Construction Management and Economics (March 2007) **25**, 289–296

Interorganizational use of building information models: potential for automational, informational and transformational effects

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Received 9 December 2005; accepted 4 July 2006

Numerous potential barriers to the interorganizational use of building information models (BIMs) have been reported. These potential barriers are technological and organizational. Further, potential barriers are specific to building information models and general to the diffusion of innovation. In spite of potential barriers, there is interorganizational use of BIMs in Finland. The research was carried out in Finland, and investigated organizations' existing and planned interorganizational use of BIMs. The research revealed the potential for interorganizational use of BIMs to enable three types of effects. These are automational effects, informational effects and transformational effects. The generalizability of findings is restricted by at least three factors. First, the research involved only 20 organizations. Second, the research was carried out in one country. Third, the research participants had previously developed skills which can contribute to the interorganizational use of BIMs. Notwithstanding these limitations, consideration of findings suggests that there are few, if any, fundamental barriers to the achievement of automational, informational and/or transformational effects.

Keywords: Information technology, interfirm collaboration, building information model

Introduction

A number of software companies are offering proprietary software products that enable the creation of computer-interpretable information models for different aspects of a building. For example, models of buildings' architectural designs; models of buildings' structural designs; models of buildings' heating, ventilation, air-conditioning and electrical designs (HVACE), etc. Computer-interpretable information models have a variety of names within architecture, engineering, construction and facilities management (AECFM). In this paper, the term BIM (building information model) is used (Goldberg, 2004). This is because BIM was the term that was used most by the research participants.

BIM software products used by the research participants support data exchange using the Industry Foundation Classes (IFC) of the International Alliance for Interoperability (IAI). The intent of the IAI is to provide means of passing a complete and accurate BIM from the computer application used by one participant to computer applications used by other participants—with no loss of information. To some extent, the IAI has drawn upon the Standard for the Exchange of Product Model Data (STEP) of the International Standards Organization (IAI, 2006).

The research reported here involved representatives from 20 organizations. These organizations include three building owners, seven building design consultants, two building component producers, five building contractors and three companies offering software. The objective of the research was to determine organizations' existing use and planned use of BIMs. The research was exploratory. The research involved field study and literature review. Field study included unstructured interviews, demonstrations of BIMs and two workshops. Interviews involved the consideration of five questions: what is your use of BIMs now; what will be your use of BIMs two years from now; what will be your use of BIMs beyond two years from now; what

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Construction Management and Economics
ISSN 0144-6193 print/ISSN 1466-433X online © 2007 Taylor & Francis
http://www.tandf.co.uk/journals
DOI: 10.1080/01446190600892995

technological challenges do you face; what organizational challenges do you face. Participants' existing use was verified through demonstrations and reference to reports in Finnish industry magazines. The response to requests for interviews was 100%. Over half of the companies have operations in more than one country. All of the research was carried out in Finland. The use of BIMs is advanced in Finland (Fischer and Kam, 2002; Heesom and Mahdjoubi, 2004). The research was carried between October 2003 and May 2006. By the end of that period, the participant organizations had made commercial use of over 500 BIMs (combined total) and the use of BIMs had become part of companies' operations (Hallikainen, 2006). In particular, the opportunity to ask and answer many more interrelated 'what if' questions about building design, construction and operation is regarded as an important benefit from BIMs by research participants. Examples are provided in subsequent sections of this paper.

Existing literature, which is discussed in subsequent sections of this paper, provides insights about individual aspects of BIMs such as needs for data exchange standards (e.g. Construction Specifications Institute (CSI), 2005) and the future potential of BIMs (e.g. CSINet, 2005). However, existing literature provides little, if any, information about the scope of BIM use and effects from BIM use across a broad range of companies. By contrast, the research reported in this paper investigated BIM use across a broad range of AECFM companies during building design, construction and operation. The research provided insights into scope of BIM use, barriers to BIM use and effects from BIM use.

