Factors Influencing Construction Technology Adoption

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Abstract

History has shown that innovative new technologies are key contributors to improving productivity, quality and safety in construction. While the innovation process has been studied in the past, procedures that companies apply to make decisions on what technology to adopt, have received little attention. This paper presents the initial results of an on-going study to understand the processes, sources of information and the critical success factors that companies depend on when buying new technologies. It presents an adoption model that is being validated with an in-depth study of vendor strategies and visitor behaviour at two equipment exhibitions in Australia. Vendors displayed an array of products ranging from spirit levels to large hydraulic excavators and applied various methods to attract potential customers to their booths. The analysis presented below uses a wide range of measures to categorize each vendor booth to include the nature of the product, the area occupied and type of information offered. As was expected, the analysis reveals heavy clusters of vendors applying similar strategies strongly influenced by the size of the vendor company and the technology. The data also supports the adoption model as the vendors make use of specific techniques to serve the needs of novices as well as better informed customers with the aim of establishing a relationship that extends beyond the exhibit.

Key words: Technology, Adoption Decision, Construction industry, Marketing Strategies, Factors.

1. Introduction

Like every other industry, new technologies are constantly introduced to construction. Companies trying to improve their productivity, safety, and quality have to make a decision if and which technology should be adopted. However, surmounting the complexities facing this industry makes technology enormous challenging to adopt. Considerable research by, for example, Allmon et al. (2000), Goodrum and Haas (2004) and Astebro (2002) report that new technologies have a large beneficial effect on overall productivity in construction. Adding vibration to the rolling action of compactors exhibited a 260% increase in productivity during the mid 1980s when Caterpillar introduced this technology for example (HAAS et al., 1999). However, the whole industry continues to lag in technology adoption and is generally

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adverse to change (Nicolini (2001); Nikas et al. (2007); Harty (2008); Milliou and Petrakis (2010)). Data from the Melbourne Institute of Applied Economics and Social Research (2010) shows that the construction innovation index lags significantly behind other industries. This index even fell by 18.2% between 2005 and 2006. Averseness to risk and the adoption lag is due to many reasons such as the variability of a company's expertise, the uniqueness of the product (Munkvold, 1999) and the nature of industry itself (ABS, 2009). These reasons make the construction industry very different compared to other industries. Thus, the question is raised which factors critically influence the adoption decision in the construction industry.

The decision to deploy a technology is a function of a variety of influences. There is little known about the decision making process and the influencing factors. Deriving a clear benefit is a critical objective in construction projects and cost is often not the most important factor influencing the technology adoption decision. The TriComB2B (2011) survey reveals that total cost of ownership is considered 56% of the time in the construction purchasing decision, while it is 71% for purchasing in energy related industries. Technology exhibitors do reveal price of items in trade shows as the cost is not the first or main question of visitors. On the other hand, car exhibitors show price as one of first pieces of information to the visitors. Thus, other factors are likely to be critical in the adoption decision in construction industries which should be investigated.

Frambach and Schillewaert (2002) recommend future research should focus on the factors influencing different pre-adoption stages, rather than the adoption decision itself. They suggest the factors affecting the use of innovations should be studied in future. Linton (2002) concluded that there is still a need for theory building in how to implement decisions to purchase technology. At the same time, the technology adoption process in construction and also the influencing factors are not clearly understood. The research in this paper briefly introduces the technology adoption model and then investigates key factors likely to influence the decision. In order to support the main point of the study, two technology trade shows have been studied in Australia. Then, the study focuses on assessing the how vendors attract visitors to exhibitions on mining and construction equipment and what differences are discernible. Nineteen measured variables reduce to three main factors which vendors apply to attract potential adopters. The research attempts to clarify the adoption process in the construction industry and also addresses vendor business behaviour and customers' needs.

