Strategic factor analysis of innovation adoption in Thai architects: A case study of Building Information Modeling

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Abstract. Inspiring competition and enhancing standards of living as the foundation of a progressive knowledge-based society, innovation has been acknowledged as having an indispensable influence on the economic development of nations for a long time. Currently being implemented in nations throughout the world for the design and application of design projects, building information modeling (BIM) involves computer technology in the structure and facility design industry. BIM’s adaptive design technology is presently being distinguished and embraced by the Thai architectural design industry. Exploratory factor analysis (EFA) statistical approaches have been employed to examine, categorize and evaluate the factors associated with BIM adoption behavior in the industry. A total of 199 Thai architects with familiarity in the utilization of BIM were employed to accumulate the empirical data. Using EFA, factors were categorized into four major clusters including (1) adopter characteristics, (2) BIM characteristics, and (3) vendor characteristics, as well as (4) environmental characteristics. In order to articulate, exhibit, and deliberate an approach to develop BIM implementation by the Thai architectural design industry, the outcomes were applied.

1. Introduction
For a variety of research fields such as economics, business, engineering, science and sociology, the topic of innovation has gained increasing interest. In spite of this, similar words and concepts including change, invention, design and creativity have often been misunderstood to mean the same as ‘innovation’. As precision by its very features restricts inventiveness, the characterization of innovation covers a wide range of conceptions. By completely altering the data input procedure from traditional coordination (x, y-axis) in computer-aided design (CAD) to 3-dimensional object orientation, resulting in significantly improved potential, recent enhancements in design technology have led to a new approach called ‘Building Information Modelling’ (BIM) [1]. For the execution of projects in numerous nations globally, BIM is computer technology being implemented in the building and facility design industry. The design technology of BIM is also being utilized by the Thai architectural design industry, though prevalent application throughout the nation remains somewhat limited by a lack of comprehension and awareness by architects. Therefore, the objective of this research is to study the factors related to BIM adoption in the Thai architects using exploratory factor analysis (EFA). This paper is an extension of from previous research [2], [3] that studied the factors related to BIM adoption behaviors of Thai architects and engineers (including civil, mechanical, electrical, sanitary engineers, etc.). In this research, Thai architects working in Thailand would be
focused as samples. Researching and assessing the factors that detail the behaviour among Thai architects towards BIM adoption was the primary aim of this research study. Top managers, design managers, senior architects and architects should be able to utilize the results of this work to examine the present status of their planning. Also provided by the current work were strategies intended to reinforce the implementation of BIM by the Thai architectural design industry.

2. Research Background

As suggested by Troff [4], multiple factors relating to the effects of psychological or personal features, technology assessments, communication behaviour and socio-demographic qualities are concerned in the diffusion and adoption steps of innovation or technologies in civilization. Thus, consumer buyer behaviour comprises the study of how and why consumers buy certain goods and services. Diffusion is considered the process through which innovation is conveyed to participants of a social system using specific channels, as defined by Rogers [5]. A distinctive form of interaction involving the dissemination of messages distinguished as being new ideas can also be considered as diffusion, while any idea, practice, or object observed to be new by an entity or another unit of adoption is an innovation. Any form of innovation spreading into the Thai architectural industry is deemed to be BIM for the purposes of this study. Rogers [5] likewise offered that the diffusion of an innovation model may be characterized using five features that impact the rate of diffusion. The first feature is Relative Advantage, which is the level to which an innovation is thought to be superior to the idea that came before it by a certain group of users as determined by quantifiable measures including economic benefit, social standing, accessibility or gratification. The second feature is Compatibility, which is the level to which an innovation is thought to be in line with the standards, previous experiences and requirements of prospective users. An innovation that is well-suited with their values, norms or practices will be accepted and utilized more readily than one that is mismatched. The third feature is Complexity, which is the level to which an innovation is deemed to be problematic to figure out and use. The fourth feature is Trial Usability, which is the ease with which an innovation can be tested during a controlled period. Any innovation that is testable equates to decreased hesitation to a consumer who might be pondering it. The final feature is Observability. Consumers are more willing to adopt an innovation if it is easier for them to observe the results of its operation or function. Awareness means the state or ability to distinguish, feel or be aware of certain events, objects or sensory patterns, as defined by Wikipedia [6]. At this dimension of cognizance, sense information can be affirmed by an eyewitness without fundamentally suggesting comprehension. All the more comprehensively, mindfulness is the state or nature of monitoring something. In organic brain research, mindfulness is characterized as a human's or a creature's observation and intellectual response to a condition or occasion. The decision to fully employ an innovation as the best course of action available is the definition of adoption as found by Schiffman and Kanuk [7], while the decision not to adopt an innovation is defined as rejection. In the overall situation, adoption is viewed as an aspect of the overall procedure, whereby an entity or other decision-maker moves from the initial realization of an innovation to developing an opinion of that innovation and deciding whether or not adopt it, to the operation of the new innovation and verification of the decision. This is what is called the innovation-decision process. A conceptual framework specifying the factors manipulating the dissemination of new products was offered by Sorescu et al. [8]. They recognised four noteworthy gatherings of variables that influenced both the initial and subsequent purchases of a new item by consumers as adopter attributes, advancement qualities, firm qualities and condition qualities. Commonly employed to study the behavioural approval of technologies by people in society including smartphones and LED TVs, Davis [9] introduced a technology acceptance model (TAM) that became quite renowned by showing that the appearance of identified ease of use affected the recognised convenience of technology. The aspect of attitude towards using the technology is directly influenced by “perceived ease of use” as well as “perceived usefulness”. Ultimately, the aspect of actual system use is influenced by the opinion towards using the technology. The factors concerning BIM adoption in design organisations by concentrating on architects’ behavioural objectives in Korean firms were
studied by Son et al. [10], which identified that management sponsorship, particular standards, compatibility and computer self- proficiency were significant factors influencing the architects’ behavioural intentions to implement BIM. BIM design technology has been adopted by Thailand’s architectural design industry. Still, a logjam for BIM adoption has been created by the present shortage of administrators with suitable knowledge and awareness. BIM execution and implementation has been examined by numerous academics [11]. A significant degree of acceptance into current system practices with obvious concentration and norms aimed at satisfying the requirements of the project as well as clients is needed for the implementation of BIM [12-13]. BIM acceptance by architectural firms in other nations such as India was slow and affected by expertise, trialability and management support, as identified by Ahuja et al. [14]. The primary obstacles to BIM use by engineering consulting firms in Malaysia included a lack of proficient personnel, supervision and governmental support [15], while the critical factors for BIM implementation by architects in China comprised enthusiasm, technical flaws in BIM and BIM competence [16]. Currently, Thai architectural design firms are utilizing BIM to execute design projects.

