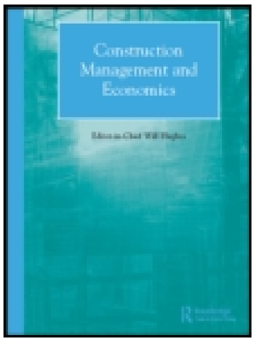

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Measurement and exploration of individual beliefs about the consequences of building information modelling use

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Information and communication technology (ICT) is becoming increasingly important in construction although the rate of adoption is considered slow and the industry faces specific implementation challenges. Mainstream information systems research has shown that individuals' beliefs and expectations of the consequences of ICT use predict subsequent usage. We describe the development of scales to measure beliefs about the consequences of building information modelling (BIM) and their use in a survey of employees of a large construction contracting organization in the United Kingdom. Scales for performance expectancy, effort expectancy, social influence, facilitating conditions, compatibility, and attitude toward using technology were adapted from existing measures. In an analysis of responses from 762 construction employees the scales showed acceptable measurement properties. Expectations about the consequences of BIM use were broadly favourable although there is a need for more data for comparisons. The structure of the responses showed that expectations that BIM would enhance job performance were strongly related to expectations that BIM use was compatible with preferred and existing ways of working. Results also suggest that social influence is complex and may be multidimensional.

Keywords: Beliefs, building information modelling, information systems, measurement, survey.

Introduction

In spite of the apparent potential for improvements from increased use of information and communication technology (ICT), the construction industry is often characterized as slow to adopt new technology with uptake described as disappointing (Brandon *et al.*, 2005). Structural features of the construction industry and its work (e.g. fragmentation, uncertain workload, product and process variation, traditional skills, the site environment) have been documented as limiting technological innovation (Winch, 1998; Gann and Salter, 2000).

Specific studies of ICT adoption in construction have shown that a variety of contextual factors can influence implementation, including contracts (Adriaanse *et al.*, 2010), organization (Peansupap and Walker, 2006), culture (Brewer and Gajendram, 2011), and established practices (Hartmann *et al.*, 2012). These and similar studies suggest that construction is a challenging context for ICT adoption. As well as contextual factors at the organizational or industry level, research has also identified individual-level factors that influence both decisions to implement new technology and individual users' decisions to adopt technology once an organizational decision has been made. In a study of construction projects' implementation of groupware, communication and document management applications Peansupap and Walker found that, 'while many construction organizations attempt to gain ICT use benefits, these may be limited when few people actually adopt and use ICT because this requires user acceptance' (2006, p. 321). Acceptance is not just a simple case of a potential user accepting or rejecting a new technology outright. Levels of enthusiasm and persistence can vary and this has implications not just for extent of adoption but for the cost of implementation. Love and Irani (2001) identified the indirect costs of construction ICT projects including

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integrating systems into ways of working or changing practices as well as training and motivating staff. Case studies of construction ICT implementation have supported the finding that individual-level acceptance or rejection can substantially affect the success of technology initiatives (Miller *et al.*, 2009; Brewer and Gajendram, 2011).

The overall aim of this paper is to explore a set of individual-level variables identified in mainstream information systems research: beliefs about the consequences of technology use. In doing so we seek to explore and demonstrate how individual-level measurement can contribute to understanding ICT use in construction. We describe the research from the information systems literature that has validated these variables and review research on ICT use in construction that has drawn on it. We then report the development, evaluation and use of measurement scales for construction employees' beliefs about the consequences of the use of building information modelling (BIM). Although we base our research on work in the information systems literature for methodological reasons, by doing so we contribute to research on ICT use in construction that connects with the information systems body of knowledge.

Beliefs about technology use and the technology acceptance model

Salient individual beliefs about the consequences of ICT use have been identified by substantial research in the field of 'technology acceptance'. This research, almost exclusively published in the information systems field, originated in attempts to improve the reliability and validity of existing system evaluation questionnaires used by practitioners. The aim was to develop valid measures that could be used by system designers and those responsible for adoption, 'to predict acceptability but also to diagnose the reasons underlying lack of acceptance and to formulate interventions to improve user acceptance' (Davis, 1989, p. 335).

The process of validating the individual belief measures led to the development of the technology acceptance model (TAM): a cognitive choice model of ICT acceptance that shows how individual beliefs about the consequences of technology adoption predict subsequent acceptance and use. The first individual beliefs that were found to influence ICT acceptance and use at work were two distinct factors: 'perceived usefulness' (whether the technology is necessary for a job or could increase speed or quality of work); and 'perceived ease of use' (whether use of the system is expected to require relatively little mental effort, physical effort, or difficulty in learning) (Davis, 1989).

TAM originally drew on a number of theories of behaviour, explicitly: expectancy theory (Vroom, 1964), self-efficacy (Bandura, 1982), cost-benefit models (Johnson and Payne, 1985), and innovation diffusion theory (Rogers, 1983). Its subsequent development (Davies *et al.*, 1989) was influenced most strongly by the theory of reasoned action (TRA: Ajzen and Fishbein, 1980) and later by the theory of planned behaviour (TPB: Ajzen, 1991). Simply put, TRA/TPB states that 'behavioural intention' and subsequent behaviour is a function of an individual's attitude towards the behaviour (in this case, technology use) and his or her perception of the subjective norms promoting the behaviour. A subjective norm is 'a person's perception that most people who are important to him think he should or should not perform the behaviour in question' (Fishbein and Ajzen, 1975, p. 302). Subjective norms in the form of 'social influence' were later incorporated into a development of TAM (so-called TAM2: Venkatesh and Davis, 2000). Other technology acceptance researchers have drawn on similar attitude–behaviour models such as Triandis' (1980) model of behavioural intention, comprising: feelings people have toward the behaviour, expected consequences of the behaviour and social expectations regarding the behaviour. This research has also found that actual behaviour is influenced by behavioural intention but also by 'habits' and 'facilitating conditions' (Thompson *et al.*, 1991).

These and other streams of technology acceptance research and associated theoretical models were brought together through a comparative review and synthesis in a version of TAM referred to as unified technology acceptance and use theory (UTAUT: Venkatesh *et al.*, 2003). Previously identified acceptance factors were categorized into five overarching predictor variables and measures developed based on previous instruments. Those measures were used in four longitudinal regression studies of technology acceptance and use in organizations. This research design enabled the study to incorporate increasing familiarity with the technology and to compare voluntary and mandatory settings. Technology use was measured by self-report and by objective usage log data. The research established the following conceptually distinct, measurable individual beliefs that had some independent predictive validity for technology acceptance and use (quoted definitions from Venkatesh *et al.*, 2003, pp. 447–55):

- Performance expectancy: 'the degree to which an individual believes that using the system will help him or her to attain gains in job performance'.
- Effort expectancy 'the degree of ease of use associated with the system'

- Social influence 'the degree to which an individual perceives that important others believe he or she should use the new system'
- Facilitating conditions 'the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system'
- Attitude toward using technology an individual's overall affective reaction to using a system'

In TAM, in common with TRA/TPB, these individual beliefs are the internal (psychological) variables through which 'external' variables influence behaviour. In technology acceptance at work, external variables might include the nature of the system being introduced; the nature of the potential adopter's work; or the types of organizational support for system users. This focus on internal variables is due to a theoretical position that it is individual perceptions and beliefs that are the proximal cause of behavioural intention and therefore behaviour. Technology acceptance research from an innovation diffusion theory perspective has also maintained this distinction, focusing on perceived characteristics of innovations rather than external, or 'primary', variables (Moore and Benbasat, 1991). More recently, this relationship between individual beliefs and subsequent behaviour had been treated by some as the core of a broader structure (King and He, 2006) to which elements can be added to incorporate specific research findings or interests or to explain more variance in criterion measures. For example, Venkatesh and Bala's (2008) proposed extension of the model (TAM3) evaluates the determinants of perceived usefulness and perceived ease of use by incorporating upstream external variables but does not alter the core TAM relationships.

