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Research Article

Barriers to Software Adoption: a study of building information modelling (BIM) technology in the Hong Kong construction industry

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Abstract

As information technologies have been used by organisations to increase productivity, efficiency and effectiveness, Building Information Modelling (BIM) technology does so by using computer software technology to integrate construction processes built on coordinated and reliable information throughout the design and construction phases, and the operations of construction projects. Amongst the various academic researches on technology usage and adoption that are currently available, the Technology Acceptance Model (TAM) is most widely used by researchers to help understand system usage behaviour. This research applied a theoretical extension of the TAM, i.e. TAM2, to the Hong Kong building and construction industry with the addition of factors, including perceived usefulness and usage intentions, to aid explaining readiness to use in relation to overall satisfaction, which consists of process satisfaction and outcome satisfaction.A quantitative analysis was conducted over a period of one year involving 203 validated responses from the Hong Kong building and construction industry to measure the effects of these variables. Correlation analysis was used to determine the effects of significant relationships. The findings support the hypotheses and also conclude with the validated expanded TAM2, which explains the more frequent adoption of BIM software technology in the Hong Kong building and construction industry than the original TAM or the TAM2. In the academic field, this research provides a further extension to TAM2 concluding a validated expanded TAM2. In professional practices, this research provides contributions to improving the understanding of user adoption behaviour of BIM Technology in the Hong Kong Building and Construction Industry.

Introduction

In various industries, information technologies have been used by organisations to increase productivity, efficiency and effectiveness and previous research indicates that organisations invest more than half of their new capital in information technology (Westland & Clark, 2000). The building and construction industry consists of multi-disciplinary professionals who handle significant amounts of information throughout the design and construction phases, right up to and including the operations of construction projects (CIRC, 2001; Li, Lu & Huang, 2009). A key issue for the industry is that computer programs currently used in building design, analysis and operation are utilised in a stand-alone manner and are therefore unable to exchange data directly, even when they are used by the same party (IAI, 2002).

To have a successful result, regardless of how powerful the technologies are, they must be well received and adopted by industry practitioners who are usually employees of organisations involved in a project (Venkatesh, Morris, Davis& Davis, 2003). As BIM technology is new to the industry (Eastman, Teicholz, Sacks and Liston, 2008), the theoretical extension of the Technology Acceptance Model (TAM2) (Davis, 1989; Davis, Bagozzi and Warshaw., 1989; Venkatesh& Davis, 2000; Venkateshet al., 2003) explains perceived usefulness and usage intentions in relation to process satisfaction and outcome satisfaction (Fayad, 2006), and this extension was applied in this research. In the information systems field, the TAM is generally used by researchers to understand system-user behaviour by assessing the effects of external variables, including perceived usefulness and perceived ease of use, on the intention to use (Yi, Jackson, Park and Probst, 2006). Researchers broadened the TAM by incorporating a theoretical extension to produce TAM2, which includes additional constructs measuring social influence processes and cognitive instrumental processes (Fayad, 2006).

Research Background

During economic downturns, concerns over the environmental impact of buildings and their actual value to tenants increase considerably (USGBC, 2011). In his 2007/08 policy address, Donald Tsang, the former Hong Kong's Chief Executive, pledged to reduce energy consumption by at least 25% between 2005 and 2030 (HKSAR, 2007). The Hong Kong Green Building Council (Hong Kong GBC) has been established and the new Hong Kong building regulations stipulate that environmental protection considerations will be one of the evaluation factors for additional funding applications (HKSAR, 2009). BIM technology is considered to be a green-design technology since construction waste from design errors can be avoided if the design is reviewed by way of digital computer models before actually being built (Huang, Kong, Guo, Baldwin & Li, 2006). In the US some projects have even incorporated an integrated project-delivery model that leverages building information modelling at its core to avoid construction waste as much as possible throughout the construction process.

By using BIM technology, an ability to provide a reliable and fast decision-making process, increased communicable building models, improved quality, higher profitability, intelligent architectural simulation of consistent and non-redundant data, and an enhanced delivery process are created (Wong, Wong and Nadeem, 2009). BIM technology is especially efficient and effective for green and sustainable designs and allows project owners to utilise this in managing project risks, improving project quality, and delivering added value to their businesses.

The Hong Kong Housing Authority has also announced a plan to implement BIM projects in 2014-2015, with the intention of training staff in the following years (Wong, Wong and Nadeem, 2011), and provides suggested standards, guidelines and model component families for successful implementation of BIM technology in its

Rationale for the Research

The rationale for this research was based on the fact that there are barriers that affect software adoption in the context of BIM technology in the Hong Kong building and construction industry, and that these barriers can be analysed by reviewing an individual's intention to use technology (Davis et al., 1989; Taylor & Todd, 1995; Venkatesh& Davis, 2000). Accordingly, BIM technology was observed in the form of the TAM2 to measure variables: the subjective norm, image, job relevance, result demonstrability, perceived ease of use, process satisfaction and outcome satisfaction, experience, voluntariness, and output quality, perceived usefulness and the intention to use. A quantitative analysis was conducted over the period of a year involving participants from the Hong Kong building and construction industry to measure the effects of these variables.

