Second International Conference on Construction in the 21st Century (CITC-II)
"Sustainability and Innovation in Management and Technology"
10-12 December, 2003, Hong Kong

Identifying the Critical Factors of IT Innovation Adoption and Implementation within the Construction Industry

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Abstract
Many AEC firms aim to achieve excellence in all aspects of their work in part driven by IT innovation, which has to be continuously reviewed. It is generally believed that failure to effectively harness the benefits of IT can result in the loss of competitive advantage. This research is primarily concerned with understanding IT innovation adoption and implementation within the construction industry. A web-based survey was undertaken by senior management within leading UK companies. The purpose of the survey is to identify the particular drivers for the initial adoption of IT innovation, and criteria for decision-making linked UK companies' current practices. These critical factors will act as the inputs of a Technology-Process-Culture model to support the selection and implementation of IT innovations. It is hoped that this research project will provide a new understanding of IT innovations adoption and implementation from an integrated perspective of technology, process, and culture within the construction industry.

Key Words
IT innovations, Critical factors, Technology, Process, Culture, Survey

1. Introduction

Previously, the increasing importance of emerging information technologies has prompted researchers and practitioners to examine the nature of IT innovation adoption and implementation within organisations. As our knowledge-based economy increasingly depends on more and better information, the introduction and

successful adoption of new information technology by business firms has become a critical element of their competitive strategy (Porter and Millar 1985). Many Architectural/Engineering/Construction (AEC) firms aim to achieve excellence in all aspects of their work in part driven by IT innovations, which must be regularly reviewed. It is generally believed that failure to effectively harness the benefits of IT could result in the loss of competitive advantage. Obviously, adoption and implementation of IT innovation continues to have a significant impact on the AEC industry.

Rogers (1995) pointed out that the effects of generic innovation characteristics have been a key aspect research in technology diffusion and assimilations. So far, many efforts have been employed with innovation characteristics research, which investigate the relationship between the attributes or characteristics of an innovation. Tornatzky and Klein (1982) reviewed seventy-five articles concerned with innovation characteristics and their relationship to innovation adoption and implementation, and found that three innovation characteristics (compatibility, relative advantage, and complexity) had the most consist significant relationship to innovation adoption. However, technologies are affected by many factors beyond the features of the technology itself and its interaction with features of the adopting unit. The body of innovation characteristic research, which comprehensively summarised by Tornatzky and Klein's (1982) research, focuses on the relationship between innovation characteristics and innovation adoption but fails to pay sufficient attention to the other factors which perceptually influence the innovation adoption. An example of this kind of factors is the characteristics of organisation. Lai and Guynes (1997) found that the organisational strategies, structures, or context facilitated the adoption of integrated services digital networks (ISDN). But their research focused on one particular IT innovations and failed to reflect the relationship between organisational characteristics and generalized IT innovations. Based on 8 case studies, Mitropoulos and Tatum (2000) identified competitive advantage, process problems, technological opportunity, and external requirements as the four forces that drive construction companies to adopt new information technologies. However, some other drivers and barriers, which identified by other literature (e.g. Leonard-Barton 1988; Moore and Benbasat 1991; Liberatore and Nydick 2003; Liberatore and Pollack-Johnson 2003) had been ignored. If those factors existed in a particular case, the IT innovation probably would not have been adopted. Further, they did not provide any evidence regarding the factors affecting the successes of implementation.

This paper outlines the preliminary result of a research project, which intends to build up a Technology-Process-Culture (TPC) triangular model to support the industrial adoption and implementation of IT. From an integrative perspective based on the TPC model, the factors affecting IT innovation adoption and implementation within organisation are classified into technology, process, and culture three categorise.
This paper is primarily concerned with understanding IT innovation adoption within the construction industry through surveying the senior management within the leading UK consultant companies. The purpose of the survey is to identify the particular drivers for the initial adoption of IT innovation, and criteria for decision-making with UK companies' current practices. This questionnaire is part of the problem-structuring phase in the proposed model. The factors identified in this paper will act as the inputs of a Technology-Process-Culture model to support the selection and implementation of IT innovations.

2. Survey

2.1 Definition

IT innovation in this study is defined as any idea, technique and/or process, old or new, based on Information Technology, which is uniquely applied to any aspect of the production of goods and services. It is fundamental organizational innovation, whether it is analyzed from the vantage point of the entire organisation, or from a lower level: that of one or more organisation's adopting subunits, or even at the individual level. In this research, adoption is the process by which an organization identifies and decides to implement a new technology (Rogers and Schoemaker 1971). IT Implementation is defined as organisational effort directed towards diffusing appropriate information technology to support particular process within a specific organisational context.