In this paper we draw on TAM primarily as a source of validated individual beliefs about technology use but it is appropriate to briefly review TAM's standing as a theoretical model of technology use behaviour. Recent meta-analytic reviews of the extensive literature drawing on TAM have confirmed the model's strong empirical base and evidence of significant predictive validity (King and He, 2006; Schepers and Wetzels, 2007; Yousafzai *et al.,* 2007b). Other positive aspects of the model are its applicability across users, technologies and settings; ease of application due to its parsimony and IT-specificity; and the existence of well-developed measurement scales (Yousafzai *et al.*, 2007a). TAM has been criticized for paying insufficient attention to contextual and social issues in adoption and, through its dominance, directing research attention away from this (Bagozzi, 2007). We acknowledge that TAM pays relatively little attention to contextual and social influences particularly in terms of the social context of the implementation of systems and discuss this in the following sections. Another issue, which has implications when assessing TAM as a model of behaviour, is that the large, diverse literature has led to some confusion over which competing version of the model is definitive (Benbasat and Barki, 2007). We approached this concern in the current research by employing King and He's (2006) concept of a core TAM component, that is retained in specific alternative models, within which individual beliefs retain their theoretical significance.

Technology acceptance in construction ICT

Research in ICT adoption in construction has identified a number of antecedents that are similar to the variables thought to influence individual beliefs, including personal motivation, contractual frameworks (Adriaanse *et al.*, 2010), strong social networks (Linderoth, 2010), and IT and senior management support (Nikas *et al.*, 2007). Research like this suggests that performance and outcome expectancies, facilitating conditions and social influence are likely to have a role in ICT acceptance in construction similar to that found in mainstream ICT research in other sectors.

Two studies have directly applied TAM to ICT in construction and facilities management. Son *et al.* (2012) investigated South Korean construction professional users' (n = 144) satisfaction with 'portable computing devices' (smartphones, tablets, etc.) and concluded that usefulness and ease of use were related to satisfaction. This study also reflected findings from TAM research that usefulness is more predictive of behaviour than ease of use. Lowry (2002) studied user acceptance of building management systems. A postal questionnaire survey of building engineers (n = 58) using perceived characteristics from innovation diffusion theory found that none of the individual beliefs predicted usage (self-reported hours per week). The only predictive variable was 'voluntariness' (R = –0.43), contrary to what TAM would predict and suggestive that users mainly used building management systems when explicitly required to do so.

Some statistical research on construction ICT adoption has drawn on similar implicit models of technology acceptance. Peansupap and Walker (2005) conducted a questionnaire survey (n = 117) with 46 items covering a variety of internal innovation diffusion variables plus self-motivation, direct measurement of external variables (software characteristics) and items derived from knowledge management approaches measuring supportiveness and information sharing. Another survey of the perceived value added by IT to construction project information management asked participants (n = 103) from large construction contractors and project management firms to rate the importance of numerous items that included similar constructs (user friendliness, quicker response times, frequency of IT support, etc.). The survey participants' beliefs of the importance of acceptance factors reflected the relative significance identified in TAM research with performance (benefits) rated more important than technology characteristics and user support/orientation. Davis and Songer (2008) explicitly referenced TAM along with TRA and TPB in a narrative review to develop a 'social architecture' factor model that seeks to describe individual and organizational-level technology change acceptance and resistance. Their questionnaire (n = 50) consisted of 554 items to measure individual differences and attitudes and beliefs to technology in general to 'identify those likely to resist an information technology change' (Davis and Songer, 2008, p. 65). Jacobsson and Linderoth (2012) measured satisfaction with impact of ICT in a Swedish (n = 294) sample. The results of their survey and further interviews with respondents showed that users were broadly satisfied with ICT in their work but that even though they agreed that it could increase competitiveness they didn't personally want to use ICT more at work.

A small number of exclusively qualitative studies are also relevant. Peansupap and Walker's (2006) study was a qualitative case study of ICT (intranet and groupware) adoption and use in three large construction organizations that drew largely on innovation theory. It focused on the implementation process and strategic management of IT rather than individual acceptance but drew on TAM explicitly to explain user acceptance following organization-level decisions to adopt technology. The findings emphasized the importance of social influence and networks in the cases. TAM, innovation diffusion and implementation research formed the background to Miller *et al.*'s (2009) participant observation case study of four computer-aided design (CAD) technology implementations in a large Australian construction firm. The research identified 'value', 'benefit' and 'usability' as the 'critical constructs' that determined implementation success. The authors proposed a 'perception-influence' model of implementation/adoption that suggests a series of steps from organizational value to project benefit to personal benefit to usability similar to Peansupap and Walker's (2006) model. Significantly, only one of the implementations was judged successful, with the others failing due to 'rejection by project staff at the individual level or discontinued use as a result of a negative perception of project benefits in project management' (Miller *et al.*, 2009, p. 178).

Another Australian case study (Brewer and Gajendram, 2011) also identified the challenge of engaging individual users: 'in spite of the presence of various state-of-the-art ICT systems including BIM […] the project participants were largely ignorant of their presence and would have been unlikely to use them if they had known of their existence, due to a lack of conviction as to their benefit' (p. 638). This interview-based case study found that individual and team-level attitudes, beliefs and values influenced adoption. A proposed model of adoption and use focused on the group level, emphasizing project organizational culture in which individual beliefs and expectations were mainly viewed as constituent parts. A 'cultural analysis' from this perspective identified social influence factors as the important issues. A qualitative study in Sweden (Samuelson, 2011) interviewed technology managers in design, contracting and supplier firms (n = 11). The aim was to study decision making and implementation of electronic document management, electronic data exchange, and BIM. An interesting finding from this study was that BIM adoptions in the design organizations studied were initially 'bottom-up', intended to achieve professional role benefits for individuals, after which the companies sought to formalize and capitalize on the initiative. Jacobsson and Linderoth's (2010) case study of ICT implementation and use of ICT on a Swedish construction project also highlighted the importance of local and individual evaluations of technology as factors that shape the development and use of new technologies. A particular feature of their findings was the existence of a specifically project (job-site) frame of reference that prioritized action and time saving and influenced the way technology was conceptualized, adopted and implemented.

