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Barriers and facilitators for BIM use among Swedish medium-sized contractors - "We wait until someone tells us to use it"

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Abstract

Background: The pace of diffusion of BIM (Building Information Modelling) use is considered to increase with governmental initiatives in which public clients in countries like Finland, Singapore, United Kingdom, and Sweden begin requiring BIM as a part of the project delivery. Currently, larger contractor firms use BIM to a certain extent. However, BIM use by mid-sized contractor firms (that is, firms with 50–500 employees that can successfully compete with larger contractors on projects costing a maximum of 50 million Euros) is relatively unknown. Hence, the aim of the paper is to explore current use and perceived constraints and driving forces of BIM-implementation with respect to mid-sized contractors.

Methods: A mixed method approach was applied, and data was collected through an interview study and a survey involving chief executive officers or their closest sub-ordinates in mid-sized contractor firms in Sweden. The survey was based on a technology-, organization-, and environment framework that is used in information systems research to study the use of inter-organizational information systems. The total population of firms in the survey corresponded to 104. The study presented the preliminary results based on 32 answers (with a 31% response rate).

Results: Fifty-eight percent of the surveyed respondents stated that they had been involved in a project in which BIM was used in some manner. The most commonly used application included visualization, which also facilitates coordination and communication. The biggest perceived constraints involved partners that did not use BIM, lack of demand from clients, and the absence of internal demand in the company. With respect to the two last obstacles, significant differences existed between users and non-users. The most common perceived driving forces included the fact that BIM is perceived as a means to follow technical development and that BIM provides competitive advantages to the company.

Conclusions: It is concluded that the main driver responsible for BIM-implementation is mainly determined by an individual's subjective positive or negative evaluation of BIM, instead of external pressure from clients and partners or by the internal capacity and knowledge to use BIM.

Keywords: BIM, Adoption, Use, Implementation, Medium-sized contractors, Sweden

Background

BIM has been launched as one of the most promising developments in the building and construction industry (Eastman et al. 2011) and is even considered as a new paradigm (see Azhar et al., 2011). Additionally, Lee and Yu (2016) claim that several researchers and practitioners seem to agree on BIM's potential applicability in and benefits for construction. The confidence in BIM as a means to increase industrial efficiency is further expressed by governmental initiatives in countries including Great Britain, Singapore, Finland, and Sweden, where public clients have started to require BIM as part of project delivery. This development is supposed to increase the pace of diffusion of BIM use. However, critics of this indicated that: *"There is seemingly no end to the academic hyperbole surrounding the potential of BIM to 'revolutionize' construction practice, through 'intelligence,' 'efficiency' and 'Integrated Project Delivery"* (Dainty et al., 2015). Thus, there is a gap between optimistic predictions on the positive effects of BIM in the industry and

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the actual implementation and use of BIM wherein several challenges are identified. Becerik-Gerber and Rice (2010) suggested that it is difficult to evaluate the benefits of BIM use with quantitative measures because the claimed benefits are often intangible. Fox (2014) questioned the positive effects of BIM use and proposed that expectations of BIM benefits could be excessively optimistic. Additionally, Vass and Gustavsson (2015) indicated that BIM professionals do not perceive any business value from BIM currently, although it holds future promise. Finally, Demian and Waters (2014), Hartman et al. (2012), and Linderoth (2010) argued that the temporary nature of construction projects create challenges when BIM use diffuses to consecutive projects.

Thus, previous research focused on identifying the benefits of BIM use and also identified constraints and questions as to whether the claimed benefits were achieved. However, in order to enable BIM to have a transformative effect on the industry, it is necessary for the use of BIM to diffuse in an encompassing and integrated use among actors in the construction process. The scope of BIM use and its application is not studied to any lager extent. Scattered success stories from single projects and a diffused discourse suggest that technical consultants and larger contractors use BIM. However, previous studies did not examine BIM use among medium-sized contractors with 50–500 employees. It is interesting to study this group because these firms can successfully compete with larger contractors in projects up to 50 million Euros although they lack resources for in-house research and development when compared with larger contractors. It is important to examine the manner in which competitive capabilities of medium-sized companies change in a case where it becomes mandatory to deliver a BIM-model as a part of the contract. Thus, the issue pertains to the extent of BIM use in the companies, the purposes for which BIM is used, and the perceived facilitators and constraints. Hence, the aim of the paper is to explore current use and perceived constraints and driving forces of BIM-implementation with respect to mid-sized contractors. A mixed method approach was used. First, interviews with mangers in medium size contractors were conducted, and this was followed by a survey that was administered to Swedish contractors with 50–500 employees.

Understanding adoption and use of BIM

In order to identify the perceived driving forces and constraints for BIM-use, the point of departure is taken from previous studies on the implementation and use of information and communication technologies (ICT), because BIM is at the bottom line an ICT. Therefore, insights from Information Systems research on the implementation and use of ICT is required to acquire in depth knowledge on the adoption and use of BIM (see also Merschbrock and Munkvold 2012).

