FACTOR ANALYSIS OF BIM ADOPTION IN THE THAI ARCHITECTURAL AND ENGINEERING DESIGN INDUSTRY

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Abstract

Building information modelling (BIM) is a computer technology in the building and facility design industry which is being adopted in many countries for implementing design projects. The Thai architectural and engineering design industry is currently perceiving and adopting the changing design technology of BIM. Factors related to BIM adoption behaviours in the industry were studied, classified, and analysed using exploratory factor analysis (EFA) statistical techniques. Empirical data were collected from 278 samples from Thai engineers and architects who were experienced in using BIM. The factors were classified by EFA into 4 groups and comprised 1) adopter characteristics, 2) BIM characteristics, 3) vendor characteristics, and 4) environmental characteristics. Results led to the formulation, presentation, and discussion of a strategy to enhance BIM adoption in the Thai architectural and engineering design industry.

Keywords: BIM, adoption, architectural and engineering design, factor analysis

Introduction

Recent improvements in design technology have resulted in a new methodology known as building information modelling (BIM) which has totally changed the process of data input from traditional coordination (x, y-axis) in computer-aided design (CAD) to 3-dimensional object oriented with greatly increased potential (Barlish and Sullivan, 2012). BIM is a computer technology which is being adopted by the building and facility design industry for

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implementing projects in many countries. The Thai architectural and engineering design industry is adopting the design technology of BIM. However, the lack of understanding and perception by professional architects and engineers is currently hindering widespread implementation of BIM in the industry. The main objective of this research was to study and analyse factors which explain the behaviours of Thai architects and engineers towards BIM adoption. Results will allow top managers, division managers, architects, and engineers to assess the current status of their preparations. Strategies for supporting the adoption of BIM by the Thai architectural and engineering design industry are presented.

Research Background

Trott (2008) stated that the diffusion and adoption processes of innovations or technologies in a society generally include multiple factors such as the influences of psychological or personal features, technology perceptions, communication behaviour, and socio-demographic attributes. The study of how and why consumers purchase goods and services falls within the arena of consumer buying behaviour. Rogers (2003) noted that diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system. He also considered diffusion as a special type of communication concerned with the spread of messages that are perceived as new ideas. An innovation is an idea, practice, or object that is perceived as new by an individual or another unit of adoption. In this research, BIM was specified as an innovation which is diffusing into the Thai architectural and engineering design industry. Rogers (2003) also suggested that a diffusion of an innovation model determined 5 characteristics that influenced the rate of diffusion and which are: 1) Relative advantage: the degree to which an innovation is perceived as better than the idea it supersedes by a particular group of users, measured in terms that are important to those users such as economic advantage, social prestige, convenience or satisfaction; 2) Compatibility: the degree to which an innovation is perceived as being consistent with the values, past experiences, and needs of potential adopters; an idea that is incompatible with their values, norms, or practices will not be adopted as rapidly as an innovation that is compatible; 3) Complexity: the degree to which an innovation is perceived as difficult to understand and use; 4) Trialability: the degree to which an innovation can be experimented with on a limited basis; an innovation that is trialable represents less uncertainty to the individual who is considering it; 5) Observability: the easier it is for individuals to see the results of an innovation, the more likely they are to adopt it. Wikipedia (2016) defined awareness as the state or ability to perceive, feel, or be conscious of events, objects, or sensory patterns. At this level of consciousness, sense data can be confirmed by an observer without necessarily implying understanding. More broadly, awareness is the state or quality of being aware of something. In biological psychology, awareness is defined as a human's or an animal's perception and cognitive reaction to a condition or event. Schiffman and Kanuk (2003) stated that adoption is the decision to make full use of an innovation as the best course of action available. Rejection implies the opposite decision not to adopt an innovation. In a larger context, adoption is seen as part of a process whereby an individual or other decision-maker unit passes from first knowledge of an innovation to forming an attitude towards the innovation, to a decision to adopt or reject, to implementation of the new idea, and finally to confirmation of this decision. This is known as the innovation-decision process. Sorescu *et al.* (2003) presented a conceptual framework that specified the factors influencing the diffusion of new products. They identified 4 major groups of factors that affected both the first and repeat purchases of a new product by customers as adopter characteristics, innovation characteristics, firm characteristics, and environment characteristics. Davis (1985) presented a technology acceptance model which became famous and has been widely used to study behavioural acceptance of technologies by consumers in societies such as smartphones, LED TV, etc. The model demonstrated that the factor of perceived ease of use influenced the "perceived usefulness" of a technology. Both the "perceived ease of use" and the "perceived usefulness" have a direct influence on the factor of attitude towards using the technology. Finally, the attitude towards using the technology has a direct influence on the factor of actual system use. Son *et al.* (2015) researched factors related to BIM adoption in design organisations by focusing on architects' behavioural intentions in Korean companies. Results showed that top management support, subjective norm, compatibility, and computer self- efficiency were all critical factors affecting the architects' behavioural intentions to adopt BIM.