Scope of BIM use

Literature review findings

In the literature, reports are provided about the very focused use of BIMs during individual building projects and/or the use of BIMs during particular types of building project. For example, the use of BIMs in determining the optimal drying process for concrete slabs (Jongeling *et al.*, 2005). Also, there is much debate about future directions for BIMs. For example, research scientists from three institutions, with support from industry experts, have argued that interorganizational use of BIMs based on file exchange will be superseded by interorganizational use based on the use of servers (Kiviniemi *et al.*, 2005a). However, there are few, if any, reports about the scope of BIM use across a broad range of AECFM companies during building design, construction and operation.

Field study findings

Field study revealed four types of BIM use among the research participants. These four types of BIM use are summarized in Figure 1. It is important to note that differences described in Figure 1 are differences of use. These different BIM uses can involve the different use of the same BIM software products.

A BIM can be used within one organization only. Alternatively, a BIM can be shared by a number of organizations. Further, a BIM may encompass only one domain. Alternatively, a BIM may encompass a number of domains (nD). Figure 1 provides a summary of different types of BIM use. The ordering of BIM uses in a relational manner shown in Figure 1 was found to be helpful by the companies involved in the research. In particular, the companies considered that it addressed a need for clarification of different organizations' BIM capabilities. For example, the interorganizational use of nD BIMs can require much more advanced BIM knowledge than the use of a single domain BIM within a single organization.

During the period of the research, the interorganizational use of BIMs involved the exchange and sharing of computer files between different organizations. In the future, the interorganizational use of BIMs may not involve the exchange of computer files. Rather, there may be shared BIM repositories with concurrent access. An example of an interorganizational use BIM is a BIM that is created by a building architect and that is also used by a building client's facilities manager, by a building cost management consultant, by a building services consultant, and by a principal contractor. Among the research participants, building architects made interorganizational use of BIMs which they had created to improve their own design processes, for example by reducing the time required to record design

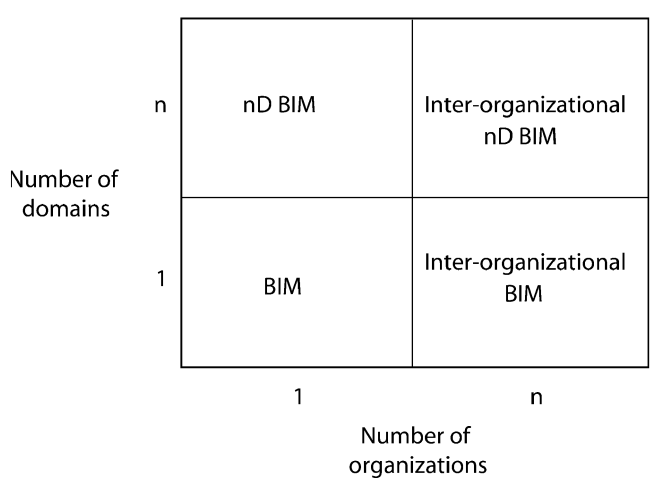

Figure 1 Scope of BIM uses

revisions across all relevant views of its design information. Time reductions are possible because all plan views, elevation views and detail views are generated from the BIM. Accordingly, only the BIM has to be revised rather than numerous different drawings. Also, a building client's facilities manager used BIM analysis software to extract building floor area data from the same BIM and calculate possible rental incomes. A building cost management consultant used BIM analysis software to extract building construction quantities data from the same BIM and calculate possible construction costs. A building services design consultant used different BIM analysis software to extract thermal properties data from the same BIM and calculate possible heat losses. A principal contractor used other BIM analysis software to calculate possible construction durations and generate construction schedules. Thus, the same BIM is used by several different organizations for their own specific purposes. The BIM created by a building architect is even more useful if it can be combined with BIMs created by a building structural designer and by an HVACE designer, in particular, combined for the purpose of checking for possible collisions between say, partition walls, structural columns, ducts and cables.