It is necessary to identify generic categories for BIM use, to identify the purposes for which BIM is used. Cases in which BIM is used can be categorized from different perspectives and include practical applications and more generic applications. A traditional classification of use involves 3D, 4D, 5D, and nD, where 3D represents classical visualization, 4D includes the time plan, and 5D represents the costs. It can be argued that the nD-definition is an empirical based classification of the type of data that can be retrieved and it in turn results in different applications. For example, a plan for purchases and payments of materials can be generated by using information from the time plan (4D) and cost of material (5D). Furthermore, studies of BIM-use often involve the application level in which clash control is a classic example along with other applications such as environmental classification of buildings (see Wong and Kuan 2014). Different individuals are interested in distinct applications (data) if practical applications or the kind of information that is retrieved from the model is discussed. For example, using the model for maintenance of facilities is a crucial concern for a facility manager, while clash controls are of crucial interest for contractors, and visualization is important for architects and clients. Furthermore. BIM use can be classified on a more conceptual level based on its capabilities (Carlo et al. 2012). Thus, BIM can be used for 3D visualization, analysis and simulation, co-ordination and communication, and data extraction and transfer. These capabilities are in turn built up by two underlying capabilities, namely object based information and xyz co-ordination that helps in accurately triangulating the geometric position of each object in the design space. However, these generic capabilities may not make sense for practitioners, and therefore the capabilities need to be translated into different use cases or activities that BIM can be used for.

In order to measure the extent of BIM-use, Cao et al. (2014) identified 13 applications for BIM in the design and construction stage (Table 1) that can be used as a point of departure when investigating the purposes for which BIM is used.

The next issue involves the manner in which perceived facilitators and constraints for adoption and use of BIM with respect to medium-sized contractors are understood. When the adoption of ICT has been studied, a wide range of theoretical frameworks has been applied to explain adoption and use of ICT. Some of these frameworks include the technology acceptance model, institutional theory, and social identity (see e.g., Gal et al. 2008).

In order to understand the reason as to whether or not technology is used, a few research streams can be identified in quantitative research and two prominent research streams include perceived usefulness and user

Table 1 BIM-application areas in design and construction stages (see Cao et al. 2014)

Stage	Application
Design stage	Site analysis
	Analysing design options
	Three-dimensional presentation
	Design coordination
	Cost estimating
	Energy simulation
	Other performance simulations
Construction stage	Clash detection
	Construction system design
	Schedule simulation
	Quantity take off
	Site resource management
	Offsite fabrication

satisfaction. The research stream on perceived usefulness includes the Technology Acceptance Model (TAM) (see Davis 1989) that is widely used. The origins of TAM can be found in the theory of reasoned action (TRA) (Ajzen and Fishbein 1980) and later in 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/her perception of the subjective norms promoting the behaviour. A subjective norm is 'a person's perception that most people who are important to her/him think s/he should, or should not perform the behaviour in question' (Fishbein and Ajzen 1975, p. 302). However, TAM focuses on the intentions of the individual actor to understand the impacts of ICT. However, impacts on the individual level were considered as antecedents for organizational impacts in the extant studies based on TAM (e.g., Fishbein and Ajzen 1975).

In the user satisfaction stream, object-based perceptions with respect to the ICT have been investigated. In contrast, TAM investigates behavioural perceptions about using ICT (Wixom and Todd 2005). In a comprehensive literature review of the DeLone and McLean construct for IS success, Petter et al. (2008) stated that the empirical results indicated a strong association between user satisfaction and net benefits (perceived impacts). User satisfaction has been found to have a positive influence on the net benefits (perceived impacts) expressed such as performance effectiveness (Rai et al. 2002); decision-making (Vlahos and Ferratt 1995; Vlahos et al. 2004); and job satisfaction (Ang and Soh 1997; Morris et al. 2002). In the user satisfaction literature, information- and system quality are major antecedents to user satisfaction and exhibit a strong relation with user satisfaction (see Iivari 2005). Information quality is described as a desirable characteristic of the ICT system output that incorporates various factors such as relevance, accuracy, comprehensibility, and usability (Petter et al. 2008).

The two research streams of perceived usefulness and user satisfaction focus on the single user and his/her perceptions of the system and the manner in which it affects a job. Additionally, an implicit assumption is that the perceived positive effects of the job lead to net benefits for the organization. It is important to understand these dimensions in the use of BIM (see Davies and Harty 2013). However, BIM can be considered as an inter-organizational system (IOS), or inter-organizational information system (IOIS), which involves a system that is used for information exchange between members of two or more organizations. Thus, it is necessary to consider the factors outside the immediate perceptions of the system and the manner in which it affects the job. In the research on the adoption of inter-organizational systems, three factors that shaped the adoption of IOS has been identified, namely nature of technology, or perceived benefits, capability of an organization, and external environment (e.g., Grover 1993; Iacovou et al. 1995; Mishra et al. 2007; Zhu et al. 2003). This framework has also been labelled as the technology, organization, and environment framework (see Henderson et al. 2012).