3. Research Method

3.1. Factor Identifications
For the purpose of gaining the unification of belief regarding actual knowledge lobbied from experts within particular fields, the Delphi technique is a commonly utilized and acknowledged approach [17]. Designed to carry out comprehensive examinations and discussions of a specific issue, this technique is intended as a group communication process among experts. Until such a time as agreement has been deemed to have been accomplished, the process can be repeated over and over again. Through identification of the factors, related theories and literature available including textbooks and research articles, this approach was employed to verify the aspects as well as the theoretical research model. Experts were employed to run through, inventory and substantiate all factors. Based on their particular experience, seven experts in correlated fields were selected as follows:

- Four experts from the Thai architectural design industry (senior architects) possessing more than 10 years of experience,
- Two BIM specialists from academic institutes with expertise in other enquiry procedures, and
- A marketing field professional from a private firm.

Through agreement of estimation among the seven specialists directly as well as independently beginning from specialists 1 to 7 and back to specialist 1, the listed factors were verified. Exclusive of having any contact with each other a minimum of three times for each expert until agreement was overwhelming, all specialists considered the listed factors cautiously and discretely. The listed factors were composed and prepared for analysis after they were corroborated and catalogued by the seven specialists. Table 1 provides a list of the preliminary factors and details.
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                          |
| Environment characteristics :EC | VC4: vendor marketing effort               |
|                                 | EC1: BIM adoption by colleagues            |
|                                 | EC2: BIM adoption by general architects and others |
|                                 | EC3: pressure by boss or client            |
|                                 | EC4: BIM training                          |

3.2. Questionnaire development
Data collection was carried out using a questionnaire survey in order to determine the principal causal factors leading to Thai architects adopting BIM. The questionnaire was subdivided into five factor categories with the items selected as listed in Table 1. The initial section covered demographic data including professional and organizational background of the respondents (3 items). The second section covered the typical characteristics of adopters (3 items). The third section covered the characteristics of BIM (4 items), while the fifth section covered characteristics of the vendors (4 items). The final section covered environmental characteristics (4 items). The demographic data were presented by frequency percentage, and the other sections asked respondents to answer using a 5-point Likert scale from ‘strongly disagreement’ to ‘strongly agreement’.

