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Determinants for Students Perceived Potential of BIM Use

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Abstract: Newly graduated students are shown to constitute an important source of innovation within the architectural, engineering and construction (AEC) industry. In relation to digital technologies like BIM (Building Information Modelling) that is claimed to have a potential to transform the industry, newly graduated students may play a vital role in innovating with BIM. The paper aims to explore determinants for students perceived potential of BIM use (PPBU) and the role of the educational background. The aim will be achieved by analysing the results from a survey conducted among third- and fourth-year students in construction and civil engineering in Hong Kong, Sweden, and Thailand (n = 194). When the different groups are compared Swedish and Thai students perceive a significant higher PPBU than Hong Kong students. In a step-wise multiple regression analysis five predictors for PPBU were identified for Thai respectively Swedish students, and one predictor was identified for Hong Kong students. It is concluded that in the contemporary BIM-discourse it is claimed that BIM can/should transform the industry, and BIM is even seen as a disruptive technology, and newly graduated students will contribute to (digitally driven) innovation. However, from the predictors of PPBU, the question can raised if the awareness of the need for structural changes is lacking in the education, if students later in their working life should contribute to a BIM-induced transformation of the industry?

Key words: Building Information Modelling (BIM), Perceived potential of BIM use (PPBU), Surveys, Students, International comparison

1. INTRODUCTION

Newly graduated students are shown to constitute an important source of innovation within the architectural, engineering and construction (AEC) industry [1,2]. In relation to digital technologies like BIM (Building Information Modelling), which is claimed to have a potential to transform the industry, newly graduated students may play a vital role in innovating with BIM. For example, it has been showed that construction engineering students perceive a higher practical usefulness of BIM, compared to employees in the industry [3]. However, it is well known that perceptions of a technology vary among groups and over time [4]. As with other technologies, BIM has an interpretive flexibility (see also [5]). It can for example be perceived as a software application, a process for designing and documenting building information, or a whole new approach to develop the profession requiring new policies, relationships between stakeholders as well as new contracts [6]. In information systems research, it is well known that peoples' perceptions of a technology shape how information and communication technologies' (ICT) are used day by day, as well as their understandings of possible or actual pre-conditions and consequences connected with technology use [7, 3]. Consequences and pre-conditions can be connected to potential benefits of technology use and changes needed in order to realize the potential benefits, as well as influences of the organizational context.

Hence, if students entering the industry would contribute to BIM-induced changes, it can be claimed that they need to be aware of BIM's potential and preconditions for realizing the potential. Even if the "potential of BIM" or "full potential of BIM" is frequently mentioned in the scholarly literature (see e.g. [8, 9]), the potential is vaguely defined. In this paper, BIM's potential will be captured by the perceived potential of BIM use (PPBU), which is operationalized by measuring students perceptions of the usefulness of different BIM applications (see also [10, 3]).

Moreover, if students would become an important source of innovation by means of BIM, they not only need to perceive the potential benefits of BIM use. As important is that they have an understanding of the preconditions of realizing potential benefits, this is, being able of identifying variables, or factors shaping the realization of benefits. Accordingly can the question be raised if students merely perceive a direct correlation between BIM use and the realization of its potential? Or, do students perceive a more complex relation between the realization of BIM's potential benefits and the influence of the context in which BIM is used? And, how does the educational background influence students perceptions of BIM?

Given this background, this research paper aims to explore determinants for students PPBU and the role of the educational background. The aim will be achieved by analysing the results from a survey conducted among third- and fourth-years students in construction and civil engineering in Hong Kong, Sweden, and Thailand (n = 194).

The remainder of the paper is divided into five sections. In the following section, a conceptual framework for adoption and use of ICT (Information and Communication technologies) is presented, as well as how the perceived potential of BIM use (PPBU) is operationalized. In third section, approaches to data collection and analysis is described. In the fourth section, the empirical results of a multiple regression analysis is presented. Finally, a concluding discussion is presented in the last section.