The technology factor captured the dimensions studied with respect to the perceived usefulness and user satisfaction and is based on Rogers (1983) theory of diffusion of innovations. The theory involves a cost/benefit view of adoption and argues that potential adopters form rational decisions to adopt an innovation based on beliefs about certain characteristics formed by them with respect to the innovation. In a meta-analysis of the theory, Tornatzky and Klein (1982) found that relative advantage, compatibility, and complexity were consistently indicated as significant to explain technology adoption. Relative advantage refers to the expected advantages or perceived benefits that can be provided by an innovation to an organization (Rogers 1983; Moore and Benbasat, 1991; Chwelos et al., 2001). Compatibility refers to the degree to which an innovation is compatible with the existing organizational practices and procedures, whereas complexity refers to whether or not the innovation is perceived as difficult to use (Rogers 1983).

The organizational factors capture the firm's ability to accommodate the system and describe the attributes of the firm that could impact adoption decisions (DePietro et al. 1990; Doolin and Troshani 2007). Attewell (1992) derived factors from an organizational learning perspective and suggested that it is difficult for organizations to learn to use complex technologies, and thus this creates an organizational learning burden that can inhibit the adoption of these technologies. Conversely, organizations with appropriate expertise may be more likely to adopt the innovation as they involve a lower knowledge burden (*ibid*).

The environmental factor captures environmental pressures and/or facilitators for the adoption of technology. In institutional theory, three specific types of pressures that lead to institutional isomorphism were identified, namely coercive pressures, mimetic pressures, and normative pressures (DiMaggio and Powell 1983). Coercive pressures arise from the factors on which an organization is dependent. For example, industry associations that are partly affiliated with the government have experienced potential benefits of BIM that imply that several countries have established plans for the mandatory use of BIM in public projects (Cao et al, 2014). Mimetic pressures lead organizations to imitate other organizations that are perceived as successful in the same industry, and uncertainty is the primary source of mimetic pressures. When an environment creates uncertainty, innovations are poorly understood or organizational goals are ambiguous and organizations tend to imitate their behaviour against that of peer organizations and to mimic those organizations that appear legitimate and progressive (DiMaggio and Powell 1983). Normative pressures are caused when other members of a network define and share the norms of the organization (DiMaggio and Powell 1983). For example, several professional bodies within specific fields gradually form shared norms and collective expectations with respect to what constitutes desirable behaviours (Cao et al., 2014).

An underlying assumption in the technology, organization, and environment framework is that the adopting firms are merely passive victims of the technology, and therefore, the approach is most suitable for smaller industry players because they are more passive then larger enterprises with respect to the adoption of new technologies (Kurnia and Johnston 2000). The actions of smaller firms are usually determined by the nature of the technologies, their capabilities, and external forces such as pressure from other more influential trading partners (Iacovou et al. 1995). In this sense, the framework could be useful to study the adoption of BIM among medium-sized contractors.

Method

A mixed method approach was considered appropriate, as the present study constitutes an explorative study. That is, the data was collected by both qualitative methods (interviews and cases) and a quantitative method based on a survey. In order to gain insights with respect to the benefits and barriers of BIM use for medium-sized contractor firms, seven in-depth interviews involving representatives of medium-sized contractor firms were conducted. The interviews involved questions related to the use of BIM in the firm, the manner in which BIM was used, and the types of benefits and barriers involved in BIM use. All the interviews were taped, transcribed, and coded thematically. Two CEOs, three construction managers, and three site managers were interviewed. The selection of representatives made it possible to cover multiple perspectives concerning BIM use in medium-sized contractor firms. The interview results in combination with extant research were used to develop the survey questions.

The quantitative data used in this study was collected through a telephone survey administered to CEOs of mid-sized contractor firms in Sweden. The target population for the study involved mid-sized contractor firms, with 50 to 500 employees. Firms belonging to this group were first identified through the membership directory of the Swedish Construction Federation (the trade association for private construction companies in Sweden). Second, a search based on industry codes in the Retriever Business (a database containing financial information on every limited liability firm in Sweden) was performed. Following a manual screening of the list of firms, the firms that had terminated or could not be seen as a contractor or by any other reason did not belong to the target population were removed, the total population consisted of 104 contractor firms.