Literature Review and Hypotheses Development

Various research reports state that information and communication technologies (ICT) enable industries such as manufacturing, finance, agriculture, building and construction to improve effectiveness, productivity, efficiency and competitive gain (Doherty, 1997; Duyshart, 1997; Skibniewski and Abduh, 2000; Peansupap and Walker, 2005). However, construction remains the most conservative industry in any economy (US Bureau of Labor Statistics, 1998). The following descriptions discuss the current situation of construction industry in Hong Kong and their application of ICT.

Current Construction Practices in Hong Kong

There has been an evolution in the construction industry over the past 20 years that has seen it progress from the traditional paper-design to Computer-Aided Design and Drafting (CADD) and now on to applying BIM (Bratton, 2009). Employing BIM effectively can result in improved design, smoother communications amongst project team members, enhanced constructability, accelerated project schedule, and ultimately savings in time and money for the owner as well as for the project team. Green and sustainable designs have become powerful forces in shaping designs of buildings and infrastructure in general. Attention to global warming and soaring energy costs are forcing architects, engineers and owners to carefully consider how their designs affect both the environment and the long-term cost of operating buildings.

building and construction projects (HKHA, 2012).BIM is one of the new technologies that integrate processes derived from coordinated and reliable information about a project starting from the design stage through to construction and ultimately on to operations (Wong et al., 2009). It is recognised as one of the ICT technologies that provide benefits of information technology implementation to realiseautomational, informational and transformational benefits (Mooney, Gurbaxani& Kraemer, 1996).

Industry Challenges

In recent years, increasing energy costs, a building and infrastructure boom and environmental issues have been hot topics worldwide (Manrai&Manrai, 2001). Environmental drivers such as global warming have increased the use of green and sustainable designs in the construction Industry.

The transition period into the BIM world can be particularly trying for professionals in the construction industry due to the industry's fragmented and prototypical nature (Birx, 2005). Unlike other industries, construction professionals face unique challenges in coordinating heterogeneous and innovative decision information (Kam, 2005). The main difficulties of technology adoption may be the psychological factors of using the systems and overcoming mental resistance (Hjelt& Bjork, 2006). As Hong Kong companies usually undertake projects for local and international markets, the factors affecting BIM adoption in the US may also be applicable to local practitioners. Furthermore, Hong Kong's geographical location allows it to act as an important regional hub that can showcase the use of such technology for the construction industry in the Greater Pearl River Delta region.

As BIM is considered to be a new technology in the construction industry (Eastman et al., 2008; Clayson, 2007; Wong et al., 2009), the theoretical extension of TAM2 that explains perceived usefulness and usage intentions in relation to process satisfaction and outcome satisfaction (Fayad, 2006) was applied in this research. The barriers to BIM adoption in the construction industry can be analysed by reviewing individuals' intentions to use technology (Davis et al., 1989; Taylor & Todd, 1995; Venkatesh& Davis, 2000).

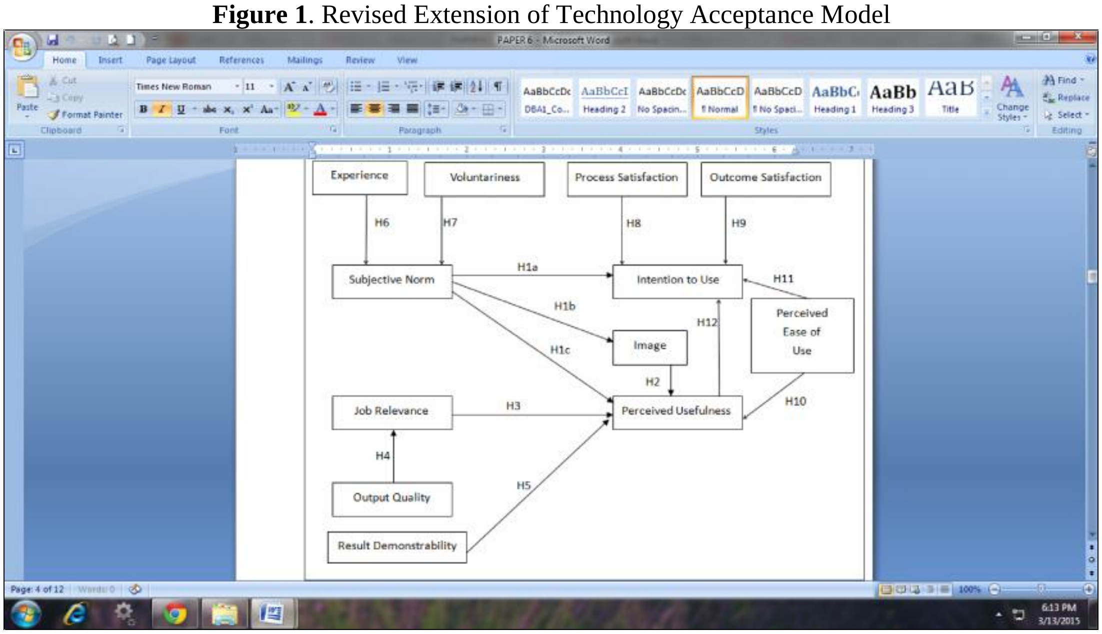
The Technology Acceptance Model (TAM)

