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What is the “Potential” of new ICT and how are Perceptions Shaped by Experience of Use and Practice? - The Case of Building Information Modelling

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Abstract

The emergence of new open ended ICT (Information and communication Technology). is often accompanied by optimistic predictions about the technologies inherent capabilities, or “potential”, to solve a wide array organizational related problems. In the building and construction industry, BIM – Building Information Modelling – is such an example. However, unrealistic expectations about a technology is also a determinant for failed implementations, but at the same time ICT-induced transformation of organizations and industries is a well-known phenomenon. This research in progress paper has two interlinked explorative aims. First, how can the “potential” of a technology be captured? Second, how does experience of practice and experience of technology use shape the perceived potential of a technology. The data is collected via a survey to practitioners, with and without BIM-experiences, in medium sized contractor companies, and last year’s bachelor students in civil engineering. The total number of respondents was 205.

In order to achieve the first aim, it is needed to inquire how users and prospective users’ perception of a technology’s “potential” can be captured? It can be claimed that constructs used when adoption of open ended ICT is studied, implicitly or explicitly, emphasize a status quo, then a transformation of organizational processes and structures. The results show that one alternative for measuring perceived “potential” is to measure respondents’ perceptions about how useful different applications are in practice. However, this scale needs to be developed in order to become more applicable different industries. Based on the measurement of perceived “potential” the results indicate that experience of practice had a negative impact on the perceived “potential”, whereas experience of technology had a positive impact compared to respondents with experience of practice but no experience of technology. It is concluded that further research is needed on which factors these shape the perceived potential when experienced technology user also gain an increased experience of practice.

Keywords Potential of ICT, Technology acceptance model, BIM (Building Information Modelling, ICT adoption.

1 Introduction

This research in progress paper aims at exploring how the role of experience of practice and experience of technology influence the perceived "potential" of open ended ICT (Information and communication Technologies). The emergence of new ICT is often accompanied by technology vendors' and business oriented mass media's optimistic predictions of the technologies inherent capabilities, or potential, to solve a wide array organizational related problems (e.g. Burton Swans and Ramillier, 1997). In the scholarly literature this "potential" is often referred to as a technology's transformative capabilities, or that the technology is enabling (Zuboff, 1988; Money et al., 1996), which also implies a need for transforming organizational processes and structures. It can be claimed that technologies triggering discussions of potential, often concern open ended technologies, i.e. technologies these provides some generic functionality where it is up to users to find use cases and applications (Elbanna and Linderoth, 2015). It is no doubts that open ended, or flexible ICT, offers companies to re-organize and rethink how products and services are designed, produced, and distributed (Cha et al, 2014), when bundled with organizational structures, work processes, and culture (see e.g. Melville et al, 2004). However, if optimistic predictions are un-critically absorbed and turned into unrealistic expectations, the way to implementation failures is paved (see e.g. Szajna and Scamell, 1993).

In the building and construction industry, BIM – Building Information Modelling - can be seen as an example where academia and policy makers have been pumping up over optimistic predictions about what can be achieved with new ICT. Dainty et al (2016:2) claim 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'...

...UK Government's Industrial Strategy (2013), which states "... only through the implementation of BIM will we be able to deliver more sustainable buildings, more quickly and more efficiently". This positioning of BIM as the only possible mechanism to deliver on these three vital prongs of performance improvement has elevated it beyond a mandated technological improvement tool to an almost mythical status of providing the basis for every significant improvement agenda, and as the vehicle for realizing the 'radical, transformational change' espoused by the Industrial Strategy (2013: 25).

At the bottom line a building information model involves representing a design as combinations of "objects" – vague and undefined, generic or product-specific, solid shapes or void-space oriented (like the shape of a room), that carry their geometry, relations and attributes. BIM design tools allow extraction of different views from a building model for drawing production and other uses. These different views are automatically consistent, being based on a single definition of each object instance. BIM software also defines objects parametrically; that is, the objects are defined as parameters and relations to other objects, so that if a related object is amended, dependent ones will automatically also change. Each model element can carry attributes for selecting and ordering them automatically, providing cost estimates as well as material tracking and ordering. (Eastman et al., 2011).

However, despite the academics' and policy makers' hyperbole around BIM, research and practice reports more of a slow adoption rate of BIM, than BIM-implementation failures. Nevertheless, some BIM-applications, like clash controls in field installations, has been rather quickly adopted (Jacobsson and Linderoth, 2010), whereas other applications, like the generation of purchase plans are hardly adopted (Isaksson et. al., 2016). This example also shows a problem when discussing the potential of an open technology and its adoption. Even if BIM is used for detecting clashes in filed installations whenever appropriate, there might be 10-15 other applications these hardly are used. Accordingly, the question is how users and prospective technology users' perceptions of a technology's "potential" can be captured?