A preliminary version of the questionnaire was tested with potential respondents and also discussed in the reference group. The final questionnaire was then controlled and scripted by the Kantar Sifo, who also collected the data based on telephone interviews with the respondents. Kantar Sifo is one of Sweden's largest and most respectable marketing research companies (https://tns-sifo.se/). The use of an external professional research firm improved validity and reliability through several levels of quality control in the data collection process. To increase the validity of our measures the questionnaire was re-verified with respect to language and ease of understanding the questions by Kantar Sifo. Inter-rater reliability was increased by using randomly selected and experienced professional callers. The interview process was monitored and recorded to ensure the consistency and quality of responses. This ensured that all problems in the manuscript (including misunderstandings) were captured in the monitoring process.

From the total population of 104 firms, responses of 32 firms were collected (a response rate of 31%). An analysis (*t*-test) of non-respondents vs. respondents using annual report data (number of employees, turnover and total book value of assets) did not reveal any significant differences between respondents and non-respondents. Table 2 lists the descriptive statistics of the sample and respondents together with a *t*-test of mean differences between the groups (respondents vs. non-respondents).

Table 2 Descriptive statistics and analysis of non-respondents

Ratio	Group	N	Mean	Min	Max	Std.Dev	Sig.
Number of Employees	Population	104	95	40	285	49	
	Non-respondents	72	98	50	246	46	0,559
	Respondents	32	87	40	285	56	
Turnover *in 000 SEK*	Population	104	352,885	68,227	1,309,453	296,076	
	Non-respondents	72	377,571	71,287	1,309,453	300,873	0,573
	Respondents	32	299,512	68,227	1,100,064	284,123	
Total assets *in 000 SEK*	Population	104	202,617	14,752	2,559,792	367,617	
	Non-respondents	72	211,76	16,582	2,559,792	398,341	0,919
	Respondents	32	185,967	14,752	1,396,886	290,802	

Variable measurement

The survey involved questions with respect to whether and when BIM is used and the main driving forces and/or constraints that are perceived with respect to the use (or non-use) of BIM. In order to measure the use and perceived challenges (constraints) and driving forces of BIM-implementation, a questionnaire was designed with three sets of questions, namely a set examining activities, a second set examining constraints, and a third set examining driving forces.

The process of designing the questionnaire followed several interlinking steps. Initially, the interviews were performed using company visits and discussions of BIM with potential users at different levels in medium-sized construction companies. A reference group for the research project was also formed with representatives from the industry who also contributed with inputs throughout the design stage of the questionnaire. Based on this a list of BIM use (activities), constraints, and facilitators was formed during a series of meetings with the research group.

The theory of planned behaviour, TPB (Ajzen 1991) and the technology, organization and environment framework (Henderson et al. 2012) were used as theoretical foundations to capture relevant dimensions of the driving forces to use BIM. Specifically, TPB is one of the most influential and popular conceptual frameworks to study human action. According to TPB, human action or in the case of the present study, the use of BIM, is driven by three types of considerations, namely attitudes towards the action, subjective norms (for e.g., normative expectations of others), and perceived behaviour control (for e.g., control beliefs). Therefore, questions or statements were constructed around these three dimensions in the study questionnaire.

Attitudes about the thoughts of individuals with respect to BIM. Four statements were defined and included the following: We perceive a strong internal demand for BIM; We believe that BIM should give us competitive advantages; We believe that BIM would be of strategic importance to the company; and by using BIM we can follow the technical development.

Subjective norms: These were related to external pressure to use BIM. Three statements were constructed to cover this dimension and included the following: BIM was a clear demand from our clients; All our partners use BIM; and BIM has become a standard in our environment.

Perceived behaviour control – this was related to the internal capacity and knowledge to use BIM. Three statements were constructed to cover this dimension and included the following: We have enough internal competence to use BIM; We have a good network of external actors who supports the use of BIM; and It is easy to implement and use BIM.

Results

In this section the results from the interview study are presented first. There after the results from the survey study are presented in order to gain a more fine grained understanding of the results from the interview study.

Interview study findings

From the interviewed respondents, only a few respondents used BIM in their firm. The few respondents that applied BIM mainly used it in the design of 3D drawings, visualization, and clash detection. However, very few individuals used BIM in production. It should be noted that the interviews indicated that none of the individuals explicitly perceived BIM as a strategic issue. With respect to the use of BIM in medium-sized contractor firms, all the respondents mentioned that the client has high control over the projects. Thus, when a client lacks BIM knowledge, consequently there are no demands on BIM for the contractor firm. All the respondents emphasized the lack of knowledge and requirement from the clients. The potential benefits as well as disadvantages of BIM are discussed in the following paragraph.

Potentials and benefits perceived by interviewees can be categorized into the following three different areas: (a) communication, (b) problem solving, and (c) practice. With respect to communication, interviewees mentioned that BIM, and especially the 3D visualization, supported communication and understanding between consultants and actors involved, and it also improved communication between the end-user and the client in multiple ways. BIM was also perceived as beneficial for problem solving in detecting issues and solving problems in a faster manner and being able to prioritize, structure, and diminish mistakes within the design. With respect to possible use, interviewees mentioned that BIM could be broken down into information and materials and that they noticed the potential to use BIM in production and logistics, and the possibility of planning with the help of BIM.