Method

Identification of the Factors

The Delphi technique is a widely used and accepted method for achieving convergence of opinion concerning real-world knowledge solicited from experts within certain topic areas (Hsu and Sandford, 2007). This technique is designed as a group communication process of experts that aims at conducting detailed examinations and discussions of a specific issue. The process can be continuously iterated until a consensus is determined to have been achieved. This technique was used to confirm the factors and the conceptual research model. The Delphi technique began by identifying the factors, related theories, and literature available as textbooks and research articles. All the factors were summarised, listed, and then confirmed by experts using the Delphi technique. A group of 7 experts in related fields was chosen based on their experience and included:

- Four experts (2 engineers and 2 architects) with more than 10 years' experience in the Thai architectural and engineering design industry.
- Two experts in BIM and other research processes from academic institutions.
- One expert in the marketing field from a private company.

The listed factors were confirmed by a consensus of opinions of the 7 experts both directly and individually starting from expert 1, 2, 3 …, 7 and returning to expert 1 circularly. Without meeting each other, aexperts carefully and individually considered the listed factors at least 3 times per expert until the consensus was saturated. Once the listed factors were confirmed and categorised by the 7 experts, they were constructed and made ready for analysis. Initial factors and items are listed in Table 1.

Questionnaire Design

A questionnaire survey was designed for data collection to confirm the causal factors or items of BIM adoption by Thai architects and engineers. The questionnaire items were designed with reference to the initial factors and items listed in Table 1. The questionnaire comprised 5 parts. The first part included the demographics of the respondents as profession, major profession, and organisational background (3 questions). The second part included the adopter characteristics (3 questions), the third part was BIM characteristics (4 questions), the fourth partwas vendor characteristics (4 questions), and the last part was environmental characteristics (four questions). The first part was measured by the frequency (percentage) of the respondents while the remaining parts were measured on a 5-level Likert scale from 'strongly disagree' to 'strongly agree'.

Validity and Reliability Tests

To ensure that the items in the questionnaire were appropriate for data collection, both validity and reliability tests were used. In the validity test, interviews with the 7 experts regarding the identification of the factors (section 3.1) confirmed the results. The experts reviewed and commented on whether the items were accurate representations to measure the model. They also suggested some items which were more appropriate in the context of the research. This exercise was useful to provide content validity and ensured that the items were neither ambiguous nor confusing.

Cronbach's alpha was used to evaluate the reliability of the questionnaire. A pilot study was conducted by 30 target samples (Thai architects and engineers) to determine the reliability. The 15 items (5-level Likert scale measurements) including 3 items of adopter characteristics (AC), 4 items of BIM characteristics (BC), 4 items of vendor characteristics (VC), and 4 items of environmental characteristics (EC) were tested by computer statistical software. The output gave the Cronbach's alpha coefficient of all 15 items as 0.890 and suggested that it would be 0.902 if AC1 was deleted. Therefore, the researcher decided to delete AC1 (experience) from the model. The Cronbach's alpha coefficients of each factor including (AC), (BC), (VC),. and (EC) were 0.92, 0.734, 0.885, and 0.733, respectively. All coefficients were above 0.7, demonstrating that the questionnaire was reliable (Nunnally, 1978).