Of all the previous research studies examining user acceptance and usage behaviour of emerging information technologies, the Technology Acceptance Model (TAM) is one of the most widely applied research models predicting IT adoption by user acceptance and usage (Venkatesh, 2000). However, different researchers have identified that the influence of perceived usefulness (PU) and perceived ease of use (PEOU) in the latter stages of user intention are different (Davis, 1989; Davis et. al., 1989; Gefen& Straub, 2000). When the software is perceived to be useful (PU), people will have the intention to use it. When it is perceived as easy to use, it is also assessed as easy to learn. Many of the TAM studies showed that PEOU would directly affect intended use only when dealing with tasks that are intrinsic to the IT, as implied by the study of Gefen and Straub(Davis, 1989; Venkatesh and Davis, 2000; Venkatesh et al., 2003; Fayad, 2006). Applying TAM in the case of BIM adoption in Hong Kong is considered as the intrinsic aspect of the IT as it has implications due to "its interface and the process involved in using it" (Gefen& Straub, 2000).

The TAM Application and Extension Models

Using Technology Acceptance Model (TAM) as the starting point, TAM2 model comprising subjective norm, voluntariness and image, and job relevance, output quality, result demonstrability, and perceived ease of use (Venkatesh& Davis, 2000; Venkateshet al., 2003) was revised and extended to be the research model of this study as shown in Figure 1

Figure 1. Revised Extension of Technology Acceptance Model



Application of BIM

From Young, Jones & Bernstein (2008), BIM is defined as "the process of creating and using digital models for design, construction and/or operations of projects". A recent survey conducted by McGraw-Hill Construction (2008) found that BIM is being used on construction projects with a rapidly growing rate. Nearly 62% of survey respondents indicated that they intended to use BIM on over 30% of their projects in 2009. The research findings also clearly indicate that through gaining more BIM expertise individuals develop a deeper understanding of BIM benefits and the value of using BIM. About 82% of BIM experts believe that BIM is having a very positive impact on their company's productivity and 44% of BIM experts now track BIM ROI on a regular basis. This powerful trend points to a growing momentum of adoption and implementation, which will lead to redefining how projects are delivered and, consequently, influence more companies in the construction industry to follow suit.

Hypotheses Development

The research model in Figure 1 for this research was derived from the studies of Venkatesh& Davis (2000), Venkateshet al. (2003) and Fayad (2006) on Technology Acceptance Model (TAM) and Extension of Technology Acceptance Model (TAM2).

Subjectivenorm is a direct determining factor of behaviouralintention in Theory of Reasoned Action (Fishbein&Ajzen, 1975) and theTheory of Planned Behavior (Ajzen, 1991). This means that when someone who is important to the user thinks that it is important for the user to perform the task, this will affect user's intention to perform the task.

In the case of Hong Kong, the government has specified that contractors need to use BIM as one of the criteria to bid for tenders of some public housing construction projects. Similar to Singapore and the US, this is a showcase in Hong Kong where government is acting as a subjective norm to companies which are or are not using BIM. With these findings, the following hypothesis is set up:

Hypothesis H1a: Subjective norm is positively correlated with intention to use the BIM system.

Subjective normhas an indirect effect on intention through perceivedusefulness (Salancik&Pfeffer, 1978). As such TAM2 theorizes thatinternalizationwill occur whetherthe context of system use is voluntary or mandatory.That is, even when system use is organizationallymandated, users' perceptions about usefulness maystill increase in response to persuasive social information. In this research that when Hong Kong government is a subjective norm who adopts BIM to improve building quality, this will create an impression among Hong Kong companies that BIM is a useful system by optimising designs, improving coordination of project stakeholders and reducing construction waste to meet government project requirements. Therefore the following hypothesis is set up:

Hypothesis H1b: Subjective norm is positively correlated with perceived usefulness of the BIM system.