Any BIM that supports analyses from the perspectives of a number of different domains, such as space management, cost management, construction management, etc., can be described as a nD BIM (Aouad *et al.*, 2005). However, a nD BIM is not necessarily a BIM which is suitable for interorganizational use. For example, among the research participants, a principal contractor undertaking design and build projects created building architectural design BIMs and used different BIM analyses software packages to extract and manipulate data relating to spaces, quantities, schedules, etc. Such BIM is a nD BIM but not an interorganizational use BIM. Conversely, among the research participants a building architectural design BIM created by one architectural firm during the concept design stage was passed on to another architectural firm for detailed design work. As shown in Figure 2, such a BIM is an interorganizational use BIM but not a nD BIM. The particular focus of this research was interorganizational use of BIMs: whether they be nD or not.

The creation of BIMs for interorganizational use, whether they be nD BIMs or not, is particularly challenging because different organizations use different BIM software packages to create BIMs, and use different software packages to analyse BIMs. Also, different organizations have different modelling practices. Information about such challenges is provided in the next section of this paper.

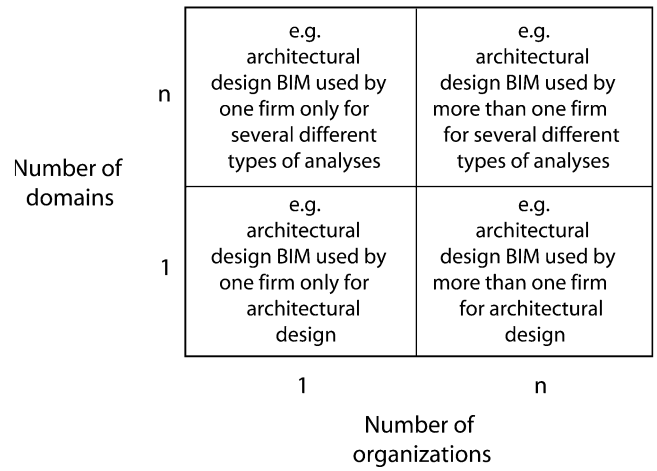

Figure 2 Examples of BIM uses

Barriers to BIM use

Literature review findings

An extensive review of empirical evidence concerning information technology and economic performance has highlighted the extent of management challenges in the achievement of financial returns (Dedrick *et al.*, 2003). With regard to the interorganizational use of BIMs, even the most positive of companies in Finland acknowledge that considerable management challenges are involved (Anteroinen, 2005a). Research carried out in several other countries also suggests that considerable management effort is required (Gao *et al.*, 2005).

Challenges which could be perceived to be barriers to the interorganizational use of BIMs have been defined by a number of authors. For example, a survey of building architects revealed numerous problems with architectural BIM software including inadequate objects and object customization capability (Tse *et al.*, 2005). Others involved in a variety of international projects draw attention to the short-comings of IFCs (Gudnason *et al.*, 2005; Kiviniemi *et al.*, 2005b). Following extensive research, Haymaker (2005) has argued that better methods are needed for the managing of dependencies between different organizations' BIMs. Cook (2004) suggests that a lack of highly skilled cross-trained staff with both construction and IT skills could hinder the realization of benefits. In the opinion of industry experts, Karstila and Hemiö (2006), the archiving of information can be complicated by the use of interorganizational BIMs. Both Bazjanac (2004) and Lee *et al.* (2004) have identified multiple design perspectives as a major challenge. For example, architects tend to define buildings (and originally populate BIMs) as systems of spaces, while HVAC engineers often see buildings as systems of thermal zones each of which may contain several architecturally defined spaces. As a result, the creation of a BIM that is fit for the purposes of several different types of analyses requires thought and execution which transcends deeply rooted differences between professions.

