yin 2003, pp32-33). When this research was originally conceived and conducted triangulation occurred variously within the literature, between the embedded cases, and between the case study findings and the industry experts, thus enabling a level of analytic generalisation.

The subsequent development of Brewer's model has enabled further, independent modes of triangulation. Firstly it enables comparisons to be made with the model of influences on BPM/BIM generated by this study. Secondly, it also opens up the possibility of conducting a qualitative meta-analysis of the data collected for the embedded cases -- specifically, the case study interviews. The overall research process described in this paper is illustrated in Figure 1.

Qualitative meta-analysis of the case study interviews has been conducted using content analysis, where the interview data has been mapped against the precepts contained in the model of Innovation & Attitudes.

Three fundamental data analysis approaches have been used throughout this research: thematic analysis, abstraction, and content analysis. An overview of each, summarising its implementation in this study is now presented.

Thematic analysis identifies common or recurring themes across a range of text-based data (Morse and Richards 2002). The use of thematic analysis, with its ability to seek "comparability [of data] by defining topics and at the same time remaining open to the views related to them" (Flick 2002, p185), was seen as the most logical method of analysis to use.

The nature of the coding techniques employed was determined by the nature of the enquiry and the desired outcomes. Following the principles established by Strauss and Corbin (Strauss and Corbin 1990) a linear coding process was developed, which revealed themes (variously in the literature, interviews, and other text-based data) using open coding, developing them where appropriate through axial coding. At times this process identified the influences within their thematic clusters, however it is important to understand that other, more reflexive processes were often concurrently at work: these are generally known as abstraction.

Abstraction arises from the themes and meanings contained in the textual data generated by the research, and results from deep immersion in it, invariably requiring multiple passes at the data. The objective of this process has to be to describe the essence of the phenomenon under consideration (Daniels 2001).

An empirical phenomenology approach to abstraction places explicit reliance upon the actual words of the subjects under consideration, whether they are academic accounts of previous research, or raw interview transcripts. Abstraction in this study has therefore been conducted with due respect to the principles described by Cohen (Cohen and Daniels 2001) : firstly, an emphasis is placed on commonality that is present in the many diverse appearances of the phenomenon; secondly, there is a reliance on the actual words of the participants/contributors; thirdly, the research design and execution is explicitly staged; fourthly, this explicitness leads to verifiability and replicability, rigour rather than creativity; and lastly, the acceptance that hermeneutic activity (interpretation) is nevertheless an intrinsic part of the process.

Content analysis is a research method that can be used to determine whether a particular concept or idea is overtly presented, or implicitly implied, within a text-based document or sets of documents (Krippendorff 2004). It particularly lends itself to quantifying the extent to which particular ideas or concepts are present.

Berelson (1971) indicates the usefulness of the technique both in determining the attitudinal and behavioural responses of a particular group, describing this use as "conceptual analysis". This involves tagging (or coding) text and tallying the occurrences of each code within a document or document set. This requires systematic application of a previously developed "code dictionary" in a stepped process (Carley 1993).

The more precise the dictionary is in its identification of concepts and their proxies, the easier it is for the research to retain focus on relevant text. Table 2 illustrates an excerpt from the coding dictionary developed to identify correlation between the two models.

Table 2. Coding dictionary excerpt.

| Concept from “Innovation & Attitude” model | Concept codes to search for in interviews |
|---|---|
| Personal Return-On-Investment | Time required to learn new systems, being personally associated with failed ICT initiatives, adverse effects on personal reputation within the industry, adverse effects on personal reputation within the firm, adverse effects on personal reputation within the TPO, etc…….. |

## 5 RESULTS AND DISCUSSION

### 5.1 *Context*

The project under consideration in this case study was a located in an Australian state capital, and was to construct a 50+ storey, mixed use tower. The project was valued at about $0.5 billion and was to be completed over a 2 ½ year period.

The TPO members who form the embedded case studies in this research were the client’s representative (project development manager), superintendent (project manager) architect (small multinational practice), builder (large multinational contractor), structural engineer (multinational practice), and services engineer (multinational practice).

This project represented the architectural practice's largest project to date, and they had decided to use it as the opportunity to introduce BPM/BIM philosophy into their practice. They were already familiar with ArchiCAD, and found that they only needed to improve their intranet and the graphics cards in individual computers to achieve technological capability.

The building model was developed from the outset, being used during conceptual design to evaluate multiple design options, capturing/explaining the design rationale underpinning the adopted design to all other stakeholders. All commented on the high degree of interactivity made possible by the model during the design process, contrasting it favourably with more traditional 2-D CAD -based processes.