In the research on 156 American knowledge workers on software adoption to perform their work, Venkatesh& Davis (2000) discovered that subjective norm, job relevance and output quality have a direct and positive effect on image of using the system. Chan & Lu (2004) also discovered the subjective norm has a direct effect on image of using the system when researching on 147 Hong Kong students when they were using e-banking software. In other words, when someone important thinks that using that using BIM is important, it is likely for users of BIM to perceive that using BIM will improve the image of the company and that BIM is very useful. With these findings, the following hypothesis is proposed:

Hypothesis H1c: Subjective norm is positively correlated with image of using the BIM system.

The reason for a direct effect of image and job relevance on perceived usefulness is that perceived usefulness is affected by a person's perception on something, so the following hypothesis is set up:

Hypothesis H2: Image of using the BIM system is positively correlated with perceived usefulness of the BIM system.

Kieras& Polson (1985) mentioned that users can enhance their work efficiency if they are clear about their job-related knowledge. It can be inferred that job relevance has direct influence on perceived usefulness. If users have more knowledge about the functions and services of BIM, they caneasily enjoy the benefits of BIM and increase their perception of the usefulness of the BIM system.With these findings, the following hypothesis is proposed:

Hypothesis H3: Job Relevance is positively correlated with perceived usefulness of the BIM system.

According to Venkatesh, Morris & Davis (et al., 2003) and Fayad (2006), when the system is able to perform tasks that meet the work goals, users tend to think that the tasks the system performs is highly job relevant.When users consider BIM system to be contributive to the execution of tasks, they will perceive an improvement of work efficiency. Such perception is perceived output quality. In the context of Hong Kong, the output quality of BIM needs to be highly relevant to the job requirements of BIM users who are under heavy job pressure to complete their jobs. Therefore the following hypothesis is proposed:

Hypothesis H4: The output quality is positively correlated withjob relevanceof the BIM system.

When a user uses a system which could not yield positive results for work, user is unlikely to accept the system. Result demonstrability mentioned by Venkatesh& Davis (2000) in TAM 2, is defined by Moore and Benbasat (1991, p. 203) as tangibility of the results of using the innovation, has direct influence on perceived usefulness of the system. Subsequent relevant research (Yi et al., 2006; Chan & Lu, 2004; Agarwal & Prasad, 1997) discovered that intention to use the system is influenced by results demonstrability. Therefore, when users experience the benefits of using the BIM system, they have a greater feeling that the BIM is very useful. As a result, the following hypothesis is set up:

Hypothesis H5: Result demonstrability of using the BIM system is positively correlated with perceived usefulness of the BIM system.

When users become experience in using the system, they are less influenced by subjective norm because experienced users tend to judge the usefulness of the system based on their own experience (Venkatesh et al., 2003). When users of BIM who have experience in using BIM to meet their job requirements, this experiential knowledge of the users is likely to supersede the recommendations given by subjective norm. This is because they have a working knowledge to evaluate and judge the recommendation by subjective norm. To certain extent, they may be able to point out in an exact way how BIM could meet their job requirements. Therefore the following hypothesis is proposed:

Hypothesis H6: Experience is negatively correlated with subjective norm.

As voluntariness is defined as “the extent to which potential adoptersperceive the adoption decision to be non-mandatory”(Agarwal & Prasad, 1997; Hartwick&Barki, 1994;Moore &Benbasat, 1991), even when users perceive system use tobe mandates from an organization, intention to use tends to varybecause some users are unwilling to comply with suchmandates. In our context, when users of BIM think that using BIM is voluntary, they are likely to use BIM when a subjective norm recommends BIM. They take it a good will from subjective norm and are more likely to explore various features and capabilities of BIM, with a good feeling that BIM will improve their work efficiency. With this finding, the following hypothesis is set up:

Hypothesis H7: Voluntariness is positively correlated withsubjective norm.

According to Venkatesh& Davis (2000) and Fayad (2006), when users are satisfied with the process and outcome of using the system, it increases the intention of the users to use the system again. Users of BIM are concerned with how easy the processes are when they need to get the tasks done because they are concerned with the project schedule. The outcomes of BIM include the design output, various analysis results and management reports etc. When these outcomes meet project requirements, users of BIM will have a greater intention to use BIM.So the following hypotheses are set up:

Hypothesis H8: Process satisfaction is positively correlated with intention to use the BIM system.

Hypothesis H9: Outcome satisfaction is positively correlated with intention to use the BIM system.