2. Theoretical Adoption Frameworks

Howard and Moore (1988, p. 34) found that the decision making path to a purchase consists of a series of mental or behavioural steps that potential adopters pass through. Here, adoption description reveals the necessary steps to introduce a product into the daily operations of an organization (Damanpour and Schneider, 2006). The Theory of Reasoned Action (TRA) by Ajzen and Fishbein (1975) is concerned with the determinants of conscious intention and attitude towards a behaviour defined by "salient beliefs (b_i) about the consequences of performing the behaviour multiplied by the evaluation (e_i) of those consequences" (Davis et al., 1989):

The Reasoned Action function: $A = \sum b_i e_i$

Extending the Reasoned Action function as a general psychological theory, Davis et al. (1989) established the well publicized Technology Acceptance Model (TAM), presented in Figure 1, to predict individual behaviour applied to the field of Information Systems (IS). TAM, as a predictor of the adoption of new IS and ITs, is psychometrically impacted by two external constructs shown in Figure 1 below. They are “Usefulness” and “Ease of Use” in accepting new technology. Since the mid 1990s, many authors such as Amoako-Gyampah and Salam (2004), Venkatesh and Bala (2008, p. 276) and Park et al. (2012) have provided theoretical underpinnings for the relative importance of the TAM in IT and IS disciplines. TAM has been extended by adding more construct determinates for actionable guidance and a complete nomological network of the determinants. However, this is not a theory or model which is able to predict construction equipment adoption.

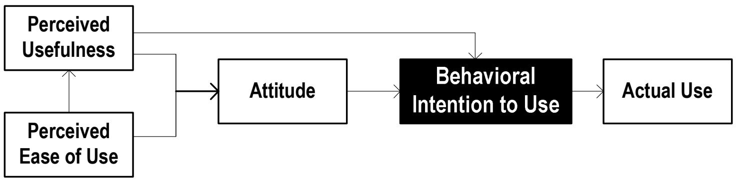

Figure 1: Technology Acceptance Model (Source: Davis 1989)

Similar to any decision-making process, the collection and processing of information is a key stage in the adoption process. Frambach and Schillewaert (2002) defined the initial stage as awareness of what is available that could respond to a need or improve the present situation. For example, Graaff et al (2008) studied factors influencing the adoption of soil and water conservation measures. They subdivided the adoption process as: 1) Acceptance, 2) Actual adoption and 3) Continued use. In contrast, Rankin and Luther (2006) proposed that acceptance followed a phase they called implementation. In practice, there does not seem to be a uniform adoption process applicable to different domains, in particular construction. The following section proposes an adoption model for construction as a hypothesis to be validated with data.

3. Research Methodology

In order to study vendors’ business behaviour and identify factors influencing the adoption decision two trade shows were visited. The first was the Construction and Mining Expo (CME) 2012 in Perth and the second, Asia-Pacific’s International Mining and Construction Exhibition (AIMEX) in Sydney. The data obtained includes brochures, catalogues, questionnaires and photos. The visits to the construction trade shows resulted in 1,812 photos and pre and post-show reports which the research used to identify critical factors. The photos directly provide in an independent way of acquiring data from the business area covering individuals’ business behaviour and technology know-how. Morse and Richards (2002) explain that photos record directly “how much” or “how many” and provides illustrations for researchers. The collected data shows how vendors try to capture attention in the trade show and how they try to diffuse their technologies. Ethnographic techniques and a Likert scale were used to identify and measure vendors’ activities in the trade show.

In the next stage of this research, testing CTAM, five groups of proposed decision variables are categorized in Table 1 such as maturity and after sale services. These variables were applied and measured at the shows based on the vendors' business behaviour. The codification of data permitted the subsequent factor analysis on nineteen variables which vendors use in their effort to support construction companies' decisions. Factor analysis was used to reduce variables to reach a better understanding of the crucial variables and reduce them from nineteen to three factors. According to Hayton et al. (2004), factor analysis can be broadly characterized as a set of multivariate statistical methods applied to determine the number and nature of common factors needed to account for the patterns of observed correlations.