2. REVIEW OF FACTORS INFLUENCING PERCEIVED POTENTIAL OF BIM USE

In research on adoption and use of information systems several factors have been identified as explanations for why and how a technology is used. Examples of these factors are: benefits of technology adoption; perceptions of the technology itself, need for change, collaboration, and external drivers and barriers. Benefits of technology adoption may be the first factor that comes into mind when it should be explained why and how a technology is used. The "benefit" is an important factor in the diffusion of innovation literature (see e.g. [11]). Especially the concept of relative advantage, this is, perceived benefits or expected advantages of using an innovation. Relative advantage refers to the expected advantages or perceived benefits that can be provided by an innovation to an organization [11, 12, 13]. The concept of relative advantage has also been one major influence on the technology acceptance model (TAM) where it is assumed that the perceived usefulness of a system predicts future user behaviour [14]. When perceived usefulness of an ICT application has been assed a construct with six items has traditionally been used ([14, 15]: 1) accomplishing tasks more quickly; 2) improving job performance; 3) increased job productivity; 4) enhancing job effectiveness; 5) making the job easier; 6) being useful on the job. The concept of perceived usefulness has been important to understand individual perceptions in pre- and post-adoption phases [16]. However, when studying benefits on the organizational level, Petter et al. [17] claim that there are insufficient data from the research to support any model that can be used to predict success on the organizational level. This observation is in line with the productivity paradox. This is, results from research focused on examining ICT's financial impact on productivity and firm performance and that has produced mixed results and invited researchers to consider mediating factors [18, 19]. Devaraj and Kohli [20] found that actual usage of technology is the missing link between ICT investment and its impact on organizational performance and showed that the driver of ICT impact is not the investment in the technology, but the actual usage of the technology.

If perceived benefits should be reached not only the consequences of technology adoption in terms of perceived usefulness, should be evaluated. Another important antecedent for the perceived benefits is the perceptions of the technology / system itself. In the literature on information system success ease of use and system quality has been factors these explains perceived benefits of a technology [17]. Important dimensions are for example; system reliability, ease of learning, system features of intuitiveness, as well as relevance-, understandability, accuracy of information [17].

The need for change if benefits from ICT would be achieved is well known in the research literature. A successful application of ICT is often supported by significant organizational changes, including workplace practice, organizational structure, rules and policies, and organizational culture [19, 21].

What is important to take into consideration is that technology can be seen as embedded in a complex and dynamic social context, where technology is neither an in-dependent, nor a dependent variable, but instead intertwined with the conditions of its use [22]. This is especially true for a technology like BIM, where an underlying assumption is that the technology would enable a seamless information flow, where value is co-created by the collaboration between stakeholders involved [23]. Finally there are external barriers for the adoption and use of an IS. These barrier are for example lack basic infrastructure, the educational level of of potential employees, research and development investments [21], the role of institutional preasure [10], as well as incentives for external partners to cooperate [23].

To sum up. Based on the above litature, it could be pointed that PPBU could be influenced by technology characteristics, change management, and external influences.

2.1 Approching of Perceived Potential of BIM Use

When BIM's potential, or the perceived potential is mentioned, the first issue to inquire is how the perceived potential of BIM use can be captured. In information systems research, different variants of the technology acceptance model (TAM) [14], have commonly been used to measure perceived usefulness of a technology. Thus, at the first glance it can be claimed that TAM could be used to measure the perceived potential of BIM use. TAM originates from the theory of reasoned action [25] and later by the theory of planned behaviour [26]. TRA/TPB state 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' [27]. When TAM inspired frameworks are used for studying perceived usefulness of BIM, the usefulness is measured by perceived impacts of BIM, for example reduction of decision-making time, work task handling time, etc.[8]. Thus, TAM inspired frameworks can be appropriate for measuring perceived impacts of BIM use.

However, because BIM can be seen as an open multipurpose technology, there is a wide array of BIM-applications [10], these can be suggested to form the PPBU. DeSanctis and Poole [28] have a similar line of reasoning in their study on group decision systems. They found that studying a technology on the application, or feature level, instead of the artefact level, revealed that people used different applications, or features, in different ways that lead to insights how technology actually was used. Accordingly, using traditional TAM measures would imply statements like "Using BIM would enable me to accomplish tasks more quickly", or, "Using BIM will improve the quality of the work I do". These statements can have completely different meanings for the architect, structural engineer, contract manager, site manager, facility manager, as well as it is hard to know which BIM applications the questions are aimed at. For example, using BIM for clash detections is a very useful application for a structural engineer and a site manager, whereas the application is less useful for a facility manager. Accordingly, in this paper the PPBU will be measured on the application level and where the perceived usefulness of different BIM-applications will form the PPBU (see table 2).