The model was used to study areas, circulation, egress, subdivisions, and construction techniques. This enabled the creation of a virtual prototype, which was used to evaluate alternative designs and construction methods, eventually being used to develop the architectural documentation, interior design, coordination of services with structure. This flowed on into the project programme and work sequencing during the construction phase, and the generation of 2-D design information to other members of the TPO -- typically subcontractors and suppliers.

Technology use on this project was comparable to world's best practice, embracing many of the attributes found in the HUTT 600 auditorium project in Finland.

Limitations placed upon the use of information generated by the model were almost exclusively confined to those imposed by the limited ICT capability of others in the TPO. This meant that the majority of the information was shared using 2-D mode, and whilst a degree of cross-disciplinary collaboration did occur, its scope was limited.

### 5.2 *Content analysis: Influence on BPM/BIM*

Once the six interviews had been transcribed, they were then coded according to the themes and influences summarised in table 1, together with any additional contextual documentation associated with each embedded case. Multiple coders worked independently on the same transcripts in parallel, coming together periodically to calibrate their coding consistency. At these meetings they would discuss discrepancies and divergences, eventually resulting in coding consistency and concurrence.

Upon completion of the coding it was collated and described quantitatively, with each influence having a tally of occurrences. These were then analysed using descriptive statistics, with frequencies, distributions and variances. Firstly, the main case was used to validate the original list of influences: 34 of the 38 candidate influences were found within the collective data, with their relative importance to the group being indicated by frequency of occurrence. The four influences that remained unseen were: implementation of flawed systems; fear of information sharing; failure to allow for unintentional and unplanned communication; and, social context. Thereafter each embedded case was analysed in order to identify the areas of most concern to the interviewee -- these results fall outside the province of this paper.

Using a combination of these results together with qualitative correlation of codes (repeated proximal occurrences of code pairs) it was possible to construct a model of influences on the adoption of BPM/BIM. This had its point of departure being an individual's awareness of the technology, thereafter branching into consideration of two clusters of influences. One related to the individual's own organisation, the other being project-specific, and indirectly linked thereafter to the wider industry at large. This is illustrated in Figure 2.

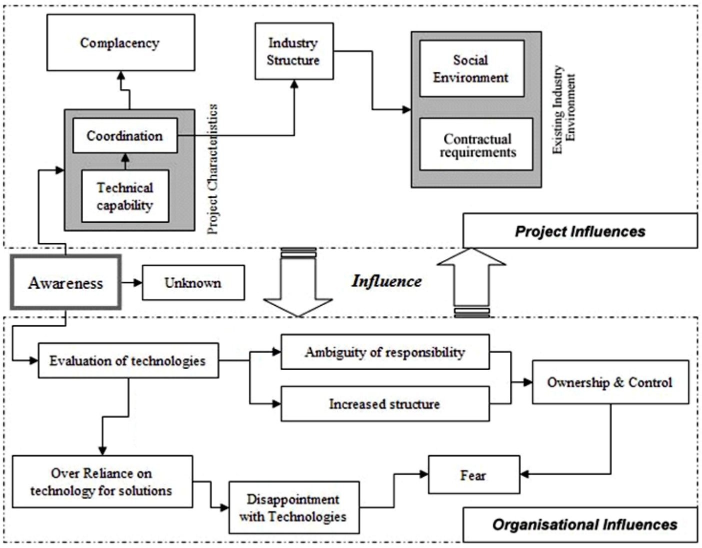


Figure 2. Framework of influences on BPM/BIM adoption

## 5.3 *Content analysis: congruence of BPM/BIM framework with Innovation & Attitude model*

The Innovation & Attitude model condenses a multiplicity of influences concerning ICT adoption into four interlinked domains, dealing with technical, business, human, and personal issues. These are addressed at both intra-firm and inter-firm levels, with reference to supply chain considerations ranging from the impact on the individual firm, through single and multiple project levels, right up to industry-wide impact. All of the issues are couched in terms that describe their potential to influence ICT decision-makers, both positively and negatively, with the intention of explaining the way their decisions have been made. The model is accompanied by 26 explanatory paragraphs that explain each feature.

In order to externally validate the BPM/BIM framework a coding dictionary was constructed using the 26 components described in the Innovation & Attitude model. This was then used in two ways. Firstly, the primary codes and their proxies were compared to the influences described in the BPM/BIM framework, together with their source definitions. This enabled framework and model to be assessed for adjacency of concepts included in each. Secondly, the dictionary was used to code the six interviews with the primary participants in the embedded case studies. This enabled the attitudinal profile for the TPO in the case study to be mapped against the theoretical constructs described by the Innovation & Attitude model, and for differences between the two to thus be identified - these are discussed below.