The following aspects were revealed from a discussion of barriers involving the use and implementation of BIM in medium-sized contractor firms:

Lack of demands from the clients

All interviewees mentioned that the client possessed significant power, and that the clients did not require or request for the use of BIM in the construction projects. Some of the interviewed companies worked mainly with renovation projects. Additionally, it is usually expensive to use BIM for renovation, and the contractor firm incurs high costs when these projects involve a client that does not request for 3D modelling. Other respondents believed that the customer often lacks knowledge and expertise in BIM, and this results in a lack of requirements with respect to BIM. It is important for the client that the use of BIM adds value from both a cost perspective as well as from a future use perspective.

Lack of knowledge

All the respondents mentioned that there was a lack in competence and knowledge with respect to BIM and especially in the use of BIM in production. Interviewees observed a generic lack of knowledge related to information technologies (IT) within the AEC industry. Several respondents mentioned that expertise and knowledge were not diffused in the industry and mentioned several types of knowledge involved including the client's lack of knowledge and the consultant's lack of knowledge and competence within the internal organization. The respondents also indicated that it was difficult to work across functional boundaries and share knowledge and information between various actors involving different disciplines, knowledge, and practices. The interviews indicated that it was sometimes difficult to understand the different players in building projects because it involved different settings, backgrounds and goals within the project for each player. A respondent provided an example of this during the design phase for a municipality building. As stated in the example, during the design, a cleaning service entered the discussion, and the cleaning service possessed completely different knowledge and ideas based on their work in relation to the contractor or architect.

Information

A few respondents stated that the availability of information could be an inhibiting factor especially given that the type of information entered or the type of information that can be added into the models (ignorance) is not known. Furthermore, a standard for the manner in which information should be transferred is not specified as demonstrated by the following statement:

> "… There is more to see the benefit of this, again, it's perhaps difficult to see. How do we access the information - it should be easily accessible. You should not need to hire an additional person to extract the information." (CEO contractor2)

Costs and benefits

All respondents reasoned that it was expensive for medium-sized construction firms to invest in BIM. Interviewees mentioned the cost of education in BIM and also investments in computers and software. The firms found it difficult to estimate the costs involved when BIM is used in a construction project. Other respondents stated that they did not observe a clear benefit despite the use of BIM in production, and that investing in BIM was not a good idea if the benefit was not clear in economic terms as demonstrated by the following response:

> "It is a good aid (BIM), but everything depends on if we collect the money, there is economics in all of it. … we cannot produce a large amount of drawings and we see that oh it costs so much … We must ensure that there is an advantage, then we can go for it." (Site manager)

Computers and Software

A few respondents argued that the software was quite complex and difficult to use in conjunction with poor usability. Additionally, it was necessary for several actors to be aware of different types of software, and this made the process more complex. A few respondents mentioned that skills with respect to different software would be resolved over time. However, they also noticed that many consultants did not have access to the software and that many players in a construction project did not have the expertise to use the software. Another aspect noted by the respondents was that the BIM software requires computing power and capacity, which implied it required investments in computers in order to use BIM.

Time

A common aspect in the construction industry and for other project-based industries was that several respondents pointed to the lack of time as a reason for the inability to learn to work with BIM. An existing high workload and few opportunities to develop new knowledge added to the issue.

Organization

A few respondents mentioned that the internal organizational structure discouraged the development of BIM and its use within the organization. Medium-sized contractors considered it important to have a project to work on. The consequence of this was that there was less room for strategic and long-term planning in the organization as specified in the following statement:

> "Before we (firm) have been in a growing phase, that is how it is. Now maybe we will come in a more mature stage. Then we can choose the jobs that we know we are capable off and good at." (CEO contractor1)

Another respondent stated that in medium-sized firms, work involved assuming multiple roles because there were limited resources when compared with that of large-sized contractor firms. This implied that there was less time and space to develop new skills and learn to use BIM as specified in the following response:

> "Well then, right now, I am the site manager … and am in charge of the project as representative and as such … I'm directly under XX who is the CEO. We are two people working like this. I take care of the design, I approve specifications and modify them. So we're not taking in consultants, but I keep those jobs here in the company as well … So this means that I lead and hold these design meetings and try to bring out what is meant, and so. So a little blended mix is what I do". (Site manager)

Other factors

In addition to the above factors, several respondents mentioned the prevailing culture in the construction industry and that the excessive focus on financial aspects of projects in conjunction with the resistance to change. Competition is highly based on price. Other factors that raised concern included the legal aspects of BIM and the lack of standards in BIM.