3. METHOD

To explore determinants for students PPBU and the role of the educational background, a survey questionnaire was further developed from a study of BIM use among medium sized contractors. The suvery questionnaire contained four main sections of question, which were: 1) respondents background; 2) attitudes towards using IT; 3) BIM implementation practices; 4) Impact of BIM implementation. Sampling of data were gather from 3rd and 4th years bachelour students from Universities in Hong Kong, Sweden and Thailand. In this research, a multiple regression analysis (MRA) was adopted to analyse the data from questionnaire. MRA is used when predict the value a dependent variable based on the values of two or more independent variables [24].

3.1. Questionnnaire Design and Data Collection

The questionnaire was earlier used in a study aiming at investigating attitudes to BIM among employees in medium sized contractor firms. In the survey to the students some statements had to be modified to fit the student context. For example, the statement "BIM can improve the quality of my work" was modified to: "BIM can improve the quality of work". In order to use the survey in Hong Kong and Thailand, the survey was first translated into English. This work was jointly done by the researchers from Hong Kong and Sweden in order to validate that the meaning of the questions remained the same after the translation. Thereafter the questionnaire was reviewed by the Thai and Swedish researcher with the purpose of establish a joint understanding of the questions. Thereafter the questionnaire was translated into Thai, but the questions were written in both Thai and English.

In Sweden a web-link to the questionnaire was sent to the students via an e-mail. There after another two reminders were sent out to the students after one, respectively two weeks. In Hong Kong, the hardcopy survey was distributed to the students at the end of the class, and the electronic version of the survey was also distributed through e-mail to all students in building construction programme. In Thailand, the web-based survey was used as a tool to collect the student's perception. Researcher translated questions to local language and put into the web-based survey. The survey link was distributed to the students via direct email, social network, and colleague from other universities who teach BIM in Thai university.

In total 194 responses were received. The distribution of responses is showed in table 1.

Table: 1. Distribution of responses.

Country	Year 3	Year 4	Total
Sweden	70	0	70
Hong Kong	65	9	74
Thailand	15	35	50
Total	150	44	194

In Sweden the questionnaire was distributed to students in the end of their sixth and last semester. The Swedish student sample represents two different three years study programs: construction- and architectural engineering. Both programs encompass three BIM related courses corresponding to one semester full time studies (30 ECTS). The first course focus on providing basic skills in drawing standards and digital building information modelling as well as an insight into the use of collision control programs. The second course focus on the creation and use of information in a model, for example quantity take off, energy simulations and the creation of design specifications. The third course is project based and focus on the use of BIM for creating production specifications, as well as planning and control of projects for coordination and quality assurance.

In Hong Kong, the survey was distributed to all of the third and the forth (final) year students in two bachelor courses, including the BSc (Hons) in Surveying, and the BSc (Hons) in Building Engineering and Management. There is no standalone subject about BIM in both courses, but BIM-related knowledge and skills are integrated into various subjects, including information and data analysis subject, measurement and estimating subject etc., in both study programs.

In Thailand, there are two degrees that though BIM at Bachelor degree in Civil Engineering and Bachelor degree in Architecture. At the time of data collection, each university provided the specific subject for students to learn about BIM. The course provided the basic understanding of building information modeling, BIM process, BIM tools. The term project was established as one of the outcomes that students needed to be completed. It used as the learning activities to understand building information modelling. In addition, students also learn about BIM topics that are related to each subject.