Data Collection

Once the questionnaire was designed, a target group of Thai architects and engineers (with experience in BIM) was selected using a convenience non-probability sampling technique. Almost all the respondents lived in Bangkok, with some from big cities surrounding Bangkok. The survey began in April and concluded in June 2015 (3 months). Face-to-face interviews were conducted to explain the details of the questionnaire and ensure that the respondents understood the aim of the survey. In total, 300 questionnaires were completed, but 22 were discarded due to incomplete or biased responses. As such, 278 were recognised as valid and were analysed.

Results

Descriptive Results

The respondents' profiles and the 278 questionnaires completed by the Thai architects and engineers were analysed and the descriptive results are shown in Table 2.

Exploratory Factor Analysis

Exploratory factor analysis (EFA) is a statistical method for uncovering the underlying structure of a relatively large set of variables (Norris and Lecavalier, 2010). EFA is used to reduce the number of variables to a smaller set of underlying summary variables called factors. In this research, EFA was implemented to determine the underlying structure of factors related to BIM adoption behaviours in the architectural and engineering design industry in Thailand. EFA was

Table 1. Initial factors and items

Factor	Item
Adopter Characteristics: AC	AC1: experience AC2: liking the new technology AC3: liking in using tools, devices, etc.
BIM Characteristics: BC	BC1: relative advantage BC2: quality BC3: ease of use BC4: compatibility
Vendor Characteristics: VC	VC1: vendor reputation VC2: vendor service VC3: trialability VC4: vendor marketing effort
Environmental Characteristics: EC	EC1: BIM adoption of colleagues EC2: BIM adoption of general architects & engineers EC3: pressure by boss or client EC4: BIM training

implemented with varimax rotation using computer statistical software and the output showed the Kaiser- Meyer- Olkin (KMO) measure of sampling adequacy – 0.850 (KMO>0.7) (Tabachnik and Fidel, 2001), Bartlett's test of sphericity had a significant value = 0.000 (less than 0.05) with the approximate Chi- square = 998.45, df = 91. Factor loading values less than 0.4 were eliminated. The extraction of EFA was based on initial eigenvalues greater than 1 (Kaiser, 1958), as shown in Table 3, and the output analysis showed 4 components as the number of factors in this EFA. The percentage of explained variance was 72.6%.

The EFA output showed that the 14 items were classified into 4 groups comprising factor 1: BC1, BC2, BC3, BC4, and VC3 (5 items); factor 2: VC1, VC2, VC4, and EC4 (4 items); factor 3: EC1, EC2, and EC3 (3 items); and factor 4: AC2 and AC3 (2 items). Furthermore, the reliability of the questionnaire (all respondents) in terms of the 4 factors was assessed on the basis of Cronbach's alpha coefficient. According to Nunnally (1978), a Cronbach's alpha coefficient of 0.7 or higher is recognised as acceptable. The average values of the coefficient were acceptable for all 4 factors, ranking from 0.769 to 0.880 and the value of all items was 0.883.

Table 4 shows the EFA results of the causal factors of BIM adoption by Thai architects and engineers classified as 4 factors. In this research, the 4 factors were named by considering the majority of the items included in the factors; they were: factor 1 BIM characteristics, factor 2 vendor characteristics, factor 3 environmental characteristics, and factor 4 adopter characteristics.

Conclusions

This research presented a factor analysis of BIM adoption in the Thai architectural and engineering design industry. A total of 278 sample questionnaires completed by Thai engineers and architects who were experienced in using BIM were analysed to confirm the factors. The respondents' profiles are shown in Table 3. Factors related to BIM adoption were identified and confirmed using the statistical

Table 2. Descriptive results

Description	Frequency	Percentage
Profession		
- Engineer	72	25.9
- Architect	176	63.3
- Others	30	10.8
Major Profession		
- Civil	54	19.4
- Mechanical	10	3.6
- Electrical	10	3.6
- Industrial	2	0.7
- Environmental	4	1.4
- Mining	0	0.0
- Computer	2	0.7
- Architecture	162	58.3
- Urban design	10	3.6
- Interior	12	4.3
- Landscape	0	0.0
- Others	12	4.3
Organizational background		
- Private sector	194	69.8
- Government sector	40	14.4
- Own business/freelance	44	15.8

technique of EFA. The 4 factors of BIM adoption by Thai architects and engineers were factor 1: BIM characteristics comprising relative advantage, quality, ease of use, trialability, and compatibility; factor 2: vendor characteristics was comprised of vendor service, vendor reputation, vendor marketing effort, and BIM training; factor 3: environmental characteristics comprised BIM adoption of colleagues, BIM adoption of general architects and engineers, and pressure by boss or client; and factor 4: adopter characteristics comprised liking new technology and liking and/or using tools/devices.