The research reviewed above shows that, consistent with mainstream ICT research, individuals' attitudes and beliefs can influence ICT adoption in construction. That is not to say that individual-level beliefs taken in isolation are the only important characteristics. Research has also demonstrated the importance of industry-, firm- and project-level factors and how these interact with people's beliefs, specifically in the context of specific implementations. However, in the main, construction research that measures individual variables has drawn only tangentially on mainstream information systems research techniques and hence misses an opportunity to more directly apply established approaches in a construction context. In the rest of this paper we report research intended to take advantage of that opportunity. The construction ICT that we focus on is building information modelling (BIM). In the following section we introduce BIM and discuss its use as a reference object in our research.

Building information modelling in our research

In the domain of ICT use in construction, architecture and engineering, substantial research, practice and policy attention is being directed to a class of technology and technology-enabled processes referred to as building information modelling. A building information model is a digital representation of a building and its components in a virtual assembly of interconnected database objects and associated metadata in a coordinated, scaled 3D model. Building information modelling (BIM) is the process of users designing buildings, individually or in collaboration, using a variety of ICT tools (3D CAD, databases, interfaces) and associated business processes to represent and manage information in the model. BIM can be used throughout project and facility life cycles, joining the design, construction and handover processes and digitally mediating construction activities (Jernigan, 2007).

Proponents of BIM have high expectations for its potential to overcome many of the problems faced by the industry and, by extension, economies and societies at large (Rezgui *et al.*, 2009). BIM, it is argued, has the power to transform the construction industry and construction work (Crotty, 2011). Others are more cautious: an interview-based study of 20 construction industry organizations in Finland found that participants' views varied on whether BIM would bring about fundamental change and improvement or was merely the latest incremental ICT introduction unlikely to change the industry (Fox and Hietanen, 2007). Industry surveys suggest that BIM adoption is still far from universal with some practitioners unaware of the technology or unconvinced by the espoused benefits. A survey of building designers and specifiers in the UK in 2011 found 21% of respondents unaware of BIM, 31% 'currently using BIM' (up from 13% with a different sample in the previous year's survey), and 90% predicting they will be using BIM in three years' time (National Building Specification, 2012). Industry concern, reports, a proliferation of seminars and courses, software vendor initiatives and the mandating of BIM in some construction markets (e.g. UK public sector construction) all point to a healthy and growing industry interest in BIM: 90% of respondents to the National Building Specification (2012) survey agreed with the statement 'You hear more and more about BIM these days'.

The centrality and significance of BIM in industry debates has meant that it has become a flexibly used term. In the UK, BIM has become part of industry improvement discourse (Green, 2011) used synonymously with effective and collaborative project delivery (Department for Business Innovation & Skills, 2012). However there are limits to the interpretive flexibility in the way ICT is perceived (Doherty *et al.*, 2006) and, in a typical implementation, BIM retains both physical and digital technology constituents. We recognize that BIM is more than 'mere technology', a view shared by our research collaborators who emphasize the importance of people and process in BIM, but it does contain significant technology components. In the remainder of this section of the paper we briefly introduce research in mental representation and concept hierarchy. We draw on this to frame a high-level operationalization of BIM in the context of previous technology acceptance research and research in the construction ICT domain.

Research in cognitive and social psychology has established that rather than perceiving the world as a chaos of features and stimuli, we categorize elements of experience into concepts. These concepts are efficient ways of organizing our knowledge about the world and are used in processes of perception, learning, memory and language (Rosch *et al.*, 1976). Concepts in attitude or belief systems are organized into classes that form hierarchical superordinate–subordinate relationships with each other. Concepts that are higher in the hierarchy are relatively abstract and general and subordinate concepts more concrete and specific (Hunter *et al.*, 1976). As well as object concepts, attitudes and beliefs themselves are also mentally structured and interrelated hierarchically. These belief structures frame and organize information in a form that allows efficient evaluation and decision making (Rediker *et al.*, 1993). In organizational settings it has been found that individuals' structured mental representations of a domain of interest serve the purpose of cognitive economy allowing individuals to cope with the scale and complexity of information (Walsh, 1988).

Within this theoretical framework, our research aims to measure beliefs about 'BIM' as a superordinate concept. Within concept hierarchies attitudes and beliefs can be measured at all levels relatively independently (Hunter *et al.*, 1976) so the existence of hierarchies does not in itself require any particular instance of research to focus on superordinate concepts. It does allow such a focus however: in attitudinal, cognitive or knowledge structures 'it is the hierarchical structure that allows an overall evaluation of an attitude object to be determined' (Thompson and Hunt, 1996, p. 657).

There are a number of reasons why a high-level focus is potentially fruitful. Core research in mental representation has shown that concepts at a superordinate level are more distinctive. Rosch *et al.* (1976) found that when people were asked to describe lower level concepts they used similar attributes for different categories suggesting that lower level categories weren't distinctive due to their sharing characteristics from superordinate levels. Tanaka and Taylor (1991) found that experts use more subordinate concept labels than novices do when naming objects because of their greater domain knowledge. This suggests that, relatively speaking, novices will operate at more superordinate levels. Communications research has shown that the structure of belief systems and connections between beliefs mean that changes in beliefs can affect related beliefs particularly those with which they have a superordinate relationship. Dinauer and Fink (2005) reviewed research that showed downward influence in attitude formation and change can be so much stronger than upward influences that the latter could effectively be ignored. In consumer satisfaction research, non-price comparisons are often made at a high level of abstraction in both object and attitude hierarchies (Johnson and Fornell, 1991).

TAM research has not explicitly problematized the issue of how target systems are conceptualized and has applied the model to technologies of different degrees of abstraction ranging from job-specific software applications to broader classes of technology such as personal computers or 'the internet' (Yousafzai *et al.*, 2007a). The literature has tended towards measuring attitudes and beliefs toward discrete applications. Venkatesh *et al.* (2003) identified a problem with previous TAM research that 'the technologies that have been studied […] have been relatively simple, individual-oriented information technologies as opposed to more complex and sophisticated organizational technologies that are the focus of managerial concern' (p. 427). Similarly, Burton-Jones and Gallivan (2007) suggested a need in the information systems literature for multilevel research that gives insight into 'the degree to which systems can be considered in aggregate terms as one considers the usage construct at a higher level of analysis' (p. 674).

Although relatively uncommon, there have been examples of applying TAM at higher levels of abstraction. Research on internet acceptance has aggregated employees' usage incorporating multiple business functions, including searching, ordering products, communicating with customers and distance learning (Shih, 2004) and varied usage in large heterogeneous samples of the public (Porter and Donthu, 2006). Other researchers have studied individual acceptance of the 'complex and sophisticated organizational technologies' referred to by Venkatesh *et al.* (2003) and analogous to the high-level BIM concept. Amoako-Gyampah and Salam (2004) applied TAM to a single high-level concept of an enterprise resource planning (ERP) system to manage multiple corporate functions such as finance, human resources, sales, manufacturing and distribution and including both technology and process changes. So and Sun (2011) measured acceptance of supply chain integration and lean production systems including technology, people and systems management elements (So and Sun, 2011). The TAM-related measurement-based research in construction has been limited to relatively simple technologies: portable computing devices (Son *et al.*, 2012) and building management systems (Lowry, 2002). However, Jacobsson and Linderoth's (2012) measurement survey of construction employees' attitudes, satisfaction and expectations used ICT in general as the attitude object despite demonstrating a variety of applications in use and heterogeneity between users.