2.2 Objectives of the Survey

- To identify the direct drivers for adopting IT innovations.
- To provide a basis for evaluating whether an organization should adopt a particular IT innovation
- To elicit the main criteria of decision-making for the Technology-Process-Culture model
- To understand the current practice of IT adoption and implementation within UK leading consultant companies

2.3 Data Collection and Response Rate

This research represents project management and managing consultant throughout the crossing-industry. The survey was conducted through an online questionnaire hosted on the Internet. Emails were used to target potential respondents known to be innovation adopters within UK leading consultant companies. The questionnaire was also promoted through 'banner advertising' on the website to encourage involvement through others in the companies who were not targeted by the Emails. A total of 93 questionnaire records were received within 8 weeks.

More than 300 hundred people viewed this questionnaire, and a total of 91 respondents completed the online questionnaire. Data from the 63 usable questionnaires was checked, edited, coded and analysed.
In relation to views, the approximate respondent rate is about 20%, which can be considered as relatively low. However, the low level of return rate may be a reflection of the low level of participation with decision-making of IT innovation adoption, which was deliberately not highlighted in the front page of the questionnaire in order to broaden the potential respondents. Notwithstanding the low response rate, the sample size for the IT professional group was large enough to be considered representative of the population.

3. Analysis

3.1 Designation of respondents

The designation of the respondents covered a wide range. The respondents varied in terms of the discipline, job position, the nature of organisation, and level of decision-making. A total of 63.4% and 36.6% of the respondents were in senior and middle management position, and professionals respectively. Upper and middle management respondents comprised managing directors, Heads of departments, principal consultants and senior consultants etc. Professionals comprised engineers, consultants, and graduate engineers etc. Because most of them had some experience of decision making on company, branch or project levels, and the respondents were generally quite senior, which gave validity to the survey results. Those respondents were responsible for making IT selection decision at different levels, 61.9% at project level, 25.4% at the business unit level, and 9.5% at the company level.

The professional discipline of respondents is highly diverse. The 63 respondents were involved disciplines such as Bridge Design & Assessment, Building Services Engineering, Business Analysis, finance, Civil Engineering, Chemical/Energy Engineering, Environment Engineering, Quantity Survey, Landscape Design, and Mechanical Engineering etc. The organisations for which the respondents work are involved in many industries. Of the 63 respondents who participated in the survey, 28.6% were from IT consultants, 7.9% were from Software development organisations, 28.6% were from architectural, structural, engineering and environmental consultant, 15.9% from transportation. Small number respondents were from other industries.

3.2 Statistical Analysis

Methodologies utilized in data analysis depend on the desired objective of this study, which is to identify the critical factors for IT adoption and implementation. The published literature related to technology, process, culture, integrated system and innovation had been structurally reviewed. A total of 70 papers or books pertaining to adoption and implementation of IT innovation were identified through a search of the literature. 56 sub-factors were drawn out to build up the “items pool” for the Technology-Process-Culture model. Both the fieldwork and the pilot study have been conducted within industry and the academic community. The Part I and Part III of the questionnaire have been designed to get personal information and empirical cases from the respondents respectively. In the Part II, the respondents were asked to rate the importance of factors relating to selection and adoption of IT innovations, and to identify whether the factors are drivers for stimulating an organisation to adopt IT innovations. 0-3 scales were employed in this research. 3 (strong importance) represents having a strong influence on the IT adoption decision and acting as one main criteria for decision-making, 2 indicates moderate importance, 1 indicates slight importance, and 0 represents having no effect on the decision to adopt IT. Detailed statistical analysis was conducted using the Statistical Package for Social Sciences (SPSS) software package and Microsoft EXCEL.

3.2.1 Technology Perspective

Due to the obvious limitations imposed by the maximum length allowed for this paper, " the technology factors", have been selected as an example of the detailed analysis undertaken. Arithmetical mean and T-test are both used for eliciting the factors that influence the IT adoption decision. The rate means for technology factors are listed in the table 1. The technology factors considered most important by the respondents in descending order were relative advantage 2.75, technology opportunities 2.65, observability or triability 2.52, result demonstrability 2.46, preparedness 2.44, cost 2.40, and profitability 2.35. Factors with means over 2.3 will be selected as the decision-making criteria. The means of 2.3 represents the factor is rated by 60% respondents as strong importance, 20% as moderate importance, 10% as slight importance, and 10% as no importance. The means of the other 8 factors, excepting the social approval and image, are between 1.71 and 2.21. Social approval and Image were considered the least important by the respondents.

Based on the sample's ratings, statistical one-sample *t*-tests of the mean were carried out to check the entire population's (respondents in general) likely response to the issues raised in the questionnaire.