When studying user adoption of ICT constructs like different variants of the technology acceptance model (TAM) has been used (see e.g. Davis, 1989). However, when studying user adoption of open ended technologies like BIM, the use of theories like TAM might be problematic. First, when for example the perceived usefulness is measured, questions like the following are asked: "Using technology X would enable me to accomplish tasks more quickly", or, "Using technology X will improve the quality of the work I do". For an open ended technology like BIM, 10-15 different applications can easily be identified and applications concerns different professional groups in different stages of the project life cycle (see e.g. Cao et.al., 2014). The questions can have completely different meanings for the architect, structural engineer, contract manager, site manager, or, facility manager. They may see the usefulness of BIM for supporting some of their work tasks, but may not realize the usefulness of BIM for work tasks concerning

other professional groups. This might be problematic if the technology not only is aimed for supporting work tasks for the own group, but also aimed at co-ordination and communication, and data extraction and transfer (see also Carlo et al, 2012).

Another problem if traditional constructs for user adoption of ICT would be used to capture the potential of open ended technologies is that the constructs implicitly or explicitly rather emphasize a status quo, than a transformation of organizational processes and structures. When potential of new ICT is discussed words like transformative capabilities, or enabling technologies are often used (see e.g. Zuboff, 1988; Money et al, 1996). The processes triggered by enabling or disruptive technologies transformative capabilities, implies changes in organizational structures, work processes, rules and policies, and organizational culture (see e.g. Melville et.al., 2004). In studies of ICT and BIM use in the building and construction industry it is revealed that user generally have a positive attitude towards ICT and BIM, and want to use BIM more if it is adapted to their way of working (Davies and Harty, 2013). Even in some scholarly literature related to the building and construction industry, it is questioned if users should have to change their way of working in order to reap benefits from BIM and ICT (see Hartmann et al, 2012). Thus, against background it can be claimed that a use of a technology that not require changed work processes is perceived as more useful than a technology that does require changes of work process. With regard to the discourses on technologies potential and an accompanying need of changed organizational work processes and structures, it can be questioned whether traditional constructs for studying adoption of ICT are appropriate in order to understand users' and potential users' perceptions of a technology's "potential"?

Another issue of central concern when the "potential" of open ended technologies is discussed, is the experience of technology use. User experience is an important concept in IS studies while it influences how the user, or prospective user forms initial expectation on the technology's functionality (i.e., perceived usefulness) and how they update such perception after gaining first-hand experience (see e.g. Bhattacharjee and Premkumar, 2004; Brown et al., 2012). It is well known that unrealistic expectations about a new technology among non-users is a predictor to implementation failures (see e.g. Szajna and Scamell, 1993). Bhattacharjee and Premkumar (2004) found in two longitudinal studies that usefulness and attitude perceptions tend to fluctuate with time across both technological and usage contexts, and that such change tend to be more prevalent during the initial phases of IT usage than in the later phases. Moreover did their study confirm the role of disconfirmation and satisfaction in driving usefulness. Disconfirmation refers to the extent to which subjects. pre-usage expectation of technology usage is contravened during actual usage experience and satisfaction reflects an individual's emotional state following IT usage experience (ibid: 237).

Accordingly, against the introductory background the paper has two interlinked explorative aims. First, how can the "potential" of a technology be captured? Second, how does experience of practice and experience of technology use shape the perceived potential of a technology?

2 Data Collection

In order to achieve the first aim of the paper, it is needed to find out how the "potential" of a technology can be captured. In one sense the "potential" can be seen as phenomenon linked to sense making. I.e. peoples understanding and sense making of a technology determines the future use (Griffith, 1999). Because BIM is used in an industry where actors on all levels characterize themselves more as doers than thinkers (Löwstedt and Raisänen, 2014), respondents may not imagine possible applications of BIM if statements are on a too abstract level. Instead, in order to make a first attempt to measure the perceived "potential" of BIM, BIM-applications these has been identified in research (see Cao et al, 2014) will serve as items when trying to measure the perceived "potential". In this way respondents can easier connect an application to their practice.

The data was collected via a web-based survey aimed for medium-sized contractors with 50 – 500 employees. The total number of companies in the sample are 104. A link to the survey was initially sent to the managing directors for the companies, who was asked to distribute the link to all white collar workers. However, the response rate was unsatisfying at the outset. In addition, approximately 20 companies in the target population was identified, where it was possible to get access to e-mail addresses to all white collar workers in the companies. Thus, in addition 400 emails with the link to the survey were sent to individuals in the target companies. After the first mail was sent to managing directors and individuals, another two reminders were sent. In total 194 responses received. 67 respondents had participated in a project where BIM, or 3D-models had been used, 68 respondents had not participated in a project where BIM, or 3D-models had been used, but were knowledgeable about how BIM could be used in the building and construction process. Finally, 59 respondents claimed they did not know how

BIM could be used in the building and construction process, accordingly they did not answer the BIM-related questions. In order to get a sample of individuals who are knowledgeable about the technology, but have less experience of practice, the survey was also sent to third year bachelor students in civil engineering. In total 70 responses were received from the students. In the survey to the students some statements had to be modified. For example, the statement "BIM can improve the quality of my work" was modified to: "BIM can improve the quality of work".