Aims and objectives

We have reviewed research on ICT in construction that has leant support to the salience of individual-level variables as a necessary part of understanding ICT acceptance and implementation. Information systems research around the technology acceptance model has validated specific individual beliefs but these have rarely been measured in a construction context and then only for relatively simple technologies. Jacobsson and Linderoth (2012) have argued that, 'for the industry to take advantage of ICT's transformative capacity, more fine-grained knowledge would be needed regarding perceptions of ICT impacts' (p. 339). The latest class of construction ICT to which such a 'transformative capacity' has been attributed is building information modelling or BIM. Adoption and acceptance research on BIM has been largely qualitative and has not reliably measured individual beliefs. In order to develop a literature based on measurement of variables it is necessary to evaluate the feasibility and value of doing so. The variety of technologies and processes associated with BIM represent a potential challenge for measurement although we have shown that beliefs about technology have been measured for heterogeneous systems and there is a sound theoretical basis for assuming that high-level beliefs about the consequences of BIM use can be measured reliably.

The overall aim of this paper is to explore a set of salient individual-level variables identified in previous research: beliefs about the consequences of BIM use. In doing so we seek to explore and demonstrate how individual-level measurement can contribute to understanding ICT use in construction and to contribute to research on ICT use in construction that connects with the information systems body of knowledge. Our specific research objectives are:

Table 1 Measurement scales selected

UTAUT construct	Corresponding scale title	Scale description
Performance expectancy	Relative advantage	The degree to which using an innovation is perceived as being better than using its precursor[a]
Effort expectancy	Complexity	The degree to which a system is perceived as relatively difficult to understand and use[b]
Social influence	Social factors	The individual's internalization of the reference group's subjective culture, and specific interpersonal agreements that the individual has made with others in specific social situations[b]
Facilitating conditions	Facilitating conditions	Objective factors in the environment that observers agree make an act easy to do, including the provision of computer support[b]
	Compatibility	The degree to which an innovation is perceived as being consistent with existing values, needs and experiences of potential adopters[a]
Attitude toward using technology	Affect toward use	Feelings of joy, elation or pleasure; or depression, disgust, or hate associated by an individual with a particular act[b]

Notes: [a]Moore and Benbasat (1991).
[b]Thompson *et al.* (1991).

- To develop usable, reliable measurement scales for individuals' high-level beliefs about the consequence of BIM use. Given the existence of validated measurement scales developed in the IS/TAM literature, scales will be developed by adapting existing measures.
- To evaluate the resulting scales in a cross-sectional survey of employees of a large construction organization with respect to research participant acceptance, internal reliability and discriminant validity. Scale reliability will be assessed via internal consistency coefficients. Discriminant validity will be explored through factor analysis of belief structure
- To analyse the resulting scale scores as substantive research results in their own right in order to assess and benchmark beliefs about BIM and to explore relationships between specific beliefs using factor analysis and correlations between scale scores

Method

Measures

Measures were developed for the salient high-level beliefs validated by TAM research (Venkatesh *et al.*, 2003). Specific intact scales were selected from existing measures developed in previous research on the basis of domain coverage, face validity and ease of completion. Item tenses were altered to form prospective scales, references to named technologies in the original items were replaced with 'BIM' and references to the organization changed to fit the survey context. Research collaborators suggested minor changes to aid clarity in the construction and project context. For example the word 'job' is common in the original scales, meaning a person's organization role or job title, but in UK construction parlance a 'job' is a construction project usually defined in terms of a site.

The original scales were selected from those developed by two early TAM research projects. Thompson *et al.*'s (1991) measures are based on Triandis' behavioural intention model and include affect, perceived consequences of use, complexity, job fit, long-term consequences, and facilitating conditions. Moore and Benbasat (1991) developed a 'tool for the study of the initial adoption (by individuals) and eventual diffusion of IT innovations within organizations' (p. 192). Their measures are based on innovation diffusion theory and include measures for perceived characteristics identified by Rogers (1983), namely: relative advantage, compatibility, complexity, observability, and trialability. Scales were mapped to UTAUT constructs using the analysis in Venkatesh *et al.* (2003; see Table 1). Scales were chosen to represent two different aspects of 'facilitating conditions': one measuring provision of computer support and the other compatibility with the user's working style. Responses were recorded on a seven-point scale with the following anchors; 'strongly disagree', 'disagree', 'slightly disagree', 'neither', 'slightly agree', 'agree', 'strongly agree'.

Questionnaire design and content

A self-completion questionnaire was created and hosted on a commercial survey website. The form was pilot tested by eight selected employees in different locations to check technical issues and the usability of the forms. No technical issues were encountered and there were only minor issues of content such as expanding abbreviations and adding text to clarify how the results would be used.

An opening section included a description of the research; participation statement; navigation and completion instructions. Opening questions to count numbers of participants with self-reporting awareness and/or experience of BIM; and to record self-certified level of BIM knowledge (nothing, a little, something, a lot) were based on existing UK industry surveys (National Building Specification, 2012).

Participants were presented with an inclusive definition of BIM consistent with the high-level BIM reference object discussed previously:

> Building Information Modelling (BIM) is a method to describe a project and its spaces, strictures, components and materials with their essential information and properties. The model is a container for the information. BIM can also be described as a collaborative approach making sure the right people get the right project information at the right time.

The items in the scales measuring beliefs about BIM were presented in a single page titled 'Your opinion of BIM in <Organization>'. This section was headed with the following introductory text developed with our research collaborators: '<Organization> takes a broad view of BIM, with an appreciation that it is not only about CAD systems and computers but more importantly: the right blend of People, Processes and agreed Technologies. This section asks you about your own personal opinions about future use of BIM in your work with <Organization>'.

Following this the items were presented arranged in vertical format with 'radio button' response options labelled with the scale anchors described in the 'Measures' section above. The order in which the items were listed on the page was randomly varied for each respondent using a feature of the survey software. This was to minimize the contribution of method and priming effects on intra-scale item correlations (Podsakoff *et al.*, 2003). In the later sections of the questionnaire respondents were also asked for personal details and about their exposure to BIM information within the organization; some of these results are given in the section 'Sample description' below.

Recruitment

The population from which the sample was drawn was all employees of the organization in which the research was conducted. The organization is the UK arm of a major multinational construction group. At the time of writing, the UK business employed approximately 4000 people and had an annual turnover of around £1 billion. It provides construction (building and civil engineering), refurbishment, maintenance and specialist contracting services. It is structured into a number of partly autonomous divisions operating as separate companies serving either geographical regions throughout the UK and/or specific market sectors. The organization also contains numerous 'head office' support departments that work across the other divisions.

An e-mail invitation to participate was sent to all employees by a senior UK manager in November 2011. The short e-mail asked for employees' 'views on Building Information Modelling' from all staff even if they currently had no direct BIM involvement. It also briefly associated increased used of BIM with achieving the medium-term company business plan although without specifying how. The e-mail contained a link to the survey. Additionally, a news item 'button' was visible on the front page of the corporate intranet that opened a webpage containing the same text as the original e-mail and a link to the survey. The survey was live for two weeks and the organization ran a prize draw in which one participant would be randomly selected to receive a tablet computer as a gift.