Table 1 Means of Rating and Percentage of Drivers For Technology Factors

Technology Factors	Means of Rating	Percentage of Drivers
Relative advantage	2.75	75.0%
Compatibility	2.21	47.3%
Complexity	2.17	43.1%
Observability or Triability	2.52	45.1%
Technologies Opportunities	2.65	81.0%
Centrality	2.08	57.4%
Cost	2.40	62.3%
Communicability	1.87	17.6%
Divisibility	1.71	25.0%
Profitability	2.35	65.4%
Social Approval and Image	1.29	13.7%
Voluntariness	2.10	31.4%
Result Demonstrability	2.46	63.0%
Visibility	1.95	36.0%
Preparedness	2.44	51.9%

The null hypothesis H_o: $m = m_o$ and the alternative hypothesis H_1: $m > m_o$ were set out, where m is the population mean and m_o is the critical rating above which the factor was considered the critical criteria for decision-making. Here, m_o was temporarily set up as 2.3 (refer to the criteria set in the first method). A rating >2.3 represented 'the criteria for decision-making'. From the table of critical values of t-distribution, for degree of freedom (d.f.) = n-1, and the level of significance for t-test at 0.05, p=*Sig*. This meant that if the calculated *Sig* was <0.05, the null hypothesis for that issue was rejected and the alternative hypothesis accepted. The T value and *Sig* value of those variables were calculated by SPSS. The *Sig* values of relative advantage (0.00), technology opportunities (0.00), observability or triability (0.02), result demonstrability

(0.02), preparedness (0.01), cost (0.03), and profitability (0.04) are all less than 0.05. The alternative hypotheses have been accepted. The *Sig* values of other factors are greater than 0.05, so the null hypotheses have been accepted in those case. It was then concluded that the factor rated highly by the respondents are among those criteria. The *t*-tests method produced the same result as arithmetical mean method did.

In this research, the driver for adopting IT innovation was elicited using the threshold percentage method. The factors identified positively by more than 60 percent respondents are defined as the drivers. Under this criteria, technology opportunities, relative advantage, profitability, cost and result demonstrability are direct drivers for adopting IT innovations. As illustrated in table 1, technology opportunities are the most significant driver for adopting IT innovation, and relative advantage is the second strongest driver force.

3.2.2 Process and Culture Perspective

The analytical method for process and cultural factors is the same as that for technology factors. The process factors identified by the literature review include process integration, process problems and adjustment (including five sub-factors, say supply chain change, process adjustment resulting from the company growth, process adjustment resulting from an increase complexity of high-tech facilities, clients demand and other process problems), and Market pull (pressures from market and competitors etc). Based on the arithmetical means and t-test method, Process problem resulting from the conflict between different stages of process 2.43, clients demand to use specific process 2.32, and market pull 2.31 are sequentially among the most important process factors which influence the decision-making of IT innovation adoption. All of them are also acting as driving force for IT innovation adoption.

20 factors are elicited from the culture perspective, including characteristics of organisational structure, innovativeness of organisation, characteristics of communication environment, organisation training and learning, characteristics of key individuals (say top managements, change agents, workforce, and champions), management attitude (including leadership, management style, motivation, attitude to risk, relationship etc.), internal environment (including R&D intensity, IT intensity, Rate of technical change) and external environment (institution, IT supplier, and Policy). The culture factors considered most important by the respondents in descending order were leadership (top management's attitude toward technologies) at 2.43, management style 2.4, motivation 2.31. And characteristics of Top management (72.7%) and champions (73.5%), leadership (68.1%) are direct drivers for initial adoption.

4. Preliminary Conclusions

The results suggest that the initial adoption of IT innovation is driven by not only the technological characteristics but also process and culture factors. In addition to reviewing and evaluating the IT innovation characteristics, other independent variables for IT adoption are also investigated. The driver for stimulating organisation to adopt IT, are technology opportunities, relative advantage, profitability, cost, result demonstrability, process problems, market pull, characteristics of top management and champions, and leadership. The analysis presented in this paper in general provides strong support for early work

conducted with academic communities and industries (Tornatzky and Klein 1982; Alshawi and Faraj 2002; Whyte and bouchlaghem 2002), which has found the top management support of the implementation effort, good IT design (take serious consideration of the IT characteristics as critical factors). Moreover, the research model proposed by this paper, provides a basis for recognizing the criteria for the IT selection and implementation processes that build upon prior research and have a good probability of significantly enhancing an understanding of the initial adoption and implementation process. The decision-making criteria identified by this research, will act as the inputs of a Technology-Process-Culture decision-making model to support the selection and implementation of IT innovations, which are mainly based on Analytic Network Process theory (Saaty 2001). Current work is looking at the dependence and interaction between the technology, process, and culture factors and their attribution to IT adoption and implementation. The current mathematical model will be used for simulation and measurement. It is hoped that his research will provide a new understanding of IT innovations adoption and implementation from an integrated perspective of technology, process and culture within AEC industry.

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