3.3. Tests of reliability and validity
Validity and reliability tests were employed to ensure that the questionnaire items were suitable for their purpose. The validity testing involved interviews with seven experts to discuss the factors which were identified from Section 3.1. The expert reviewers confirmed that the items selected were appropriate for the measurement of the model, while also making further suggestions for items which might improve the model in this particular context. This is an import step in ensuring that the items are valid while avoiding confusion and ambiguity. To analyze the reliability of the items, Cronbach’s alpha was used in assessing the responses in a pilot study which involved 30 participants, who were Thai architects, in order to match the study population. The fifteen questionnaire items measured by Likert scale (AC [3 items], BC [4 items], VC [4 items], and EC [4 items]) underwent analysis using statistical software. The overall Cronbach’s alpha coefficient for the 15 items was 0.912, and it was observed that the result would be 0.935 without the presence of item AC1. Accordingly, AC1 (experience) was removed from the model. For each of AC, BC, VC, and EC categories, the Cronbach’s alpha coefficients were 0.734, 0.872, 0.885, and 0.831 respectively. Since none of the coefficients fell below 0.7, it can be concluded that the questionnaire was reliable [18].
3.4. Data collection
Having completed the questionnaire designed, the next stage involved the selection of the sample group of BIM-experienced Thai architects using a convenience non-probability sampling approach. The respondents were predominantly based in Bangkok, with a minority coming from other large urban centers nearby. The survey was carried out over a three-month period. Interviews were first conducted face-to-face in order to ensure that all the respondents fully understood the purposes of the research. A total of 250 questionnaires were distributed, while 199 were accepted for the study and thus underwent further analysis.

4. Results

4.1. Descriptive results
The profiles of the 199 respondents are given in the form of the results shown in Table 2.

| Description                  | Frequency | Percentage |
|------------------------------|-----------|------------|
| Major profession             |           |            |
| - Building architecture      | 178       | 89.5       |
| - Urban design               | 7         | 3.5        |
| - Interior                   | 8         | 4.0        |
| - Landscape                  | 6         | 3.0        |
| Organizational background    |           |            |
| - Private sector             | 135       | 67.8       |
| - Government sector          | 30        | 15.1       |
| - Own business/freelance     | 34        | 17.1       |

4.2. Exploratory factor analysis
Exploratory factor analysis (EFA) is a statistical technique which can be applied in order to determine the structure which underpins large sets of variables [19]. EFA can take these variables and eliminate those which are irrelevant, leaving only the summary factors. This study used EFA to establish the set of factors which influence the adoption of BIM among members of the Thai architectural community. The implementation of EFA was performed with varimax rotation which required statistical software from which the output presented the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy = .824 (KMO>0.7) [20]. Meanwhile, the value reported for Bartlett’s test of sphericity was significant at = .000 (less than .05) with and approximate chi-square value = 1314.32, and df = 91. Any factor loading values below 0.5 were discarded. The extraction of EFA was conducted on the basis of initial eigenvalues in exceeding 1 [21] as shown in Table 3, while the output analysis displayed four components as the number of factors for this particular EFA. The percentage value for explained variance was found to be 69.9%.
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         | 5.487 | 39.192       | 39.192       | 5.487 | 39.192       | 39.192       | 3.010 | 21.503       | 21.503       |
| 2         | 1.753 | 12.520       | 51.712       | 1.753 | 12.520       | 51.712       | 2.783 | 19.878       | 41.381       |
| 3         | 1.544 | 11.029       | 62.741       | 1.544 | 11.029       | 62.741       | 2.214 | 15.811       | 57.192       |
| 4         | 1.002 | 7.155        | 69.896       | 1.002 | 7.155        | 69.896       | 1.779 | 12.704       | 69.896       |
| 5         | .788  | 5.631        | 75.527       | .788  | 5.631        | 75.527       | .788  | 5.631        | 75.527       |
| 6         | .621  | 4.435        | 79.962       | .621  | 4.435        | 79.962       | .621  | 4.435        | 79.962       |
| 7         | .597  | 4.263        | 84.225       | .597  | 4.263        | 84.225       | .597  | 4.263        | 84.225       |
| 8         | .469  | 3.352        | 87.577       | .469  | 3.352        | 87.577       | .469  | 3.352        | 87.577       |
| 9         | .360  | 2.572        | 90.149       | .360  | 2.572        | 90.149       | .360  | 2.572        | 90.149       |
| 10        | .344  | 2.458        | 92.608       | .344  | 2.458        | 92.608       | .344  | 2.458        | 92.608       |
| 11        | .318  | 2.270        | 94.877       | .318  | 2.270        | 94.877       | .318  | 2.270        | 94.877       |
| 12        | .270  | 1.931        | 96.808       | .270  | 1.931        | 96.808       | .270  | 1.931        | 96.808       |
| 13        | .228  | 1.632        | 98.440       | .228  | 1.632        | 98.440       | .228  | 1.632        | 98.440       |
| 14        | .218  | 1.560        | 100.000      | .218  | 1.560        | 100.000      | .218  | 1.560        | 100.000      |

The output from EFA indicated that the 14 remaining items could be categorized into four groups, which were: factor 1 (BC1, BC2, BC3, BC4, and VC3); factor 2 (VC1, VC2, VC4, and EC4); factor 3 (EC1, EC2, and EC3), and factor 4 (AC2, and AC3). For these factors, the average values for Cronbach’s alpha were 0.765, 0.792, 0.814, and 0.839 respectively, and given that Nunnally [18] reports that a value greater than 0.7 can be deemed acceptable, these factors are acceptable, with the overall value for the four factors being 0.869.