Sample description

Given the population identified for the research this was a whole population survey with sample attrition for non-completion; the sample can also be characterized as a volunteer sample (Sapsford, 2006). The total sample size was 1301 completed forms. This is a response rate of around 30% which is within the typical and acceptable range of response rates for organizational research (Baruch and Holtom, 2008). Analysing responses from participants who chose to give personal details (n = 1142) showed that participants came from all departments in the organization in the following approximate proportions: building construction (25%); civil engineering (25%); facilities and utilities (20%); specialist contracting (10%); support departments (20%). Our research partners confirmed that these proportions reflected the numbers of people employed in these areas suggesting that organizational unit was not a major source of sampling bias.

Participants identified their primary areas of work as: pre-construction (13%), construction (50%), operations and maintenance (10%), and support (27%). As

Table 2 Scale items

UTAUT construct	Item ID	Item wording used in survey
Performance expectancy	PE1	Using BIM would enable me to accomplish tasks more quickly.
	PE2	Using BIM will improve the quality of the work I do.
	PE3	Adopting BIM processes would make it easier to do my work.
	PE4	Using BIM tools should enhance my effectiveness in my role.
	PE5	Using BIM will give me greater control over my work.
Effort expectancy	EE1[R]	Using BIM would take too much time.
	EE2[R]	Working in the BIM way would be so complicated; it would be difficult to understand what's going on.
	EE3[R]	Applying or working with BIM will involve too much time undertaking mechanical operations (e.g. data input).
	EE4[R]	It would take too long to learn how to apply BIM to make it worth the effort.
Social influence	SI1	I would use BIM because of the high proportion of co-workers who use BIM.
	SI2	The senior management of my <organizational unit> strongly supports the use of BIM.
	SI3	My line manager would help with the use of BIM on future projects.
	SI4	In general, <organization> has supported the adoption of BIM.
Facilitating conditions (Facilitating conditions)	FCFC1	Guidance would be available to me for the selection of BIM tools.
	FCFC2	Specialized instruction concerning BIM will be made available to me.
	FCFC3	A specific person (or group) is available for assistance with BIM difficulties.
Facilitating conditions (compatibility)	FCC1	Using BIM would be compatible with my core job functions.
	FCC2	I think that using BIM fits well with the way I like to work.
	FCC3	Using BIM fits into my work style.
Attitude toward using technology	ATUT1	BIM would make my work more interesting.
	ATUT2	Working with BIM would be enjoyable.
	ATUT3[R]	BIM is ok for some project roles, but not the kind of role I would choose.

Note: [R]Reverse scored.

an indication of the sample makeup, the 10 most common job titles in the sample were engineer, project manager, director, assistant, quantity surveyor, commercial manager, supervisor, design manager, administrator, construction manager. The level of exposure to and familiarity with BIM was similar to that in the wider industry according to recent surveys (e.g. National Building Specification, 2012). Eighty per cent of the total sample had 'heard of' BIM, 25% had used BIM and 16% were 'currently using' it. The responses to the question about self-assessed level of BIM knowledge were: 'Nothing' (27%), 'A little' (36%), 'Something' (29%), and 'A lot' (8%). Of those who knew more than 'Nothing' about BIM 42% had attended a BIM awareness presentation, 61% had accessed BIM information on the intranet and 21% informal and 6% formal training.

Our sample for the analysis reported in this paper was a sub-sample selected based on two criteria: level of BIM knowledge and position in the organization.

Participants who responded that they knew 'Nothing' about BIM in response to earlier items were not presented with the scale items. The rationale behind this was that participants with no knowledge of BIM would have not formed beliefs about BIM and therefore had difficulty responding to items and would be overly reactive to features of the measurement instrument. On a large-scale survey of this kind it was not possible to give participants with no pre-existing BIM knowledge enough information or exposure to enable them to respond meaningfully to the items.

The need to further filter respondents was due to the company-wide nature of the survey which led to an assessment of the appropriateness of including respondents in the current analysis. Our aim was to select a sample that was as large and broad as possible but had an interpretable degree of homogeneity. It was also necessary to ensure that the measurement items were similarly applicable to all respondents in the dataset. For example item ATUT3 refers to 'project role': this is potentially not applicable for an employee who doesn't work in a project environment or at least open to different interpretations that could contribute to measurement error. In consultation with our research collaborators we identified the organizational units in which BIM was potentially relevant and which contributed directly to construction delivery projects. Included in this were all of the divisions that directly delivered projects for clients plus a number of support departments that had project-based roles (environmental,

Table 3 Item descriptive results and correlations

Item ID	Mean	SD	PE1	PE2	PE3	PE4	PE5	EE1	EE2	EE3	EE4	SI1	SI2	SI3	SI4	FCFC1	FCFC2	FCFC3	FCC1	FCC2	FCC3	ATUT1	ATUT2
PE1	5.16	1.34																					
PE2	5.34	1.29	0.654**																				
PE3	5.25	1.29	0.692**	0.629**																			
PE4	5.41	1.24	0.639**	0.655**	.0674**																		
PE5	5.19	1.31	0.673**	0.629**	0.672**	0.671**																	
EE1	2.81	1.33	−0.478**	−0.395**	−0.449**	−0.437**	−0.441**																
EE2	2.50	1.21	−0.348**	−0.318**	−0.346**	−0.341**	−0.347**	0.562**															
EE3	3.22	1.41	−0.390**	−0.357**	−0.378**	−0.383**	−0.368**	0.626**	0.493**														
EE4	2.47	1.23	−0.406**	−0.358**	−0.387**	−0.419**	−0.335**	0.586**	0.525**	0.524**													
SI1	3.78	1.49	0.177**	0.191**	0.179**	0.186**	0.177**	−0.084*	−0.04	−0.07	−0.104**												
SI2	5.26	1.32	0.222**	0.202**	0.177**	0.170**	0.234**	−0.198**	−0.201**	−0.180**	−0.144**	0.202**											
SI3	4.93	1.53	0.329**	0.347**	0.317**	0.316**	0.356**	−0.240**	−0.217**	−0.239**	−0.215**	0.272**	0.380**										
SI4	5.29	1.30	0.108**	0.157**	0.085*	0.090*	0.101**	−0.125**	−0.120**	−0.096**	−0.115**	0.185**	0.465**	0.289**									
FCFC1	5.25	1.22	0.262**	0.251**	0.243**	0.259**	0.248**	−0.272**	−0.225**	−0.186**	−0.242**	0.251**	0.347**	0.374**	0.355**								
FCFC2	5.03	1.30	0.311**	0.239**	0.263**	0.298**	0.303**	−0.233**	−0.204**	−0.192**	−0.234**	0.249**	0.288**	0.337**	0.266**	0.648**							
FCFC3	5.19	1.39	0.206**	0.156**	0.181**	0.208**	0.216**	−0.229**	−0.230**	−0.272**	−0.234**	0.148**	0.348**	0.283**	0.348**	0.449**	0.410**						
FCC1	5.23	1.38	0.579**	0.543**	0.599**	0.638**	0.545**	−0.382**	−0.345**	−0.342**	−0.406**	0.128**	0.135**	0.307**	0.05	0.257**	0.296**	0.158**					
FCC2	5.40	1.21	0.613**	0.576**	0.628**	0.604**	0.601**	−0.486**	−0.437**	−0.411**	−0.448**	0.142**	0.200**	0.314**	0.132**	0.277**	0.279**	0.205**	0.619**				
FCC3	5.25	1.22	0.628**	0.598**	0.641**	0.657**	0.616**	−0.463**	−0.410**	−0.424**	−0.406**	0.121**	0.241**	0.336**	0.100**	0.279**	0.286**	0.194**	0.645**	0.718**			
ATUT1	5.27	1.26	0.457**	0.493**	0.489**	0.499**	0.462**	−0.332**	−0.322**	−0.267**	−0.296**	0.127**	0.177**	0.270**	0.112**	0.255**	0.209**	0.188**	0.386**	0.488**	0.482**		
ATUT2	5.39	1.10	0.464**	0.459**	0.506**	0.485**	0.461**	−0.452**	−0.403**	−0.386**	−0.388**	0.06	0.188**	0.240**	0.110**	0.235**	0.233**	0.205**	0.434**	0.554**	0.516**	0.612**	
ATUT3	3.06	1.46	−0.487**	−0.455**	−0.480**	−0.470**	−0.448**	0.454**	0.392**	0.409**	0.415**	−0.03	−0.095**	−0.225**	−0.02	−0.169**	−0.162**	−0.087*	−0.523**	−0.496**	−0.541**	−0.330**	−0.392**