The development of the survey was based on both practical and scholarly knowledge on BIM. For example, the 14 applications of BIM were identified both from practice and the scholarly literature (see Cao, et al, 2014) describing "potential" BIM applications. In addition, 31 statements about BIM were developed, by drawing on for example TAM and the technology – organization – environment framework from the inter-organizational information system literature (see e.g. Henderson et al, 2012). However, only statements that make an immediate sense for the aim of the paper will be showed in the result section. After the development of the survey, it was tested on practitioners in order to secure that the terminology used was correct and questions made sense for practitioners.

3 Results

In this section the results from the survey will be presented. First respondents perceived "potential" of BIM will be presented. Because BIM can be considered as an open ended technology, this is, a technology with a wide array of applications, it can be questioned if it is suitable to use the traditional instrument for measuring perceived usefulness. In this study, using the traditional instrument, had implied that four to six questions have had to be asked for each one of the 14 BIM-applications. Instead the respondents got the question: "How useful do you think BIM is for the following activities?" (table 1). They were asked to grade each of the 14 different applications on a five grade scale where 1 = not at all; 3 = neither nor; 5 = very useful. It can be assumed that the scale measure some kind of perceived usefulness because the internal consistency was excellent: $\alpha = ,926$. Thereafter some results from the attitude questions are presented, where significant differences between users and students were detected. Contrary to the measurement of the perceived "potential" of BIM, there were no significant differences between users and non-users' attitudes towards BIM with one exception.

When the three groups attitudes towards BIM "potential" for different applications are compared, three observations stand out (Table 1). First, the three groups make a very similar ranking of the applications. Users rankings of applications' "potential" corresponds with the frequency of use for the eight top ranked applications, with exception for "site logistics" and "site lay-out" these had switched ranks compared to the frequency of use. Clash controls and visualization for different purposes get the highest scores among all three groups, which might be less surprising because BIM and 3D-CAD, is generally associated with clash controls and visualization in the building and construction context. The second observation that stands out is that non-users grade the usefulness for applications with a low frequency of use significantly higher than users do (Table 1). One plausible explanation can be that users may, due to their experience of technology and the context for use, perceive that a higher effort is needed to implement the applications with the lowest frequency of use. The third observation that stands out, is that students, with one exceptions, perceive a significantly higher "potential" for all 14 applications compared to users and non-users (Table 1.). The most plausible explanation to students relatively high scores on the different applications is the rather comprehensive use of BIM in courses corresponding to 33 ECTS during 3 study years. In this sense students get hands on experience with technology, but also some more theoretical understanding of the context for use.

In order to get a measure for BIM's perceived "potential" an index was constructed from the items in table 1, with a min value = 14, max value = 70. The average value for the different groups were the following:

- User = 46,2
- Non user = 51,5
- Students = 58,6

The difference between user and non-users was significant on the $>,05$ level, and between non-users and students the difference was significant on the $>,000$ level. Thus, non-users perceive that BIM has higher "potential" than users, and students perceive that BIM has a higher "potential" than non-users.

Application	Average			p-value		
	User	Non-User	Stud.	User-non user	Stud-user	Stud-non user
Clash controls	4,39	4,50	4,77	ns	0,005	0,016
Visualization in the detailed design	4,38	4,43	4,74	ns	0,003	0,011
Visualization for users	4,23	4,29	4,67	ns	0,002	0,002
Visualization for production planning	4,03	4,20	4,44	ns	0,005	ns
Quantity estimation	3,71	3,91	4,47	ns	0,000	0,000
Site lay-out	3,48	3,73	4,06	ns	0,001	0,024
Logistics on site	3,48	3,77	4,00	ns	0,004	ns
Cost estimation	3,32	3,74	4,16	0,009	0,000	0,001
Prepare the model for facility management	3,29	3,55	3,94	ns	0,000	0,009
Simulation of a building energy consumption	3,25	3,76	4,04	0,001	0,000	0,046
Time planning	3,16	3,41	4,06	ns	0,000	0,000
Generating purchase plans	2,95	3,49	3,86	0,001	0,000	0,008
Environmental certifications of buildings	2,93	3,29	3,84	0,020	0,000	0,000
Staffing plans	2,80	3,29	3,69	0,002	0,000	0,010

Table 1. Average scores for perceptions of how useful 14 BIM-applications are and significant differences among groups evaluation of applications.