4. Theoretical Concept of Technology Adoption in Construction

Understanding the process of technology adoption including the decision making process and influencing factors is critical for vendors. It assists them in successful marketing and improves the innovation process. Meanwhile it is important for construction companies to get better solutions and services. Companies are looking for a solution when they perceive a need such as contractual obligations, owner or consultant requirements, or government green regulations. In contrast, according to Rogers (2003) some customers of IS may accept a technology and then start to create a need. Construction companies want claims made by vendors about improved productivity, safety and/or reduction of muda-waste tested, while they prefer to "buy into" a technology only after it has already been successfully used by another company, especially a competitor. Furthermore, vendors try to provide "convincing" information and support each node of a decision making process leading from the recognition of a need to an "in the field" assessment of an adopted technology.

The construction company goes through three phases from solution to technology implementation, while vendors proceed from diffusion to after-sale services as the second side of the process. The vendor side could be replaced by a manufacturing representative, innovator, dealer, supplier or sale persons. Technology adoption occurs in an environment with two main players such as vendors and construction companies. Holt and Edwards (2012) state that machinery sales analysis ultimately support business decisions and the sale occurs in an environment characterised with both supply and demand influences. Therefore, the interaction between the two sides - vendors and contractors - is considered in modelling.

Building on work by other researchers, Figure 2 presents the Construction Technology Adoption Model (CTAM), consisting of three distinct phases:

1) The solution phase initiated by a need or desire,

2) Decision or purchase decision, and

3) Implementation.

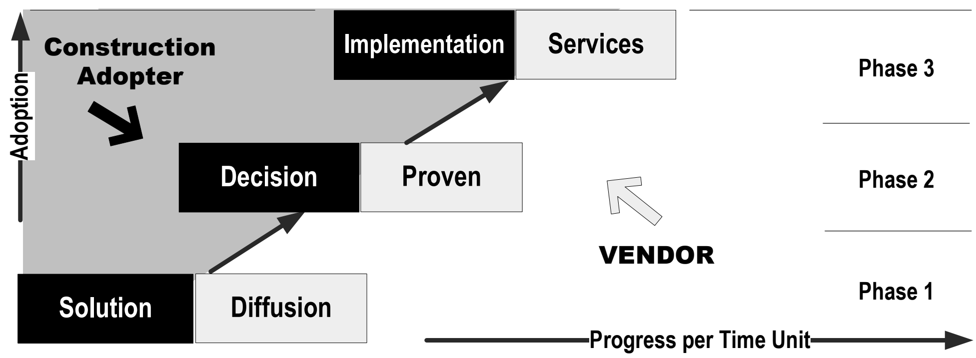

Figure 2: Construction Technology Adoption Model (CTAM)

From the vendor side, the three corresponding phases are namely Diffusion, Proven Technology and Services in this research. The phases cover eight stages from the perspective of the consumer and the vendors. The first phase including three first stages mostly focused on the identification of solutions and information gathering which will be explained below. The information collected in this phase is followed by an in-depth analysis which is consistently refining and tightening the decision criteria applied by the construction company. Vendor representatives offer a trial or actively demonstrate the technology to complement this evaluation, and then construction companies are approach with three options: adopt, reject or gather more information. Following CTAM, factors influencing the decision are discussed in the following section focusing on vendor and technology attributes.

5. Factors Influencing the Decision

The technology adoption process is influenced by different factors in each phase of CTAM. Proposed factors are classified in five categories which ultimately influence consumer intentions towards the adoption of new technology as shown in Figure 3.

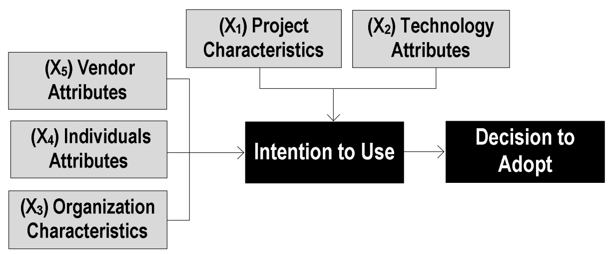

Figure 3: Decision Making Categories of Factors

According to CTAM, this overall decision tree is modelled as a sequence of decision nodes. At each level, the following generic function can be established:

$$Y_A = f(aX_{A1} + bX_{A2} + \cdots) = \sum_{i=1}^{n} cX_{ci}$$

Where, A, B, C … = Decision nodes (e.g., Examination of Potential); Y_A= 1 if the decision is made at node A technology; Y= 0 if the individual is a non-adopter of new technology; and c is the coefficient related to each node of the decision path.