Notes: ** Correlation is significant at the 0.01 level.

* Correlation is significant at the 0.05 level.

health and safety, procurement, pre-construction, in-house design). Examples of support departments excluded are: internal communications, finance, and legal. We recognize that BIM or BIM products may well be relevant to the work of these departments in a broader sense but for the reasons outlined above they are excluded from this analysis.

Application of these two criteria resulted in a sample for analysis of n = 762 (1057 respondents were from relevant units of which 295 were excluded for answering that they had no BIM knowledge). Predictably, this sub-sample had higher levels of BIM exposure and knowledge than the company-wide sample: 39% had used BIM and 25% were currently using. The levels of knowledge reported were: 'A little' (45%), 'Something' (43%), and 'A lot' (12%). The following sections report the results for the items and scales.

Results: descriptive/correlation

Item results

Descriptive statistics and inter-item correlations for all items are shown in Table 3. Most mean scores are around 5.3 between 'Slightly agree' and 'Agree' on the seven-point scale anchors. (Note here that all effort expectancy items (EE1–EE4) and ATUT3 are reverse scored from the perspective of a 'favourable' interpretation of the results.) These can be interpreted as positive expectations of BIM use although comparison with scoring norms has not featured in TAM research as the measurement hasn't held independent variables constant by measuring combinations of technology, job, setting, and workers. Reflecting on variations to the overall pattern, only one item had a mean score below the scale mid-point: the social influence item SI1 ('I would use BIM because of the high proportion of co-workers who use BIM'). This might suggest that, for this sample, influence from colleagues is relatively unimportant. However, this is a relatively complex item with an increased risk of error variance. The same item complexity issue may also apply to the reverse-scored attitude to using technology item ATUT3 ('BIM is ok for some project roles, but not the kind of role I would choose') which was one of only two items to have a mean score below five. The other relatively low scoring item was social influence item SI3 ('My line manager would help with the use of BIM on future projects'). It is suggestive that scores on this item are lower than for SI2 and SI4 which measured organizational and senior management support.

The correlation matrix shows inter-item correlations ranging between $r = 0.72$ and $r = 0.02$. Strong correlations are found consistently between items within the performance expectancy and compatibility scales suggesting strong internal consistency within these scales. The other scales have fewer strong intra-scale correlations and the social influence scale has none. There are a number of strong inter-scale correlations between performance expectancy and compatibility items. The only non-significant correlations include the SI1 or ATUT3 indicative of error variance in the scores for these items. The structure of the scales was explored further using factor analysis.

Factor structure

Technology acceptance research typically uses factor analysis or similar data reduction techniques to explore the structure of the underlying constructs in technology acceptance and to demonstrate the discriminant validity of scales. Factor analysis examines the correlations between items and 'fits' constructed variables to represent a smaller number of assumed underlying variables or 'factors'. The procedure then measures the strength of the relationship between the empirical variables and the factors. The strength of this relationship is expressed as a 'factor loading' that can take a value in the theoretical range –1.0 to +1.0 and can be interpreted similarly to a correlation coefficient with values over ±0.5 generally considered meaningful.

In previous TAM research factor solutions reported often have clear structures with items grouped into factors on which they load very highly. Davis *et al.* (1989) found very distinct factor loading patterns for usefulness and ease of use with loadings of 0.84 to 0.91 for corresponding items and off-factor loadings in the range 0.01 to 0.10 only (principal components analysis with varimax rotation; $n = 107$). In UTAUT, Venkatesh *et al.*'s (2003) tests of the structural model ($n = 215$) found high internal consistency reliabilities, high item loadings on constructs, and low inter-construct item correlations. The research that developed the scales used in our research showed that adding additional constructs to models also introduced greater ambiguity in factor structure. Thompson *et al.* (1991) found that job fit (usefulness) and complexity (ease of use) were distinct factors but that social factors and facilitating conditions were more ambiguous with some cross-loading (principal components analysis, varimax rotation; $n = 212$). Moore and Benbasat (1991) found a clear factor structure for all scales and items with the exception of relative advantage and compatibility whose items loaded on a single factor (principal components analysis, varimax rotation; n = 540). In a construction (building operations) sample using Moore and Benbasat's measures, Lowry (2002) repeated this finding that items measuring relative advantage and compatibility were combined in the first factor but

Table 4 Technology acceptance factors: rotated component matrix

	Component				
	1	2	3	4	5
PE1	**0.759**	–0.245	0.098	0.079	0.119
PE2	**0.766**	–0.164	0.017	0.132	0.127
PE3	**0.799**	–0.201	0.081	0.026	0.069
PE4	**0.811**	–0.210	0.139	0.017	0.101
PE5	**0.779**	–0.151	0.115	0.110	0.102
EE1	–0.329	**0.771**	–0.110	–0.066	0.012
EE2	–0.249	**0.712**	–0.082	–0.150	0.137
EE3	–0.259	**0.760**	–0.077	–0.097	–0.040
EE4	–0.282	**0.743**	–0.145	–0.024	–0.055
SI1	0.163	–0.001	0.134	0.214	**0.742**
SI2	0.126	–0.096	0.136	**0.786**	0.080
SI3	0.325	–0.066	0.250	0.485	0.290
SI4	–0.022	–0.066	0.167	**0.777**	0.014
FCFC1	0.160	–0.131	**0.814**	0.226	0.056
FCFC2	0.204	–0.063	**0.847**	0.068	0.125
FCFC3	0.034	–0.189	**0.584**	0.394	–0.076
FCC1	**0.719**	–0.243	0.156	–0.057	0.079
FCC2	**0.731**	–0.310	0.119	0.100	–0.077
FCC3	**0.771**	–0.280	0.100	0.087	–0.023
ATUT1	**0.646**	–0.068	0.129	0.195	–0.358
ATUT2	**0.600**	–0.265	0.106	0.187	–0.428
ATUT3	**–0.542**	0.436	0.005	0.022	0.003

identified further complexity with items from ‘results demonstrability’ and ‘ease of use’ also contributing to the factor. Additionally, a second factor was identified containing items from ‘voluntariness’, visibility’, and ‘results demonstrability’. It should be noted that this was a small sample for this analysis (principal components analysis, varimax rotation; $n = 58$) and ‘voluntariness’ is a different class of construct from the individual belief items.