The students' positive attitudes to the different applications could at the first glance be interpreted as an over optimistic view on technology, where implementation challenges are neglected. However, when the attitude questions are closer examined and a first categorization is done, the result is mixed regarding differences between students and users' attitudes (see table 2). When the significant differences are scrutinized, students value "potential" benefits related to decision making higher than the users. When potential obstacles with significant differences are closer examined, there is both an over- and under emphasizes of the potential obstacles compared to the users. But a common theme for five of the eight potential obstacles is that they concern the firm's relations to the environment.

But when it comes to internal aspects of organizing, this is, the need for internal changes, the students emphasize these variables more than the users.

Statements with significant differences	User	Stud.		User	Stud.
<u>Benefits</u>			BIM is of strategic importance for the company	2,95	3,92
BIM can improve the quality of my work	3,83	4,26	<u>Perceived obstacles</u>		
BIM facilitates to document and transfer information about a building	3,78	4,32	BIM is not demanded by the clients	3,58	2,94
BIM can help me making decisions that decrease the company's costs	3,63	4,06	Our partners do not use BIM	3,23	4,12

BIM can help me making decisions that increase the quality of our products and processes	3,62	4,07	<u>Organizing</u>		
BIM gives the company competitive advantages	3,54	4,33	I would use BIM more if it is adapted to our way of working	4,11	3,30
BIM can help me making decisions that decrease the company's environmental impacts	3,09	3,67	To use the "potential" with BIM we need to develop and change our way of working	4,00	4,26

Table 2. Categories of users and students' attitudes towards BIM

4 Concluding discussion

The aim of the paper has been to explore how an ICT's perceived "potential" can be measured and how experience of practice and technology shape perceived "potential". In order to do this, first it was necessary to try to measure the perceived "potential". This is, however, a complex task and a few concerns can be raised. First, open-ended technologies offers a rather wide range of applications and using a traditional TAM construct will either be too unprecise, or too encompassing. Because if a statement is made about BIM in general, a fine-grained knowledge about BIM's "potential" will be lost. On the other hand, in practice, it may be problems with non-responses if respondents should judge 14 different applications by using a TAM construct for evaluating each application. Therefore, in this stage, the decision was made to present 14 applications for respondents ask them to judge how useful each of the 14 BIM-applications were, which gives a finer grained knowledge about the perceived "potential" and the possibility to create an index for perceived "potential". This leads however to a second concern, the lack of generalizability of the scale. At the moment the scale, even if has a high internal consistency, can only be used for measure the perceived "potential" among actors involved in the design and production stage. A next step would be to raise the level of abstraction of the scale. (see also Carlo et al, 2012). In the case of BIM, its generic capabilities like 3D visualization, analysis and simulation, co-ordination and communication, and data extraction and transfer, could be used for developing a more generic scale for measuring perceived "potential" of ICT. This is, a next step would is to investigate how these capabilities can be used for measuring, for example, the perceived "potential" of the analysis and simulation capabilities. But still would the challenge be to make the scales and items broad enough to be applicable on a wider range of technologies and industries, at the same time as scales and items should allow for an adaptation to industry and technology specific circumstances. Finally, a third concern, the index developed measures the perceived "potential" with regard to how useful respondents find an array applications are in a daily practice. What not is measured in the index is respondents' readiness to changes their work practices if an application requires changed work practices. In this sense the lower perceived "potential" among technology users who have an experience of practice, may be explained by the fact that they realize changes necessary to use some applications and therefore not consider applications as useful with regard to the efforts needed.

The study's results also show that experience of practice and experience of technology use has an influence on the perceived "potential". By scrutinizing the preliminary results, it seems that experience of practice has a negative impact on the perceived "potential". It could be argued that experience of technology use has a positive influence on the perceived "potential" when students and non-users are compared. But when including the group with both experience of practice and experience of technology use, in this study, it becomes evident that experience of practice has a negative impact on the perceived "potential". By drawing on the influence of the concepts disconfirmation and satisfaction (see Bhattacharjee and Premkumar, 2004), and the items in table 2, may give some indications of the differences in perceived "potential". Students score BIM benefits, like quality of work and cost reduction, higher than users with experience of practice. A plausible explanation may be that enthusiastic lectures from consultants and software vendors tell about the "potential" with BIM, and by technology use this is confirmed. On the other hand, users with an experience of practice imagine benefits with some applications, but realize the effort needed in order to implement some of the leaser used applications and therefore not judge them as not too useful. Moreover, the user group wants to use BIM more if it is adapted to their way of working. This may be another variable that explains a lower perceived "potential" than the student groups. Even if there is an awareness of need for changes (see table 2), these changes may concern other groups then the own. Thus, further research is needed to more in detail inquire which factors these shape the perceived potential when experienced technology user also gain an increased experience of practice.

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