In addition to these quite BIM-specific barriers, it has been argued more generally that differences between parties can impede the diffusion of innovation (Van de Ven, 1986) This proposition has been found to be relevant within AECFM (Larsen and Ballal, 2005). For example, Rogers and Bhowmik (1971) have argued that communication between dissimilar individuals may cause cognitive dissonance because an individual is exposed to messages that are inconsistent with existing beliefs, resulting in an uncomfortable psychological state. This tendency has been described as heterophily and has been contrasted with homophily which is the tendency to like people similar to oneself (Lazarsfeld and Merton, 1964). In the innovation literature, it has been argued that individuals avoid messages that are in conflict with their own existing opinions, and that heterophily is a problem in the diffusion of innovation (Rogers, 1995).

Field study findings

Participants were not deterred by reports of challenges. Indeed, the increasing interorganizational use of BIMs by companies both large and small was being reported by the end of the research period (Anteroinen, 2005b; Uuskoski, 2005). Participants took practical actions to overcome possible barriers to use. For example, a number of participants mentioned inconsistency among creative thought processes which had led to inconsistencies in the ways in which BIMs were created. Companies took action to overcome such inconsistencies by establishing interorganizational guidelines for the creation of BIMs. In doing so, these participants overcame a challenge identified by Bazjanac (2004) and by Lee *et al.* (2004). Further, participants made efforts to define the required content of data exchanges between different parties at different phases of the building life cycle.

The companies' attitude to barriers was summed up by one participant who stated that, 'we can do business with this technology today'. Companies had come to such conclusions by carrying out pre-studies and trial projects. Reports such as *Science, Technology, and Industry Outlook* rank Finland high in terms gross domestic expenditure on research and development (Organization for Economic Co-operation and Development (OECD), 2004a). Further, reports such as *Information Technology Outlook* (OECD, 2004b) show commercial use of information and communications technology (ICT) to be well advanced in Finland. Accordingly, the participating organizations had considerable experience of evaluating emerging ICTs. Their opinions that they could overcome challenges and do interorganizational business with BIMs was borne out by their success in meeting ambitious targets for use. For example, one principal contractor set out to achieve interorganizational use of BIMs on 60% of residential projects by the end of the year 2005. This target was met and a new higher target set for the next year.

Further, field study revealed no cases of the diffusion of BIMs being impeded by differences among the research participants. Differences included participant organizations' different: stages of development; scope of activities; sources of competitive advantage; and strategic plans. The differences between participants were not restricted to impersonal corporate statements. Indeed, individuals had markedly different personal opinions about the interorganizational use of BIMs. For example, some individuals had the opinion that the interorganizational use of BIMs was just a continuation of many years of ICT introductions that had done little if anything to improve an AECFM industry which did not need much improvement anyway. By contrast, some individuals had the opinion that the interorganizational use of BIMs could bring about fundamental improvement to an AECFM industry that needed fundamental improvement. The differences between the participants are summarized in Table 1.

Yet, although there are notable differences between the research participants, the interorganizational use of BIMs increased throughout the research period. This increase is apparent through the setting and meeting of ambitious targets for use by the research participants. For example, one building architect has progressed from the use of interorganizational BIMs during the minority of its residential projects to the use of interorganizational BIMs during the majority of its residential projects. Further, the same architect has begun to use interorganizational BIMs on some of its commercial projects. Moreover, at the beginning of the

Table 1 Sources of differences

Source	Example
Organization's stage of development	Consolidation
Organization's scope of activities	Whole building life cycle
Organization's strategic plans	Diversification
Organization's source of advantage	Incorporation of production
Individual's personal opinions	Fundamental change needed

research period, Finland was one of the world leaders in the use of interorganizational BIMs (Fischer and Kam, 2002). There is little, if any, evidence to suggest that Finland has lost its relative position during the research period. One possible explanation for the diffusion of BIMs not being impeded by differences between the organizations could be that the organizations had complementary use priorities for BIMs. For example, if every organization was preoccupied with a grand vision of BIMs changing the AECFM industry, no organizations might have been focused on the details of making data exchanges work in practice.