Survey results

Fifty-eight percent of the respondents stated that they had been involved in a project where BIM was used in some way. Furthermore, 39% stated that they were never involved in such projects, and 3% did not know. For the respondents that have used BIM, we asked them questions regarding the extent of BIM use for different activities. The results are presented in Table 3.

The responses clearly indicated that BIM's visualizing capabilities were most frequently used. An unexpected finding indicated that clash controls were only the third most used application. However, this could be because respondents had the production stage in mind and since visualization in the detailed design was the most frequently used application, it is possible toassume that clashes in field installations were reduced due to visualization in the detailed design. Furthermore, it should be noted that there was a rather high frequency of use of each application in some companies in the sample as indicated by the "Max" values in Table 3.

Next, respondents were asked as to what they considered as the main constraints in the use of BIM. Table 4 presents these results, and four main constraints were identified. The biggest constraints for using BIM involved the contractors' environment, that is, either clients did not demand BIM or partners did not use BIM. However, there was a significance difference in the strength of this perceived obstacle between users and non-users, and the ranking of the constraints differed between the two groups (Table 5). The perceived differences in demands from clients could be explained by the fact that users were involved in projects in which clients indicated a demand for BIM. In contrast, non-users had not yet been involved with clients that demanded BIM. Furthermore, it was interesting to note that investments in hardware and software were perceived as a major constraint, and was perceived by the users as the biggest obstacle. This was somewhat puzzling because it could be claimed that the initial step for contractors to start with BIM is relatively easy. Thus, by downloading a viewer it would be possible for contractors to begin exploring the visualizing capabilities of BIM.

The fourth perceived obstacle involved a lack in internal demand within the company. However, there were significant differences between users and nonusers. This obstacle had the highest rank among the non-users, while it was of less importance to the users (as shown in Table 5). Finally, there was a significant difference between users and non-users with respect to perceived obstacles including "Partners do not always give access to the 3-D model", "takes a long time to learn", and "expensive operating and maintenance costs" (as shown in Table 5). The scores indicated that it was necessary to consider the obstacle, although non-users might have a tendency to slightly exaggerate the obstacle.

With respect to the driving forces for adopting and using BIM, the technology is first and foremost seen as a means to follow the technical development and

Table 3 The extent to which BIM used for the following activities. Answers are on a scale from 1 (never use) to 5 (always use)

Activity	Rank	Mean	Max	Min	SD
Visualization in the detailed design	1	3.61	5	1	1.01
Visualization for users	2	3.44	5	1	1.34
Clash controls	3	3.00	5	1	1.45
Visualization for production planning	4	2.83	5	1	1.57
Quantity estimation	5	2.56	5	1	1.57
Logistics on site	6	2.39	5	1	1.57
Site lay-out	7	2.11	5	1	1.52
Prepare the model for facility management	8	1.78	5	1	1.27
Cost estimation	9	1.50	4	1	0.96
Time planning	9	1.50	5	1	1.01
Generating purchase plans	11	1.44	4	1	0.83
Staffing plans	12	1.28	4	1	0.73

something that offers a competitive advantage (as shown in Table 6). It is interesting to note that non-users do not agree on any of the statements of the perceived driving forces for BIM-adoption. However, some non-users see BIM as a means to follow the technical development, but they mostly do not perceive BIM as of strategic importance or something that, at the moment, offers competitive advantages to the firm. Furthermore, there were significant differences in the perceptions of five of the ten driving forces, and these driving forces were considered as more or less important among the users (Tables 6 and 7). Finally, the major constraints for implementing BIM in terms of low use among partners and the absence of demand from clients were further confirmed because driving forces of the environment were considered as having low importance.

Discussion

A closer scrutiny of the BIM-use applications confirmed that the visualizing capabilities of BIM were evidently the most commonly used applications when compared to the analysis and simulation, co-ordination and communication, and data extraction and transfer capabilities. However, the visualizing capabilities could also be considered as a proxy for the co-ordination and communication capabilities, because the visualization capabilities could be used to facilitate co-ordination and communication. This was confirmed in the interviews to a certain extent wherein improved communication and problem solving - for example better communication among actors - were stated as two benefits of BIM use.