To recommend strategies for enhancing BIM adoption in the Thai architectural and engineering design industry, the first and second items in terms of factor loading (Table 4) were selected as a guideline to formulate the strategy for each factor. The factors of BIM adoption by Thai architects and engineers are shown in Table 5.

The factors and items (Table 5) could be used as strategies for enhancing BIM adoption in the Thai architectural and engineering

Table 3. Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5..41	41.723	41.723	5.841	41.723	41.723	3.343	23.880	23.880
2	1.745	12.465	54.188	1.745	12.465	54.188	2.794	19.957	43.837
3	1.472	10.511	64.698	1.472	10.511	64.698	2.207	15.765	59.602
4	1.106	7.900	72.599	1.106	7.900	72.599	1.820	12.997	72.599
5	0.685	4.895	77.493						
6	0.543	3.880	81.373						
7	0.497	3.548	84.921						
8	0.472	3.368	88.289						
9	0.375	2.678	90.967						
10	0.309	2.209	93.176						
11	0.272	1.940	95.116						
12	0.254	1.812	96.929						
13	0.221	1.579	98.07						
14	0.209	1.493	100.000						

Table 4. Factor loading and Cronbach's alpha

Item	Factor 1	Factor 2	Factor 3	Factor 4	Cronbach's alpha	
BC1	0.822	0.172	0.050	0.109		
BC2	0.814	0.120	0.107	0.272		
BC3	0.751	0.135	0.140	0.214	0.880	
VC3	0.704	0.464	0.139	0.126		
BC4	0.607	0.312	0.302	0.288		
VC2	0.083	0.865	0.205	0.106		
VC1	0.216	0.829	0.087	0.123	0.827	0.883
VC4	0.312	0.789	0.066	0.185		
EC4	0.450	0.497	0.187	-0.265		
EC1	0.103	0.038	0.867	0.052		
EC2	0.055	0.120	0.840	0.163	0.769	
EC3	0.265	0.252	0.706	-0.097		
AC2	0.219	0.150	0.133	0.856	0.801	
AC3	0.303	0.107	-0.002	0.829		

Table 5. Factors of BIM adoption in Thai architects and engineers

BIM Adoption	BIM characteristics	- Relative advantage - Quality
	Vendor characteristics	- Vendor service - Vendor reputation
	Environmental characteristics	- BIM adoption of colleagues - BIM adoption of general architects & engineers
	Adopter characteristics	- Liking the new technology - Liking using tools, devices, etc.

design industry to increase competitive advantage. The strategies can be summarised as follows:

Strategy I: promote BIM by focusing on the relative advantages and qualities of BIM itself. This strategy should be implemented by academicians and experts in educational institutions. Other organisations that can promote this strategy include professional organisations such as the ACT (Architect Council of Thailand), EIT (The Engineering Institute of Thailand), CEAT (The Consulting Engineers Association of Thailand), and COE (The Council of Engineers). This will support Thai design companies and personal professionals through the understanding and implementation of BIM. Strategy II: prepare good services and present company profiles and reputations to customers (architects and engineers or draftsmen) who are interested in BIM. This strategy should be implemented by BIM vendors in their marketing efforts. Strategy III: survey and observe colleagues and general architects and engineers in architectural and engineering design firms in terms of BIM adoption and application. The information received can be discussed to enhance BIM adoption in a company. This strategy should be implemented by design managers or senior architects/engineers in the design firms to keep pace with the future competition. Strategy IV: focus on potential BIM adopters (architects and engineers or draftsmen) who prefer and like new technologies and new tools or devices. This strategy should be implemented by a BIM vendor to seek out customers.

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