From TAM to TAM2, it was clear that perceived ease of use is positively correlated with perceived usefulness (Venkatesh& Davis, 2000;Davis et al., 1989). While other conditions remain unchanged, a system that is easier to use will have greater results. The findings of Halawi& McCarthy (2008) and Yi et al. (2006) also support the view that perceived ease of use is positively correlated with perceived usefulness. Previous studies have empiricallyindicated that perceived ease of use hasindirect influence on intention to use, andperceived ease of use influences intentionto use through perceived usefulness (Venkatesh, & Davis,2000). In our context, BIM users perceived ease of useof the BIM affects their intention touse the BIM through perceivedusefulness.Therefore the following hypothesis is set up:

Hypothesis H10: Perceived ease of use is positively correlated with perceived usefulness of the BIM system.

Perceived ease of use is positively correlated with intention to use the system. A number of empirical research projects confirmed these findings (Halawi& McCarthy,2008; Chau & Hu, 2002; Venkatesh et al., 2003; Szajna, 1996; Taylor & Todd,1995). In our context, BIM users perceived ease of useof the BIM affects their intention touse the BIM through perceivedusefulness. When users think that BIM is not difficult to use, they will have a greater intention to try using BIM to see what benefits BIM could bring them in meeting their job requirements. This perceived ease of use could come from a good demonstration of BIM. An example of this is the demonstration of 3D modelling of BIM, which shows users how easy this modelling is created. Therefore the following hypothesis is set up:

Hypothesis H11: Perceived ease of use is positively correlated with intention to use the BIM system.

According to Mathieson (1991) andTaylor & Todd (1995), TAM is good in explaining the behaviour of using an information system like BIM. After removing subjective norm, attitude becomes the core of TAM. Perceived usefulness and Perceived ease of use influence a person's attitude to use the system. This further influences their intention to use the system. In our context, BIM users perceived ease of useof the BIM affects their intention touse the BIM through perceivedusefulness. When users think that BIM is a useful tool for them to meet their job requirements, they will have a greater motivation and intention to use BIM. This intention comes from the fact that many users are results oriented and they would like to see as fast as they could how BIM could generate outputs meeting their job requirements. As a result, the following hypothesis is set up:

Hypothesis H12: Perceived usefulness is positively correlated with intention to use the BIM system.

Methodology

The following sections describe the sample, data collection method, measuring items and statistical analysis approach.

Sample and Data Collection

A sample size of 500 research participants was approached. These were all members of professional associations including, but not limited to, the Hong Kong Institute of Architects (HKIA), the Hong Kong Institution of Engineers (HKIE), the Hong Kong Institute of Surveyors (HKIS) and the Hong Kong Institute of Building Information Modelling (HKIBIM). Contact details of these groups are publicly available. Some of these associations have been arranging BIM related seminars dating back to as early as 2007. Since then, over 5000 attendees have participated in these seminars, and it was found that most of these attendees had actual prior working experience with BIM projects in HK. Therefore, it was thought that approaching a sample size of 500 research participants was a reasonable estimate.In this research, questionnaires are used to collect data from respondents. Professionals in the AEC industry who have current BIM projects were identified and their contact information obtained from public websites.

Measuring Items

The questions for measuring each item of the constructs of this research are listed in Table 1 below.

Table 1. Questions for measuring each construct of this Research

Construct	Question
1. Subjective Norm	Q1. People who influence my behaviour think that I should use the system.
	Q2. People who are important to me think that I should use the system.
2. Image	Q3. People in my organisation who use the system have more prestige than those who do not.
	Q4. People in my organisation who use the system have a high profile.
	Q5. Having the system is a status symbol in my organisation.
3. Job Relevance	Q6. In my job, usage of the system is important.
	Q7. In my job, usage of the system is relevant.
4. Result Demonstrability	Q8. I have no difficulty telling others about the results of using the system.
	Q9. I believe I could communicate to others the consequences of using the system.
	Q10. The results of using the system are apparent to me.
	Q11. I would have difficulty explaining why using the system may or may not be beneficial.
5. Process Satisfaction	Q12. I find using the system enjoyable.
	Q13. The actual process of using the system is pleasant.
	Q14. I have fun using the system.
	Q15. I am satisfied with the process of using the system.

6. Outcome Satisfaction	Q16. I find that by using the system, I achieve the work that I need to deliver.
	Q17. I find that by using the system, I complete my work on time.
	Q18. I am satisfied with the outcome of using the system.
7. Perceived Ease of Use	Q19. My interaction with the system is clear and understandable.
	Q20. Interacting with the system does not require a lot of my mental effort.
	Q21. I find the system easy to use.
	Q22. I find it easy to get the system to do what I want it to do.
8. Experience	Q23. I have been trained to use the system.
	Q24. I have previous experience in using the system.
9. Voluntariness	Q25. My use of the system is voluntary.
	Q26. My supervisor does not require me to use the system.
	Q27. Although it might be helpful, using the system is certainly not compulsory in my job.
10. Output Quality	Q28. The quality of the output I get from the system is high.
	Q29. I have no problem with the quality of the system's output.
11. Perceived Usefulness	Q30. Using the system improves my performance in my job.
	Q31. Using the system in my job increases my productivity.
	Q32. Using the system enhances my effectiveness in my job.
	Q33. I find the system useful in my job.
12. Intention to Use	Q34. Assuming that I have access to the system, I intend to use it in the next 2 months.
	Q35. Given that I have access to the system, I predict that I would use it in the next 2 months.