3.2 Measuring Perceived Potential of BIM use

When developing the measure of PPBU, the point of departure is taken from Cao et al. [10] and Linderoth et al. [3]. Cao et al. [10] identified in a literature review 13 application areas for BIM in the design- and production stage when measuring the extent of BIM adoption. Building on Cao et al. [10] and Linderoth et al. [3], an instrument containing 14 items (application areas) for measuring the PPBU was developed. However, in this study, another two applications were added; documenting and transfer information, and simulation of the production process. In the survey the students got the question: "Based on your knowledge about BIM: How useful do you think BIM is for the following activities. 1= not useful at all, 2= not so useful, 3=neither nor, 4= rather useful, 5= very useful". The students' judgements of the activities are shown in table 2.

Table 2. Items for measuring perceived potential of BIM use

Items	Mean	Std. Deviation
1. Visualization in detailed design	4.40	.812
2. Clash controls	4.33	.879
3. Visualization for user	4.29	.822
4. Quantity take off	4.24	.801
5. Visualization production planning	4.22	.810
6. Documenting and transferring information	4.11	.812
7. Simulating the production process	4.07	.773
8. Cost estimation	4.05	.801
9. Site lay out	3.99	.887
10. Time planning	3.99	.874
11. Preparation for facility management	3.93	.845
12. Simulation of energy consumption	3.90	.899
13. Generate purchase plans	3.87	.828
14. Site logistics	3.86	.893
15. Staffing	3.74	.927
16. Environmental certification of buildings	3.69	.965

All applications where highly correlated with each other. From a principal component analysis (PCA with varimax rotation), we could see that all variables could be attributed to one single component (explaining 57.6 of total variance). Furthermore, an analysis of measure of internal consistency reviled a Cronbach's Alpha of .950 indicating a very high internal consistency [29]. Hence, we could create an additive index describing the perceived potential of BIM useBIM (PPBU), ranging from a theoretical minimum of 16 to a theoretical maximum of 80.

4. RESULTS

In this section, the results from the survey will be presented. First the results from the PPBU analysis and eventual differences between the different students groups will be presented and analyzed. There after the predictors for PPBU among the different student groups will be presented.

4.1. Perceivied potential of BIM use (PPBU) and predictors

The first step in the analysis was to inquire the PPBU and if there were any differences between the countries, and finally to identify predictors for PPBU. In table 3 the mean values for the PPBU of the three student groups is presented.

Table 3. Mean values for students PPBU

Country	N	Mean	Std. deviation
Sweden	69	66.9	8.85
Hong Kong	73	60.3	11.17
Thailand	50	67.7	8.78
Total	*192*	*64.6*	*10,31*

From table 3 it can be seen that the mean values for Thai and Swedish students were rather similar, whereas the mean value for Hong Kong students were lower. The next step in the analysis was accordingly to investigate if there were some significant differences between the mean values. This was done via a one-way ANOVA test (table 4).

Table 4. One-way ANOVA test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2220.719	2	1110.360	11.604	0.000
Within Groups	18084.260	189	95.684		
Total	20304.979	191			

The results from the one-way ANOVA test showed that there exists a significant difference between the groups. Accordingly, a Post Hoc Tukey test was conducted (Table 5).

Table 5. Post Hoc Tukey test

		Mean Difference			95% Confidence Interval	
(I) Q0COUNTRY	(J) Q0COUNTRY	(I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Sweden	Hong Kong	6.66647*	1.64240	0.000	2.7866	10.5463
	Thailand	-0.74696	1.81670	0.911	-5.0386	3.5447
Hong Kong	Sweden	-6.66647*	1.64240	0.000	-10.5463	-2.7866
	Thailand	-7.41342*	1.79567	0.000	-11.6554	-3.1715
Thailand	Sweden	0.74696	1.81670	0.911	-3.5447	5.0386
	Hong Kong	7.41342*	1.79567	0.000	3.1715	11.6554

*. The mean difference is significant at the 0.05 level.

From the Post Hoc Tukey test it is revealed that there is a significant difference in PPBU between Hong Kong students on one side, and Swedish and Thai students on the other side. Between Swedish and Thai students were no significant differences for the PPBU. Thus, these results indicate the influence of the educational background, but the similarities between the Thai and Swedish student groups indicate that we have to go into deeper details in the analyzis.