The interviews elicited a wide array of technical, organizational, and environmental constraints. In contrast,

Table 4 Perceived constraints for BIM-implementation

Statement (1 totally disagree, 5 totally agree)	Rank	Mean	Max	Min	SD
No demands from the clients	1	3.71	5	1	1.22
Our partners do not use BIM	2	3.61	5	1	1.10
High investments in hard- and software	3	3.50	5	1	1.09
No internal demand in the company	4	3.48	5	1	1.34
Problem with the user-friendliness	5	3.08	5	1	1.03
High demands for technical competence	6	3.07	5	1	1.00
Partners do not always give access to the 3-D model	7	3.00	5	1	1.24
Does not give any clear competitive advantages	8	3.00	5	1	1.37
Difficult to integrate with other systems	9	2.91	5	1	1.06
Takes a long time to learn	10	2.83	5	1	1.00
Expensive operating and maintenance costs	11	2.67	5	1	1.31
BIM-models are too complex	12	2.63	5	1	1.22
The information in the model is often wrong	13	2.38	5	1	0.79
Major internal resistance in the company	14	2.32	5	1	1.15
Difficult to know if BIM will persist in the future (a fashion)	15	1.90	5	1	1.03

Table 5 Rankings of perceived constraints for BIM use and differences between users and non-users

	User		Non-user			
Statement (1 totally disagree, 5 totally agree)	Rank	Mean	Rank	Mean	*p*-value	
High investments in hard- and software	1	3.76	10	3.18	0.15	
Our partners do not use BIM	2	3.39	3	3.92	0.17	
No demands from the clients	3	3.11	1	4.62	0.00	***
High demands for technical competence	4	2.89	7	3.33	0.29	
Problem with the user-friendliness	4	2.89	6	3.38	0.34	
Difficult to integrate with other systems	6	2.75	11	3.14	0.33	
No internal demand in the company	7	2.67	1	4.62	0.00	***
Partners do not always give access to the 3-D model	8	2.65	4	3.78	0.02	**
Does not give any clear competitive advantages	9	2.59	5	3.54	0.07	
Takes a long time to learn	10	2.56	9	3.25	0.05	**
BIM-models are too complex	11	2.44	12	2.75	0.57	
Expensive operating and maintenance costs	12	2.39	7	3.33	0.04	**
Major internal resistance in the company	12	2.39	15	2.15	0.59	
The information in the model is often wrong	14	2.38	13	2.40	0.94	
Difficult to know if BIM will persist in the future (a fashion)	15	1.59	14	2.33	0.09	

*** = significant at the 0.01 level ** = significant at the 0.05 level (2-tailed)

driving forces were mentioned to a lesser extent. Conducting the survey made it possible to extract more fine grained knowledge with respect to the perceived constraints by analyzing the perceived strength of constraints and differences between users and non-users. There was a consensus among the interviewees that the major constraints for using BIM included lack of demand from clients, lack of knowledge, and cost versus benefits issue. The survey results indicated that the biggest perceived constrains involved the lack of any environmental pressure from clients, partners, and regulatory bodies. It was somewhat surprising that non-use among partners was perceived as a major obstacle because medium-sized contractors often co-operate with the same partners as larger contractors that use BIM. The question arises as to whether some of the partners worked with BIM or 3D-models, and this was either not communicated to the mid-sized contractors or they did not demand BIM. The lack of internal demand as a driving force for BIM use (see Table 5) could indicate that the question as to whether or not partners use BIM was never raised. A response recorded during an interview indicated that this could in fact be the issue. A site manager was asked if they used BIM during the detailed design and he indicated that he did not think that BIM was used. However, a contract manager joined the interview later and stated that BIM was often used in the detailed design. This evidence of a lack of internal communication and information transfer in a company could be a strong indicator that contractors actually did not really know the extent to which BIM was used by their partners in the detailed design. Evidently, this is a topic for further research.

Table 6 Perceived driving forces for BIM adoption and use among users and non-users

Statement (1 totally disagree, 5 totally agree)	Rank	Mean total sample	Mean users	Mean non users
By using BIM we can follow the technical development	1	3.57	4.00	2.80
We believe that BIM should give us competitive advantages	2	3.00	3.67	2.08
We have enough internal competence to use BIM	3	2.87	3.17	2.46
We believe that BIM would be of strategic importance for the company	4	2.81	3.33	2.08
We have a good network of external actors who support the use of BIM	5	2.77	2.88	2.62
It is easy to implement and use BIM	6	2.66	2.88	2.38
All our partners use BIM	7	2.13	2.35	1.85
We perceive a strong internal demand	8	2.06	2.67	1.23
BIM was a clear demand from our clients	9	2.03	2.00	2.08
BIM has become a standard in our environment	10	1.97	2.41	1.33

Table 7 Perceived driving forces for BIM-implementation, rankings, and differences between users and non-users

Statement	User		Non-user		*p*-value	
	Rank	Mean	Rank	Mean		
By using BIM we can follow the technical development	1	4.00	1	2.90	0.008	***
We believe that BIM should give us competitive advantages	2	3.67	5	2.15	0.001	***
We believe that BIM would be of strategic importance for the company	3	3.33	5	2.15	0.010	***
We have enough internal competence to use BIM	4	3.17	2	2.62	0.227	
We have a good network of external actors who support the use of BIM	5	2.88	2	2.62	0.588	
It is easy to implement and use BIM	6	2.88	4	2.38	0.146	
All our partners use BIM	7	2.67	9	1.46	0.004	***
BIM has become a standard in our environment	8	2.41	10	1.33	0.003	***
We perceive a strong internal demand	9	2.35	8	1.85	0.280	
BIM was a clear demand from our clients	10	2.00	7	2.08	0.890	