In common with previous TAM research we used principal components analysis with varimax rotation. This is the closest to a default factor analysis option and maximizes interpretability in the results (Nunnally, 1978). The other analytical decision in factor analysis is how many factors to extract to best explain the data. There are three approaches to this question: Eigen values (a measure of variance explained by the factor) greater than one, review of the ‘scree plot’ (Cattell, 1966), and judgement of interpretability (Gorsuch, 1983) based on minimizing ambiguity in the pattern of item loadings and consideration of the nature of the constructs and items. The Eigen value greater than one criterion suggested a three-factor solution. Examination of the scree plot suggested four factors although the fourth and fifth factors explained nearly equivalent amounts of variance. In terms of the ambiguity of item loading, the three- and five-factor solutions had one item with maximum loadings < 0.5. The four-factor solution had two such item loadings and one item that

Table 5 Scale descriptive results and correlations

	Mean	SD	PE	EE	SI[a]	FCFC	FCC	ATUT[a]
PE	5.27	1.11	*0.91*[b]					
EE	2.75	1.06	–0.551**	*0.83*				
SI[a]	5.16	1.06	0.342**	–0.284**	*0.64*			
FCFC	5.16	1.07	0.352**	–0.348**	0.523**	*0.75*		
FCC	5.29	1.12	0.805**	–0.573**	0.305**	0.341**	*0.85*	
ATUT[a]	5.33	1.07	0.625**	–0.479**	0.280**	0.308**	0.599**	*0.68*

Notes: [a]Adjusted scale: see text of paper.

[b]Italicized figures on diagonal are reliability coefficient alpha.

**Correlation is significant at the 0.01 level.

*Correlation is significant at the 0.05 level.

loaded equally across two factors so was rejected on that basis. Out of the remaining options, the five-factor solution was chosen as the one ambiguous factor loading was higher (0.49 versus 0.42) and it explained more variance in the data. The rotated factor structure is shown in Table 4.

The data give a reasonably clear factor structure broadly in line with findings from previous research on these constructs and with these measures. The performance expectancy and effort expectancy items are distinct and facilitating conditions is a clear and separate factor. We have replicated that compatibility and performance expectancy items load on the same factor and found that the factor also includes attitude to using technology. We will return to this finding in the discussion. There are two issues with the structure of the social influence items. One issue is the item SI1 forms a factor on its own. It is possible that social influence from managers and social influence from colleagues are conceptually distinct but we are cautious about concluding this given the concerns over the complexity of the item. The other issue, in terms of a clear factor structure, is the low loading for SI3. Again, this is suggestive of a possible structural difference: SI3 was the 'line manager' item which also had a lower mean score than the senior manager items.

Scale reliability

The previous sections have already indicated some issues with the internal consistency and discriminant validity of the scales. We explored this further by examining the internal reliability of the intended scales. All scales had an internal consistency reliability analysis (coefficient alpha) sufficiently high for research scales (Kline, 1993). The two weakest scales in this respect were social influence (SI) and attitude (ATUT) with coefficients of 0.62 and 0.68 respectively. The problems with social influence item SI1 have already been discussed so it was dropped from the scale (slightly increasing alpha to 0.64). This scale has consequently lost some domain coverage and should be interpreted as a 'management social influence' scale in the following. Item ATUT3 seemed less clearly problematic in the factor structure results but was also removed as the reliability analysis showed that removing it significantly increased the reliability of the scale (from 0.68 to 0.76). Reliability coefficients are shown on the diagonal in Table 5 along with scale descriptive and relational statistics.

Mean scale scores are around 5.2 (recall that effort expectancy is reverse scored) and show an overall mildly favourable set of beliefs about the consequences of BIM use corresponding to 'Slightly agree' on the scale anchors. All of the measurement scales are significantly inter-correlated. Strong correlations (Cohen, 1988) are shown between the performance expectancy, compatibility, and attitude to using technology and we have discussed that there seems to be a structural relationship between these scales. Additionally, effort expectancy has strong relationships with performance expectancy and compatibility and perception of (management) social influence is strongly related to perceived facilitating conditions. The two weak relationships shown in Table 5 are between social influence and effort expectancy and attitude to using technology. In the next and final section we discuss these findings and propose some implications for practice and for further research in this area.

Discussion and conclusions

The current interest in BIM and the enthusiasm of its proponents has echoes in previous waves of CAD-related ICT innovation. Beatty and Gordon (1988) studied the introduction of computer-aided design/computer-aided manufacture (CAD/CAM) in the manufacturing, engineering and automotive industries of the 1980s. They documented the high expectations of those decision makers but also the many subsequent disappointments when CAD/CAM technology, bureaus and processes failed to meet them. As well as showing that CAD/CAM involved more than just technology, Beatty's research identified the factors that contributed to these failures including: 'structural' issues of organization and company arrangements; 'technical' problems of software and hardware; and 'human barriers', namely uncertainty avoidance, outright resistance and, more broadly, 'employees perceptions, skills, and biases' (Beatty and Gordon, 1988, p. 25). Recent research on ICT in construction has also recognized the importance of structural factors while retaining an explanatory role for individual beliefs, attitudes and expectations. In this paper we have explored this area through the measurement of individuals' high-level beliefs about the consequences of BIM use and shown that it is possible to measure these beliefs with acceptable levels of reliability. In this section we discuss the results and the limitations of the research. We also reflect on some intriguing findings about the structure of these beliefs that could have significant implications for BIM implementation and adoption at all levels of analysis and which imply a variety of avenues for further research.

Measurement scale properties, scores and relationships

Our findings confirm that it is possible to measure the individual beliefs validated by TAM when applied to a high-level BIM concept while maintaining good internal reliability. Overall, the measures functioned as predicted, showed good discrimination and consistency with previous research with other technologies.

The modestly favourable mean scale scores are encouraging for those seeking to implement BIM but, given the lack of comparable research, difficult to interpret for the construction context. Moore and Benbasat (1991) found similar mean scores of 5.6 for relative advantage and 5.4 for compatibility albeit in a sample in which 77% had used the technology under consideration in that study. Future research using the same scales for different construction organizations, technology, time or setting would allow comparisons to be drawn. In interpreting how positive the sample's beliefs about BIM were, we acknowledge that the administration and design of the questionnaire communicated to respondents that they should hold and express positive beliefs about BIM. Examples of this include the reference to BIM being part of company strategy in the invitation e-mail, possible meaning attached to the mere existence of the survey, as well as more general issues such as the positively framed statements in the measures that respondents had to 'disagree' with to express the contrary view (Krosnick, 1999). As only those respondents who knew at least a little about BIM completed the technology acceptance items, the beliefs scores elicited won't have been entirely reactive to the measurement instrument. Also, positive framing of the object of study is common in survey research to maximize respondent salience and hence response rate. However, the framing of the survey was not neutral and any future comparisons with other samples should consider this. We have included detailed descriptions of the measures and administration to assist with this. It is at least difficult to interpret these findings as evidence for widespread hostility, suggesting that those adopting BIM can anticipate reasonably favourable user beliefs.