Effects from BIM use

Literature review findings

Mooney *et al.* (1996) provide a framework for defining business value from information technology which includes three categories. Those categories are automational effects, informational effects and transformational effects. Automational effects refer to the efficiency perspective of value deriving from ICTs being substituted for labour. Within this dimension, value can derive from impacts such as productivity improvements, labour savings and cost reductions. Informational effects emerge primarily from ICT's capacity to collect, store, process and disseminate information. Following these effects, value can accrue from improved decision quality, employee empowerment, decreased use of resources, enhanced organizational effectiveness and better quality. Transformational effects refer to the value deriving from ICT's ability to facilitate and support process innovation and transformation. The business value associated with these effects can be manifested as improved responsiveness, and service and product enhancement as a result of re-engineered processes and redesigned organizational structures.

Mooney *et al.*'s (1996) framework draws upon previous work by others (Davenport, 1993; Venkatraman, 1994; Zuboff, 1988). For example, Zuboff (1988) argued that IT automation often reduces the amount of routine work that must be done by human beings, thus, potentially providing more opportunities for individuals to use their wider cognitive capacities. Zuboff (1988) further argued that when IT is used to 'informate' a deeper level of transparency is provided to activities and events by generating information about the underlying productive and administrative processes through which an organization accomplishes its work. Mooney *et al.* did not make claims for significant net benefits from the introduction of ICT. Rather, they provided a synthesis of the extant literature on IT business value and IT-supported organization and process design. Automational, informational and transformational effects are widely recognized (Heikkilä and Heikkilä, 2003). For example, Ahearne and Schillewaert (2001) draw attention to automational effects in relation to salesperson performance. Vicente and Suire (2004) highlight the role of informational effects in the formation of clusters. When describing the impact of IT on marketing, Brady *et al.* (1999) highlight the importance of transformational effects. More recently, Ross and Beath (2002) have described transformational effects at an airline company.

In AECFM, Mooney *et al.*'s framework has been applied to high-density bar coding in maintenance management (Marsh and Flanagan, 2000). In that case, automational effects included automatic generation of completion documentation. The organizational restructuring involving the removal of existing devolved maintenance management arrangements was identified as a potential transformational effect. Also in AECFM, Money *et al.*'s framework has been incorporated into an information technology planning framework for large-scale projects (Pena-Mora and Tanaka, 2002).

Field study findings

During the period of the research, the participating organizations were at what Larsen (2005) describes as the use stage of innovation diffusion. Following research in AECFM, Larsen emphasizes the early elements of the innovation diffusion process before the use stage and describes these as: awareness, interest, opinion forming and decision making. In the following three sections, the automational, informational and transformational use priorities of research participants are reported. Their use priorities are the interorganizational uses of BIMs which they considered to be most important for their businesses' future success.

The achievement of automational effects was a priority for seven of the 20 organizations participating in the research. For example, building architects create building architectural design BIMs and 'export' them to the principal contractors. Proprietary analysis software is then used by principal contractors to 'extract' building quantities from the interorganizational BIMs that they 'import' from the building architects. This automational effect eliminates the work of one person 'taking-off' quantities using hand held measuring devices. Prior to 'exporting' BIMs, building architects check that the BIMs are fit for the intended use by the principal contractor. This checking is carried out using proprietary BIM checking software. Automational effects are also being achieved when building structure design consultants exchange and share BIMs with producers of structural steel components. The work of one person converting design details into production details is eliminated when the structural steel producers use proprietary software to 'extract' production details from a BIM. Some of the participants perceived automational effects to be an inevitable change that they must keep up with in order to keep up with competitor companies. Whether this view of the future proves to be correct, or not correct, remains to be seen. For example, it has been argued that the adoption of Manufacturing Resources Planning (MRPII) systems led to companies becoming less competitive compared to their Japanese competitors (Maskell, 1993). However, this view is so strongly held by the participants that it is driving them to invest in interorganizational use of BIMs, for example, in the purchase of hardware, software and training. Thus, this view may turn out to be a self-fulfilling prophesy—at least for the research participants.