*** = significant at the 0.01 level (2-tailed)

When the survey results were scrutinized in detail and the user and non-user categories were separately analysed, a more complex picture emerged with respect to the perceived constraints and included details such as the significant differences between perceived constraints (Table 5). Non-users perceived a lacking internal demand and a lacking client demand as the biggest obstacles. In a separate analysis of this data we could also see that there was a highly significant correlation between these two variables (with a Pearson correlation coefficient of .617 and *p*-value <,000). Hence, it could be claimed that the lack of internal demand was a result of a lack of client demand. Conversely, these obstacles were not perceived as strong by the users when compared with the non-users (Table 5). Instead, the users perceived a combination of organizational and technological factors as the biggest obstacle. The perception of the need for "high investments in hard- and software" could be considered as a proxy for organizational resources (see Orlikowski and Iacono 2001) in conjunction with the fact that costs exceeded the benefits. It is necessary to investigate the perception of the need for "high investments in hardware and software". The major investments in "BIM-equipment" is made by technical consultants involved in the detailed design, and contractors who want to use the model for visualization purposes could download free software. The perception could be grounded in the opinion that it is necessary to upgrade the company's computer capacity if it would be possible to use BIM in a more encompassing and advanced manner. However, it was remarkable that learning cost in terms of time was not perceived as a big constraint (see Table 4). In an interview, a managing director of a non-user company confirmed that the lack of client demand was the biggest constraint, but when clients began demanding BIM, it would be relatively easy for the company to accommodate the changing customer demands.

However, among the users, the relative advantage of the technology factor was perceived as the strongest driving force. This was expressed by the perception that BIM is a means to follow the technological development and that BIM provides competitive advantages to the company. The non-users did not have these types of strong perceptions (Table 7). In this sense, it could be claimed that the role of the lack of demand as a constraint diminished for users because the users perceived that they could gain competitive advantages by following the technological development. This assumption was supported by a strong correlation (600; *p*-value <,01) between the two variables follow technological development and competitive advantage.

As previously stated, advocates for BIM see it as a process that will have a significant impact on the industry (e.g., Eastman et al. 2011) and it is claimed that the client would be the greatest beneficiary (Olofsson et al. 2008). However, the process perspective was less obvious from the results of the study. The results indicated BIM was perceived foremost as a tool for visualization. However, the perception that BIM could provide the company with a competitive advantage contributed to a more multi-faceted view of BIM. Moreover, the question arises as to whether the low score with respect to the competitive advantage of non-users raised questions as to how these companies perceived the discussion of public clients for whom BIM would be a compulsory part of the project delivery. Finally, users and non-users had considerably different perceptions with respect to BIM. Users focused on the technology and the relative advantages of using BIM, while non-users focused on the (non-existing) environmental pressure. Thus, another topic for future research involves a study of the underlying reasons for the differences in the perceptions of BIM.

Conclusions

The results indicated that more than half of medium-sized contractors in the sample used BIM in some projects. The use was limited foremost to utilizing the visualizing capabilities of BIM, but the visualization can also facilitate BIM coordination and communication among actors. An observation of the perceived constraints for BIM use (Tables 4 and 5) indicated a few significant observations. Statements that measured subjective norms (i.e., external pressure) were given the highest scores and statements that measured attitudes (i.e., how respondents perceived BIM) were awarded the lowest scores. For instance, the question arose as to whether the lack of internal or external demand was the main reason for non-users to use BIM. Although the respondents appeared to agree that BIM was generally user friendly and that the complexity of the model was not a major obstacle, there were significant differences between users and non-users in this aspect. Users to a much higher degree than the non-users of BIM believed that BIM-use required high investments in hardware and software.

With respect to the main driving forces for BIM use, attitudes related to the technical development and achievement of competitive advantage were observed as the main forces. Norms (internal and external demands) were given the lowest scores in terms of a driving force. Several statements of respondents about attitudes and norms also showed significant differences between users and non-users. As expected, users generally valued driving forces much higher than non-users.

The findings indicate the main obstacles for BIM-implementation is related to the lack of normative pressure while the main driving forces were primarily driven by the subjective positive or negative evaluation of BIM by individuals, instead of external pressure from clients and partners or with respect to the internal capacity and knowledge to use BIM.

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Authors' contributions

All authors contributed extensively to the work presented in this paper. HL reviewed and analysed the literature, PB and ML conducted, analysed and drafted the data from the qualitative interviews. All four authors were involved in the development of the survey and it was implemented by AI and HL, who also were responsible for the analysis of the survey results. HL coordinated the research activities and the drafting of the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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