Data Analysis

A sample size consisting of over 200 respondent questionnaires (assuming over 30% response rate) is being targeted. Measurement assessment for this research was conducted by using correlation analysis.

Findings

The following section describes the findings of this research.

Characteristics of the Sample

Table 2 shows the demographics details of the respondents.

Items	Values	Frequency	Percent (%)
Age Group (years)	20 to 30	50	24.6
	31 to 40	102	50.2
	41 to 50	45	22.2
	51 to 60	6	3.0
Gender	Male	194	95.6
	Female	9	4.4
Occupation	Architect	62	30.5
	Engineer	46	22.7
	Project Manager	36	17.7
	Civil engineer	2	1.0
	Quantity Surveyor	2	1.0
	Others	55	27.1

Years of Experience in the Industry	less than 5	30	14.8
	6 -10	64	31.5
	11-15	50	24.6
	16 - 20	35	17.2
	more than 20	24	11.8
Percentage of Those Having Implemented BIM	Yes	122	60.1
	No	13	6.4
	partially	66	32.5
	others	2	1.0
BIM Trained	Yes	121	59.6
	No	18	8.9
	Basic	59	29.1
	Advanced	3	1.5
	Other	2	1.0

Table 2. Demographics Details of Respondents (n=203)

Testing of Hypotheses

To evaluate the extent of the barriers that affect BIM adoption, the significant correlations among these factors were first validated, followed by evaluating the effect of those significant correlations. In addition, the exploratory factor analysis of the two constructs, Perceived Usefulness and Intention to Use are a single factor, so they are grouped together and are named with Readiness in Use for further statistical analysis with other constructs. Table 3 below shows the correlations (r) and the significance at the level of $p < 0.05$:

Table 3. Correlations Among Barriers of BIM Adoption

	Image	**Job Relevance**	**Result Demonstrability**	**Overall Satisfaction**	**Perceived Ease of Use**	**Readiness in Use**
Subjective Norm	0.45	0.31*	0.30*	0.23*	0.31*	0.27*
Image		0.38*	0.21*	0.30*	0.22	0.34*
Job Relevance			0.34*	0.58*	0.29*	0.56
Result Demonstrability				0.48	0.34*	0.38*
Overall Satisfaction					0.60*	0.69*
Perceived Ease of Use						0.75*
Readiness						

*** p< 0.05**

From the analysis, correlation coefficients marked with * are significant correlation between the two constructs. To further evaluate the extent of the correlations, these significant correlations marked with * were further evaluated against Hopkins' (2002) table of correlation effects.

Table 4 below shows the effect of significant correlations according to Hopkins's interpretation.

Table 4.Effects of Significant Correlations among Barriers of BIM Adoption

	Image	Job Relevance	Result Demonstrability	Overall Satisfaction	Perceived Ease of Use	Readiness
Subjective Norm		0.31* Moderate	0.30* Moderate	0.23* Small	0.31* Moderate	0.27* Small
Image		0.38* Moderate	0.21* Small	0.30* Moderate		0.34* Moderate
Job Relevance			0.34* Moderate	0.58* Large	0.29* Small	
Result Demonstrability					0.34* Moderate	0.38* Moderate
Overall Satisfaction					0.60* Large	0.69* Large
Perceived Ease of Use						0.75* Very Large

Since the intention to use and perceived usefulness are combined as readiness to use, it can be seen that correlation between subjective norm and readiness to use is small (r=0.27). So the following two hypotheses H1a and H1b are accepted.

Hypothesis H1a: Subjective norm is positively correlated with intention to use the BIM system

Hypothesis H1b: Subjective norm is positively correlated with perceived usefulness of the BIM system

Since there is no significant correlationbetween subjective norm and image, hypothesis H1c is rejected.

Hypothesis H1c: Subjective norm is positively correlated with image of using the BIM system.

Since there is a significant correlationbetween image and readiness to use factor and the effect of the correlation is moderate (r=0.34), hypothesis H2 is accepted.

Hypothesis H2: Image of using the BIM system is positively correlated with perceivedusefulness of the BIM system.

Since there is no significant correlationbetween job relevance and readiness to use, hypothesis H3 is rejected.