As would have been predicted from the factor structure, there were strong correlations between performance expectancy, compatibility and attitude. This suggests that BIM is judged to be likely to improve job performance to the extent that it supports existing ways of working. The relationship with the attitude measure is a reminder that these items did not ask about using technology in the abstract but asked in the context of a way of working that has implications for performance that in turn may have implications for enjoyment. The one scale correlation that overlaps with Lowry's study of building management system acceptance is between performance expectancy and compatibility and is similar (0.81 compared to 0.74 in Lowry, 2002). The strong relationship between performance expectancy and effort expectancy is consistent with TAM research that found ease of use predicted perceived usefulness (Venkatesh and Davis, 2000). The strong correlation between social influence and facilitating conditions shows that expectations of practical support for adoption are related to perceptions of management and organizational commitment.

There was only a weak relationship between social influence and effort expectancy suggesting that individuals' expectation of the difficulty of BIM adoption is not strongly related to their perception of management support. The relationship between effort expectancy and facilitating conditions (which in turn was strongly related to social influence) is only moderate. TAM research has shown that effort expectancy is less important than performance expectancy in predicting subsequent use. However, we believe that effort expectancy remains an important issue for BIM use in construction. In developing the survey we observed that BIM managers in the organization believed that the key issue for adoption was perceived difficulty and cost of BIM use, rather than any lack of agreement about the likely benefits of BIM. The other weak relationship identified was between social influence and attitude to using technology. This result is not is surprising although it should be recalled that the social influence scale measures management interest rather than co-worker interest. Given that job satisfaction in general is related to social interaction at work it might be that a social influence scale that incorporated attitudes of co-workers would have a stronger relationship with attitude to using technology.

Structure of beliefs about BIM: performance expectancy, compatibility and social influence

Two structural features merit further discussion as they signal potential issues for practice and future research. The first of these is the loading of 'compatibility' items in the same factor as 'performance expectancy' and the strong correlation between these scales. These results show that BIM is viewed as likely to improve job performance if it is compatible with existing ways of working; this has implications for BIM implementation, job design and communicating the transformative role ascribed to BIM. TAM predicts that employees will make adoption decisions based on their hard-won understanding of what constitutes performance in their current role and whether BIM will improve it or make it worse. There is other evidence in construction that compatibility with existing methods is a prerequisite to adoption. Hartmann *et al.* (2012) conducted two action research case studies of introduction of BIM tools to support risk management using '4D' models and automate quantity take-offs using BIM data. They found that users 'only perceived that application of BIM based tools [was] useful after close alignment between the tool and the existing work processes was established' (p. 611). They argue that organizations and individuals should not have to change their work processes to benefit from BIM particularly where these are established, consistent project management best practice. However, BIM is expected to change, and even includes, new 'best practice'. Further research could usefully explore interrelationships between technical and process components, particularly where both technical and social changes are proposed simultaneously. Measurement-based approaches could be complemented by idiographic research to explore the structure of individuals' mental representation of BIM.

Compatibility also seems to be important for perceptions of ease of use. The strongest relationship with effort expectancy in our research was also with compatibility suggesting that this is an important concept. In the research that validated the scales adapted in our research Moore and Benbasat (1991) also found performance expectancy (relative advantage) and compatibility loaded on the same factor. However, throughout the four-stage item sort with expert judges that they used to develop their scales, relative advantage and compatibility had been judged consistently distinct throughout the process. More recent research (Karahanna *et al*., 2006) has suggested that compatibility is multidimensional including compatibility with (1) existing work practices; (2) preferred work style; (3) prior experience with technology; and (4) values. Venkatesh *et al*. (2003) characterized the compatibility measure we used as measuring 'the fit between the individual's work style and the use of the system in the organization' (p. 453) and classified it as an aspect of facilitating conditions.

What these findings do is sensitize BIM advocates to the need to strike a balance between claims that BIM will improve current work performance (a claim based on compatibility) and that it will transform future work (a claim based on incompatibility). It seems to us that this aspect of employee perceptions is particularly important given the role frequently ascribed to BIM in 'transforming' the construction industry and construction work (Rezgui *et al*., 2009; Crotty, 2011). If the implementation problem to be solved is one of user adoption and acceptance then these findings suggest that change managers should emphasize continuity. An implicit strategy to change behaviours (or even the industry) through the introduction and expansion of BIM may raise adoption challenges as the transformation message also conveys the information that BIM is incompatible with existing ways of working. The persuasion challenge then becomes one of convincing potential users that the work transformation will take place and be sustained. Recognizing this issue, Jacobsson and Linderoth (2010), following their case study of ICT implementation and use, recommend implementing individual components of BIM that may have more immediate benefits and fewer barriers to adoption. Further research could usefully measure technology acceptance for such components to test the hypothesis that they might score higher on acceptance than the high-level BIM concept that is the focus of our research.

There were also some interesting findings with respect to the social influence factor although our ability to explore this thoroughly was limited by the possible error variance in item SI1. Of interest here are both the low loading for SI3, the 'line manager' item on the social influence factor and the lower mean score than the two senior manager items. The factor loadings suggest the possibility that social influence could be multidimensional with senior managers, line managers, and co-workers being viewed differently and having different relationships with other beliefs and expectations. There is some evidence for this in the pattern of relationships between individual items in Table 2. The correlations between the performance expectancy items and social influence items appear to vary with 'closeness' to the individual as follows: 'organization' (0.09 to 0.16); 'senior managers in own unit' (0.17 to 0.23); 'line manager' (0.32 to .036). A similar if weaker pattern can be seen for effort expectancy.

Speculatively these measures might be picking up on the autonomous nature of many of the divisions that make up the overall organization or the project-centre distinction common to construction contracting organizations (Gann and Salter, 2000). Alternatively this could be a version of the distinction between senior and 'middle' managers with respect to innovation and change processes identified by the organizational change literature (e.g. Huy, 2001). It is notable in this respect that expectation of support from line (middle) managers was lower than for senior managers and the organization in general. Further investigation of the effects of 'level' of social influence would require further research with validated scales for each level. This post-hoc analysis is implicitly treating the social influence items as single-item scales without having established their validity or suitability for comparison. Developing relevant scales and testing for the effect of closeness in different organizational arrangements would give a better idea of the role of social influence. Such research could also be extended to other relevant social reference such as professional institutions, the construction project team or, in matrix organizations, the functional organizational structure.

Our research has demonstrated that it is possible to reliably measure some salient, high-level individual beliefs about the consequences of BIM use for research purposes although the possibility of social influence being multidimensional suggests further development would be useful. Application of these measures in a survey of construction employees has shown that beliefs about the consequences of BIM use are broadly favourable and have provided comparable benchmarks for research with other samples and technology definitions. Our exploration of structure and relationships between scales suggests an important role for compatibility in beliefs about performance expectancy and effort expectancy. We would recommend balancing messages about the transformative nature of BIM with reassurance about compatibility, relevance and continuity for individual-level acceptance.

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