4.2. Predictors for perceivied potential of BIM use (PPBU)

The final step in the analysis was to identify predictors for the PPBU among the three student groups. This analysis was done separately for each group to identify eventual differences among the groups and that could be a further indicator for the role of the educational background.

When analysing predictors for the Swedish student group a significant model was obtained by using the stepwise method, ($F_{5.47} = 19.400$, $p < 0.000$, adjusted R square = 0.639) (table 6).

Table 6. Predictors for Swedish students PPBU

	Unstandardized Coefficients		Standardized Coefficients	
Model	B	Std. Error	Beta	Sig.
BIM facilitates decisions these increase the quality of products and processes	2,819	1,259	,250	,030
BIM gives the company competitive advantages	2,950	1,249	,226	,022
BIM leads less errors, omissions and conflicts	3,642	1,129	,308	,002
BIM is of strategic importance for a contractor company	2,317	1,097	,199	,040
BIM facilitates decisions these decrease the company's environmental impact	2,039	,974	,218	,042

For the Swedish student group five predictors were identified and these had a rather similar strength and similar significance levels, even if the predictor [the use of BIM can lead to] "less errors, omissions and conflicts" is slightly stronger. The predictors are very much aligned with what students are taught in the BIM courses. Even if contractors view on BIM as a means for creating competitive advantages are very mixed, the students view competitive advantages as afctors that is significantly correlated with PPBU. An explanation for this could students exposure for guest lectures from different software vendors and consultants who emphasize the need of adopting BIM in order to stay competitive.

When analysing predictors for the Thai student group a significant model was obtained by using the stepwise method, ($F_{5.44} = 20.868$, $p < 0.000$, adjusted R square = 0.670) (table 7).

Table 7. Predictors for Thai students PPBU

Model	Unstandardized Coefficients		Standardized Coefficients	
	B	Std. Error	Beta	Sig.
BIM facilitates decisions these increase the quality of products and processes	7,937	1,262	,651	,000
BIM is of strategic importance for a contractor company	5,473	1,213	,443	,000
The model is too complicated	-1,822	,628	-,244	,006
Small contractors lack enough internal competence	2,083	,718	,255	,006
BIM gives the company competitive advantages	-3,710	1,398	-,305	,011

For the Thai student group five predictors were identified, but a bit contrary to the Swedish student group predictors vary more in strength and have a stronger significance. This predictors can be obtained from the learning of BIM concept and process, and also case studies that lectures provide in class.

The strongest predictor was “BIM facilitates decisions these increase the quality of products and processes”. An example of this is that BIM use could help to improve the process of model modification that will be reflected to other drawings and plans, which in turn reduce reworks or mistakes. The second strongest predictors was “BIM is of strategic importance for a contractor company”, which can be seen as a bit condradictive because the predictor “BIM gives the company competitive advantages” had a negative value. However, from a long-term viewpoint, it could be seen that BIM use for contractor can create the business opportunity by making the differentiate strategy when compare with contractors who not adopt BIM in their organization. But from a short-term viewpoint, students do not see the clear benefit from industrial cases that BIM use would bring competitive advantages today. Thus, students perceived that Thai construction industry do not see the competitive advantage today as they are starting the use of BIM, but advantages may come in the long term. Moreover, the Thai students felt that the competence on BIM use is perceived as essential to start use of BIM. It has the positive relation of BIM use because they felt that industry have this problem during the implementation. Based on the class seminar, several experts from the industry explains the issues of user’s competence. Therefore, student felt that lack of internal competence influence on the BIM use. Finally do the Thai students not perceive that models are too complicated. With regard to the perception of small contractors lack of internal competence, this is most probably the students own perception.

When the first regression model for the Hong Kong students was obtained, two predictors were identified “The use of BIM can lead to less errors, omissions and conflicts” and “BIM can support in making decisions these decrease the company’s cost”. However, the tolerance, $< 0,5$, indicated problems with collinearity. The two variables were combined into one. Using the stepwise method, a significant model was obtained (F 1.64 = 135.169, $p < 0.000$, adjusted R square = 0.674) (table 8).

Clash detection has been considered one of the fundamental functions of BIM.