Hypothesis H3: Job Relevance is positively correlated with perceived usefulness of the BIM system.

Since there is a significant correlationbetween result demonstrability and readiness to use and the effect of the correlation is moderate (r=0.38), hypothesis H5 is accepted.

Hypothesis H5: Result demonstrability of using the BIM system is positively correlated with perceived usefulness of the BIM system

Since there is a significant correlationbetween overall satisfaction and readiness to use and the effect of the correlation is large (r=0.69), hypotheses H8 and H9 are accepted.

Hypothesis H8: Process satisfaction is positively correlated with intention to use the BIM system.

Hypothesis H9: Outcome satisfaction is positively correlated with intention to use the BIM system.

Since there is a significant correlationbetween perceived ease of use and readiness to use and the effect of the positive correlation is very large (r=0.75), hypotheses H10 and H11 are accepted.

Hypothesis H10: Perceived ease of use is positively correlated with perceived usefulness of the BIM system.

Hypothesis H11: Perceived ease of use is positively correlated with intention to use the BIM system.

Since the factor analysis shows that these two constructs are in fact a single factor, the hypothesisH12 is eliminated.

HypothesisH12: Perceived usefulness is positively correlated with intention to use the BIM system.

Table 5 below shows that significant correlation (marked with *) and the corresponding correlation effect.

Table 5. Effects of Significant Correlations among Barriers Related to Subjective Norm and Job Relevance

	Experience	Voluntariness	Output Quality
Subjective norm	0.26	-0.06* Trivial	
Job relevance			0.17* Trivial

* $p < 0.05$

Since there is no significant correlationbetween experience and subjective norm (r = 0.26), hypothesis H6 is rejected.

Hypothesis H6: Experience is negatively correlated with subjective norm.

Since the effect of the significant correlationbetween voluntariness and subjective norm is negative (r = –0.06) and the effect is only trivial, hypothesis H7 is rejected.

Hypothesis H7: Voluntariness is positively correlated withsubjective norm.

Since the effect of the significant correlationbetween output quality and job relevance is only trivial (r = 0.17), hypothesis H4 is rejected.

Hypothesis H4: The output qualityis positively correlated withjob relevance.

Discussion

Based on the extended TAM2 model, this research has expanded the construct of "perceived ease of use". The readiness to use is found to be influenced by the critical factors, namely: subjective norm, image, job relevance, results demonstrability, perceived ease of use, and overall satisfaction. Readiness to use additionally includes the user's mental attitude and intention to use the software in the coming two months. Readiness to use is a critical factor in an individual's usage behaviour regarding software adoption. If BIM technology is to be broadly used by the building and construction industry, all of these critical factors should be considered to achieve a successful implementation. One such example, which illustrates this well, is an architect whose direct manager encourages him/her to use the BIM approach to implement a project (i.e., subjective norm) as it is able to help deliver green design (i.e., image) requested by the client (i.e., job relevance). The manager in this scenario would also support the architect's undergoing basic and advanced training before a project began (i.e., perceived ease of use). As a result, the final 3D digital model of the architectural design could be presented to the client containing all necessary information components and, as an additional benefit, potentially could aid the team in winning an international green design award (i.e., result demonstrability). This architect would then gain satisfaction from the good results generated through the advantages that BIM technology provides for new design approach.

The results of expanded TAM2 show that adoption of software in the Hong Kong context could be enhanced, should companies be willing to provide training and support to their staff in the areas of the critical factors. It would be remiss not to mention that support from senior management, who should be aware of the benefits of this, would be vital to the efforts in adopting the software. Besides design visualisation, BIM has been implemented along the building cycle from design to documentation stage, then on to construction and even facility management. After obtaining more experience through training, consultation and implementation, such as establishing their own standards and guidelines (Building Information Modelling, 2010), more projects have adopted BIM technology. Other than government, the commercial sector also has increasing career-growth opportunities with BIM technology as a required skill set. The immediate implication of this validated model is that building and construction companies in Hong Kong could try to adopt BIM in a smaller scale to see how BIM could serve the companies. This small-scale adoption provides opportunities for companies to explore new way to increase their work quality before large-scale implementation.The broader implication to this validated model is that BIM could be a movement or culture for Hong Kong building and construction industry to use BIM. The workflow and output of BIM become a common language and standard for the industry. Training programs for using BIM become a standard item.

New insights are gained for the benefit of other researchers who apply expanded TAM2 model to technology adoption. The findings of this researchoutline the fact that experience and voluntariness may not have significant effects on readiness to use when a technology is specific to the construction industry and implemented under different economic circumstances. During stable economic times, an individual may be exposed to more career-advancement prospects regardless of whether the individual's knowledge is as competitive as his or her peers in an environment where the talent pool competing for one vacancy is smaller. However, the situation may be different during economic downturns. Workers may wish to advance their knowledge regardless of whether or not this skill is required for the position they are seeking (i.e., regardless of voluntariness and experience).