Informational effects include better decision making through the more effective collection, storage, processing and dissemination of information. The achievement of informational effects was a priority for six of the 20 organizations participating in the research. For example, a building owner, a building architect, a building HVACE designer, a building cost consultant and a principal contractor had exchanged and shared interorganizational BIMs. For one building project, the building architect had created a BIM which is fit for the purposes of extracting quantities, quantifying construction costs and quantifying energy consumption. This BIM has been exchanged and shared with the other parties. They have exploited this interorganizational use of a BIM by analysing it with proprietary software programs. The various analyses revealed that the original building architectural design had a number of limitations. Subsequently the original building architectural design was modified. The revised design retained the original aesthetic intent but the volume-to-surface ratio was changed. In the opinion of the parties involved, the design limitations would not have been revealed without interorganizational BIM use—until those design limitations had become costly realities.

It would have been technically feasible to carry out the analyses without interorganizational BIM use. However, in the opinions of the parties involved, exchanging and sharing a BIM better enables comparative analyses of factors such as construction cost and energy consumption. Moreover, in their opinion, the creation of BIMs for interorganizational use will enable rapid reiterations of multiple building design analyses. This, in turn, will lead to better building designs, the term 'better' meaning a design based on decisions informed by a wider range of more refined information about building construction and building operation. As the parties involved have considerable experience of creating and exploiting BIMs, their opinions do merit consideration. Further, the parties involved are continuing with their efforts to create, exchange and share BIMs. A review of the literature suggests that informational effects lead to changes within roles. In this case, for example, the building architectural design was still carried out by building architects. By contrast, transformational effects can lead to changes among different parties' roles and create new roles (Haines, 1999; Mutch, 1998).

The achievement of transformational effects was a priority for seven of the 20 organizations participating in the research. For example, one building component producer plans to provide property developers with BIMs for interorganizational use. As a result, the roles of the building architect and the property developer would change significantly. During the design of certain types of buildings, such as distribution centres, the property developer could carry out the building architectural design.

One principal contractor plans to set up a far more interactive building development process that will be enabled by the interorganizational use of BIMs. The principal contractor envisages a process in which a range of customer types will be able to collaborate in activities ranging from building site selection to building detail design. Two building owners envisage a procedure whereby parties contributing to building design and building construction would input the necessary information into an 'as-built' BIM that would be used by the building owner's facilities management personnel, such as janitors and cleaners, using highly interactive interfaces. Whether such views of the future prove to be technically feasible and economically viable remains to be seen. However, the research participants are determined to make them feasible and viable, for example, through continuing investments in the technology.

Moreover, participant organizations are already making interorganizational use of BIMs to facilitate the achievement of transformational effects. One building design consultant, for example, has developed BIM user-interfaces that enable building owners to take a far more active role throughout building design. This BIM 'viewer' provides graphic presentations of information, which for the purposes of analyses, could be limited to numeric formats. Also, the building design consultant has developed BIM-enabled services for the presentation of aggregated information from property portfolios. This service enables the directors of companies which own property portfolios to view graphic presentation of information which previously was confined to numeric formats used by technical personnel. Whatever transformation effects do take place, it is important to recognize that the participants' plans are driven by their own and their colleagues' innovative thinking.

Conclusions

Numerous potential barriers to the interorganizational use of building information models (BIMs) have been reported. These potential barriers are technological and organizational. Further, potential barriers are specific to building information models and general to the diffusion of innovation. The research findings indicate that, although there are potential barriers, interorganizational use of BIMs is already established among some of Finland's AECFM organizations. Moreover, the research findings suggest that interorganizational use of BIMs can lead to the achievement of different effects, in particular, automational effects, informational effects and/or transformational effects.

The generalizability of these findings is restricted by at least three limitations. First, the research involved only 20 organizations. Second, all of the research was carried out in one country. Third, the research participants had previously participated in a number of research and development projects during which they had developed skills which can contribute to the interorganizational use of BIMs. Notwithstanding these limitations, consideration of the findings suggests that there are few, if any, fundamental barriers to the achievement of automational, informational and transformational effects from the interorganizational use of BIMs.

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