## 5.4 *Discussion*

Upon completion the first part of the analysis revealed that the BPM/BIM framework and the Innovation & Attitude model were closely aligned. The addition of the four influences not confirmed by the case study and therefore missing from the BPM/BIM framework increased the alignment. Bearing in mind that the Innovation & Attitude model was synthesised from research using 13 Delphi panellists and 39 in-depth interviews, the reintroduction of these four influences was justified for subsequent confirmation in further research.

It was noted that the language developed to describe the influences within the BPM/BIM framework was largely negative, indicative of them being likely barriers to adoption. As an outcome arising from a single case study this is entirely understandable, and provides a suitable basis for developing theoretical propositions relating to BPM/BIM adoption. However it equally highlights the need for theory to be developed using much broader data sources, thus justifying a study to assess adjacency and congruence with a larger study's findings.

The second part of the analysis mapped the group's attitudinal profile within the Innovation & Attitude model. A key outcome from this process was to confirm the existence of two subgroups within the case study, namely those who were familiar with BPM/BIM technologies and their capabilities, and those who had little if any prior knowledge. The former clearly fell into the category of ICT champions, both within their own organisation and with their trading partners, whereas the latter could be described as "reluctant followers" with all that entailed.

The significance of the reluctant followers group was that it was largely, arguably exclusively populated by firms whose representatives often had a sketchy understanding of the capability of BPM/BIM systems. Their own capability to interact with such systems, or with their trading partners using such systems was generally non-existent. The practical consequence of this was that although the architect was modelling the project in three or more dimensions, they were distributing contract documents exclusively in 2-D

Codes highlighting reticence and fear were, perhaps unsurprisingly more common in the "reluctant followers" cadre. What was surprising was that this included the client and builder, given their relationship as joint-venture partners with the architect. Acceptance of the benefits that BPM/BIM provided was offset by reluctance to champion future use of the technology, instead preferring to use 2-D outputs, as provided by the architect in the case study.

A number of codes straddling the human and business process domains were used repeatedly. Collectively they could be explained in terms of the cultural characteristics of the TPO, which were arguably closer to the industry norm than the ideal within which to foster collaborative BPM/BIM use. Interestingly these characteristics spaned both the ICT champions/enthusiasts and the reluctant followers, and could be attributed in part to a fear of sharing too much information, combined with a fear of informal communication. Concerns centred on a loss of control over intellectual property and information flows, and the use to which that information might later be put. It was often expressed in terms of increased project risk, and arose out of a perceived inadequacy of contractual mechanisms, which were felt to be incapable of permitting freer communications whilst concurrently protecting the interests of all participants.

## 6 CONCLUSIONS

This research was conducted in order to identify the influences on the adoption of BPM/BIM in the construction industry, which resulted in the development of an influence framework. This was subsequently tested for adjacency with a more widely applicable Innovation & Attitude model that described the influences on decision-makers considering the innovative use of ICT in the construction industry. The former was based upon a single case study, whilst the latter drew upon two larger studies. At a fundamental level the BPM/BIM framework was found to be largely congruent with the Innovation & Attitude model. Moreover, this model was demonstrated to be easily capable of accommodating the full range of specifics found in the case study, and explaining them in terms of human, business, technology, and personal influences on decision-making.

Analysis of the results revealed that significant differences in language were evident in the terms used in the framework and model to describe what essentially were adjacent concepts. This could be explained in terms of the conditions prevailing in the single case from which the BPM/BIM framework was developed, where the architect was both the ICT champion and the sole BPM/BIM enthusiast, with all other project participants being described as reluctant followers. This was reflected in the largely negative terminology used in the framework, especially within the organisational influences.

The preponderance of reluctant followers within the case study arose from a widespread lack of prior knowledge in regard to BPM/BIM, both conceptually and in terms of capabilities. This is a significant finding. The assumption is often made that experienced practitioners in TPOs understand the capabilities of ICT and the consequent demands it may make upon their own organisations. Where this is not the case such cognitive dissonance is likely result in a drag on overall team performance - the team moves at the pace of the slowest - and consequent friction.

The implications of this finding are significant. Whilst the ideal of a fully ICT integrated industry with a seamless exchange of information across all tiers of the supply chain is almost as distant as ever, the technological push for increased adoption of BPM/BIM by informed clients, and on larger projects is increasing. If these initiatives are to be successful it is apparent that the top tier of the TPO supply chain should share similar understanding of the technological consequences of the decision to integrate significant portions of their business processes with those of their TPO trading partners. This requires all parties to be educated, willing to be assessed for suitability, and culturally prepared for such integration.

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