Moreover, the importance of overall satisfaction should not be ignored. From the validated expanded TAM2 model, both process satisfaction and outcome satisfaction of a user can directly provide positive influences on the intention to use a technology. Therefore, future researchers can add the factor of overall satisfaction to their research model when performing analysis on technology acceptance related topics. Sufficient and good quality training should also be considered as it would help the overall satisfaction.

In Hong Kong where efficiency, green and innovative management, and safety are heavily emphasized, adoption of BIM is affected in certain degree.Politically, since the Hong Kong Housing Authority specified contractors to use BIM for government housing project, Hong Kong Housing Authority has become the biggest subject norm to influence contractors to think that BIM is very important. In order to bid for government projects, contractor and their subcontractors have learned to use BIM one way or the other. The emphases by government for green technology and safety have caused contractors to look into ways to reduce construction waste and methods to the safety of the construction projects. Clash analysis in the design process is one of the tests done by BIM where contractors found to be very efficient, fast and able to reduce construction waste. Since waste reduction is possible through clash analysis by saving abortive work at design stage, company management has also looked into the increase of return of investment in order to convince top management the adoption of BIM.

Culturally, engineers may appreciate the use of BIM to solve problems more than architects as the latter may not be responsible to solve some issues at an earlier stage of the design phase of a project. Marketing staff will use BIM to promote the image of the company as a BIM-enabled company as well as using the beautiful 3D output to tell people the power of BIM. According to respondent D, this marketing is important many companies need someone to tell them something useful. This word-of-mouth has helped in the BIM adoption among Hong Kong construction companies.

Limitation and Future Development

It is important to note that some limitations were experienced whilst conducting this research. First, the computer anxiety scale was not used to measure the survey respondents. Only some levels of trained professionals were included in this research to investigate whether a trained employee would have a positive impact on user acceptance factor. AEC industry professionals who either may or may not have adopted BIM were included in this research. Future research should also consider this factor in the construct of the model. Second, as the questionnaire was anonymous, it was difficult to keep track of user behaviour, which is out of the scope of this research. It was the intent to purposely not include user behaviour as part of the focus, in order to avoid any issues that may be associated through tracking individuals' performance. It may be useful for future researchers to consider investigating effects on organisational levels, as opposed to merely individuals' levels, if these researchers are able to obtain management approval from the organisations they wish to target for the purposes of their research. Third, the research questionnaires were sent to participants and the results collected during the worldwide economic downturn of 2008 and 2009. It is likely that the survey results would vary under stable economic conditions. Future researchers may extend the research period and compare data collected during both good and bad economic environments.Fifth, the BIM momentum in 2008 was less compared with current market situation in 2013. With increasing BIM adoption from Government initiatives in other regions, the Hong Kong Government has also taken actions to accelerate BIM adoption for green and sustainable design concern. If the research survey is conducted in 2013, some of the questions may have more positive feedback than before as some industry practitioners might have more training and actual project experience with BIM in the past few years.

Conclusion

After conducting the quantitative research analysis, the findings concluded that the ten barriers to the adoption of BIM in Hong Kong's building and construction industry are subjective norm, voluntariness, image, job relevance, output quality, result demonstrability, perceived ease of use, overall satisfaction, experience and the readiness to use.Among these ten barriers, perceived ease of use, readiness to use and overall satisfaction are the major factors that facilitate the adoption of BIM. The subjective norm, image, job relevance and result demonstrability are also deemed to provide positive impact on BIM adoption. However, the effect of experience, voluntariness and output quality of an individual user may not have significant impact on the user's overall satisfaction in BIM adoption. Overall satisfaction, including process satisfaction and outcome satisfaction, provides a large positive motivation to facilitate the use of BIM for an individual.

The TAM2 was ratified to become expanded TAM2 with six critical factors: subjective norm, image, job relevance, results demonstrability, perceived ease of use, and how the overall satisfaction has significant effects on readiness to use. Expanded TAM2 tests have confirmed user intention of using new technology if it is introduced at an earlier stage and used throughout the whole system implementation project life cycle. Additionally, it verifies whether or not software adoption decisions of perceived usefulness need to be expanded from their current focus on expected individual level performance gains to study team-based structures and incentives. This provides a new insight for other researchers who apply TAM2 to technology adoption that experience and voluntariness may not have significant effects on readiness to use when a technology is specific to the construction industry and under varying economic situations. In expanded TAM2, the major contributing factors are perceived to be the ease of use and overall satisfaction.

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