Table 4. Factor loading and Cronbach’s alpha.

| Item   | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Cronbach’s alpha |
|--------|----------|----------|----------|----------|------------------|
| BC2    | .763     | .146     | .092     | .291     |                  |
| BC1    | .742     | .266     | .038     | .066     |                  |
| BC3    | .730     | .055     | .152     | .226     | 0.839            |
| VC3    | .655     | .480     | .153     | .123     |                  |
| BC4    | .578     | .300     | .345     | .217     |                  |
| VC2    | .068     | .850     | .242     | .118     | 0.814            |
| VC1    | .222     | .781     | .047     | .106     | 0.869            |
| VC4    | .292     | .775     | .086     | .182     |                  |
| EC4    | .478     | .552     | .070     | -.268    |                  |
| EC2    | .054     | .067     | .862     | .125     |                  |
| EC1    | .144     | .029     | .862     | .071     | 0.765            |
| EC3    | .181     | .304     | .686     | -.125    |                  |
| AC2    | .160     | .154     | .094     | .864     | 0.792            |
| AC3    | .363     | .084     | .001     | .814     |                  |

Table 4 presents the results of EFA for the causal factors identified for the adoption of BIM by Thai architects, separated into four principal factor groups. The four groups were names as Factor 1 (BIM characteristics); Factor 2 (vendor characteristics); Factor 3 (environment characteristics), and Factor 4 (adopter characteristics).
5. Conclusions
This study conducted factor analysis in the context of BIM adoption among Thai architects, using a total of 199 sample questionnaires completed by respondents who were professionals in the Thai architectural industry and had experience in BIM use. The data were then analyzed in order to confirm the relevant factors. The demographic profiles of the participants are shown in Table 2. EFA was used to identify and confirm the relevant factors which influence the adoption of BIM. The four factors identified by EFA were: Factor 1 (characteristics of BIM including ease of use, quality, trialability, compatibility, and relative advantage); Factor 2 (characteristics of vendors including service, reputation, marketing, and BIM training); Factor 3 (characteristics of the environment including the BIM adoption by other architects, the adoption by colleagues, and the influence from management or customers), and Factor 4 (characteristics of typical adopters, including a liking for new technology and willingness to try new devices or tools). In order to make recommendations concerning the adoption of BIM in Thailand’s architectural sector, Factors 1 and 2 from the factor loading values shown in Table 4 were chosen to develop the guidelines influencing each of the factors. The factors for BIM adoption by Thai architects are presented in Table 5.

| BIM Adoption | Factors                                      |
|--------------|----------------------------------------------|
| BIM          | Quality                                      |
| characteristics | Relative advantage                           |
| Vendor       | Vendor service                               |
| characteristics | Vendor reputation                           |
| Environment  | BIM adoption by general architects & others  |
| characteristics | BIM adoption by colleagues                   |
| Adaptor      | Liking the new technology                    |
| characteristics | Liking using tools, devices, etc.            |

The factors and items which are shown in Table 5 might be employed to formulate strategies promoting the adoption of BIM among Thailand’s architects in order to create a competitive advantage. These strategies might be described briefly as follows: Strategy One: BIM should be promoted through an emphasis upon the advantages which are offered by the attributes of BIM. The ideal candidates to deliver such a strategy would be academics and experts in institutes of higher learning. Other professional organizations also have a role to play, such as the Association of Siamese Architects (ASA) and the Architect Council of Thailand (ACT). This policy would serve to encourage Thai design companies and their personnel to better understand and implement BIM in their professional practice. Strategy Two: BIM must be presented appropriately to interested architects through displaying a professional image, positive reputation, strong company profile and excellent services. This is an approach which must be implemented by BIM vendors who have a vital role to play in marketing. Strategy Three: Conduct observations and surveys to examine the extent to which BIM is adopted and applied in the general field of architecture and design. The findings can then be used to further support the effective use of BIM within architectural design firms. Design managers or senior architects should employ this strategy in order to keep pace with the latest advances in their industry and to maintain competitiveness. Strategy Four: BIM vendors should focus strongly upon those architects who express a liking for new technology and are willing to utilize the latest tools, such as BIM. This strategy will lead vendors to potential customers.

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