Table 8. Predictors for Hong Kong students PPBU

Model	Unstandardized Coefficients		Standardized Coefficients	Sig.
	B	Std. Error	Beta	
Less errors/reduced cost	11,235	,966	,824	,000

The clash detection simulations were shown to the Hong Kong students in the classes, and they might have developed an impression of design error detection of BIM. In the same vein, Hong Kong students perceived the potential benefits of BIM use such as making design and construction site management decision which is important to contractors.

Respondents from Hong Kong are consisted of students from both building engineering management (BEM) and surveying (SUR) courses. A possible reason for the significance difference in PPBU between students in Hong Kong and Sweden Thailand was the diversity of the construction and surveying professions, including quantity surveying, general practices and building surveying, covered in the both courses. Perhaps, students who chose their undergraduate majors in construction management (including building engineering management and quantity surveying), have developed a realization of the potential of BIM application on their professions than other students in other surveying majors. Students in other surveying majors might be unable to see the potential benefits of BIM technology, and how it is linked directly to the building surveying/general practices professions.

5. CONCLUDING DISCUSSION

The aim of the paper has been to explore determinants for students PPBU and the role of the educational background. When the determinants for the perceived potential of BIM use are closer examined, almost all predictors were connected to benefits of BIM use. The only exception was the Thai student group, where it was a negative correlation between PPBU and the predictor "the model is too complicated". The integration of negative correlation is that the higher perceived potential of BIM uses a student has, the less complicated does s/he think the model is. This may be an expression for an uncomplicated view on technology where the most optimistic respondents, do not perceive any problems with complicated models. Or, students may underestimate the level of complicated model as they may focus only on structural and architectural model rather than mechanical and electrical model. Alternatively, the more knowledge a respondent has about the potential of BIM use, the less complicated s/he finds the model. What is notable is that none of predictors are related to changes in the way of working and in the way of collaborating. This may either indicate that students do not perceive that the items used for measuring the PPBU requires any changes in the way work and relations among parties are organized and regulated. Or, students may not perceive the complexities in the process when benefits of BIM would be realized? For example, using BIM for clash controls and visualization in detailed design, which were the two highest ranked items (see table 2), do not require any larger changes of work practices, whereas lower ranked items as the generation of purchase plans and staffing requires a more information rich model, that in turn put demands on how work is organised, and changes in roles and responsibilities. Nevertheless, as the differences regarding BIM and competitive advantages, and the similarities in the judgement of strategic importance between Thai and Swedish students shows a sensitivity for the context in which BIM would be used. This may also originate from the fact that contract of government in Thailand do not provide the requirement of BIM use as prequalification or BIM process but rather focus on the final model product that contractor have to submit at the end of project. (design – bid –build). Thus,even if the perceptions originate from lectures, students see the importance of BIM in both a short- and long-term perspective.

The role of the educational background, or what is taught in BIM-related courses has been obvious from the results. But, the most surprising results was that Thai and Swedish students had rather similar opinions with regard to predictors for PPBU, but Thai students' perceptions were more distinct with regard to the B coefficients and the significance level. This may be explained by the fact that Thai students are brought a rather comprehensive perspective on BIM, but contrary to the Swedish students, they have less hands-on experience with different software's that might explain the differences. Thus, Swedish students' perceptions have been moderated through their hand-on experiences. For the Hong Kong students the ,in general, limited exposure of construction management and surveying students in Hong Kong to diverse applications of BIM technologies may restrict their understanding of the BIM applications and the existing challenges. Perhaps, increasing the BIM contents in existing subjects, or develop a new subject for the innovation and applications of digital technologies and BIM would provide students a better picture of the benefits of disruptive technology, and help equip students with the necessary concept knowledge, skill, and ability to effectively deal with the BIM applications.

To conclude. In the contemporary BIM-discourse it is claimed that BIM can/should transform the industry, and BIM is even seen as a disruptive technology [30], and newly graduated students will contribute to (digitally driven) innovation. However, from the predictors of PPBU, the question can raised if the awareness of the need for structural changes is lacking in the education, if students later in their working life should contribute to a BIM-induced transformation of the industry?

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