Table 1: Categories of Variables

Project characteristics	Technology attributes	Organization characteristics	Individual attributes	Vendors' attributes
Task Productivity Quality Project cost Time Safety Project condition Geography and location of the project	Maturity Brand Reliability Versatility Capacity Power Durability Site performance	Need Goal Cost reduction Technology policy Formalization/ centralization Company culture Company size	Relationship with a vendor Response to risk Culture Innovativeness Subjective norms Personal response to motivation	After sales service Guaranty Warranty Training service Maintenance service Financial offer Relationship & Motivation program Vendor: size of organization

6. Construction Technology at CME and AIMEX

Construction technology trade shows are critical for the early adopters and adopters in early stages. The TriComB2B (2011) survey reveals that 24% of respondents in the construction industry acknowledge the importance of trade shows (above the average of all industries), while respondents in Information Technologies and energy related industries rate them at 10% and 17% respectively.

Potential adaptors from different stages of the process visit construction technology shows as shown in Figure 4. The stages are called "*Identification of potential, Study of the technology, Examination of potential*" from the construction side. The TriComB2B (2011) data indicates *identification*, *criteria creation*, and *search stages* of the purchase decision at trade shows are 17%, 25% and 42% respectively important. Thus, tradeshows are considered as a critical environment for technology adoption in construction and assist potential adopters to gather more information to progress the situation to the next phase.

Construction companies are informed about new technologies from different sources mostly from innovative companies and suppliers' representatives. For 60% of respondents, "*informal contacts to colleagues"* for gathering information is important in at least 60% of the purchasing decision *in the construction industry*. "*Distributors* and *manufacturing trade representatives"* are also important for 46% and 52% of respondents respectively. Surprisingly, the data from 448 respondents reveals that the scores for the construction industry are more than in other industries such as IT and Manufacturing. Thus, "informal contacts with colleagues, *distributors* and *manufacturing trade representatives*" are important sources for construction customers associated with the first phase of CTAM, as shown in Figure 4. The opportunity to gather information using the above sources is facilitated at trade shows. Visitors at different stages of the adoption process attend the shows and proceed to making purchase decisions In order to analyse vendors' support along the decision path, the data from construction trade shows are gathered and presented in the following.

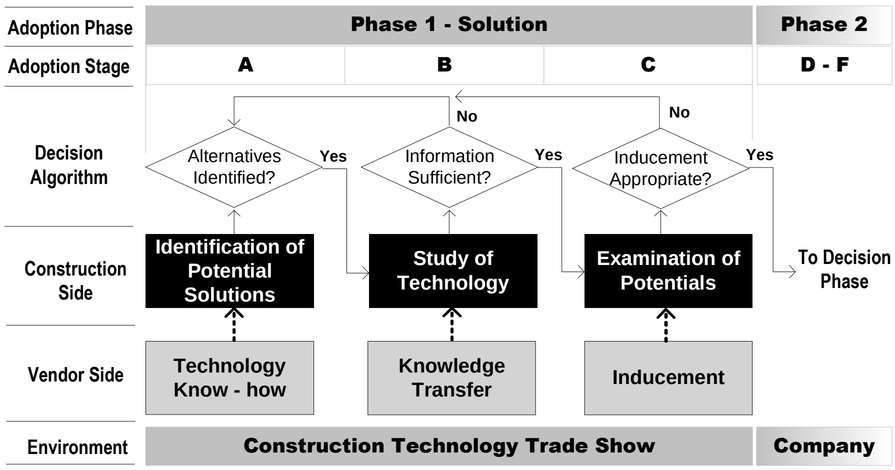

Figure 4: First Stages of CTAM at the Show

Both AIMEX (2011) and CME (2012) provided rich information about their technology such as maturity, brand, power and capacity as mentioned in the group decision variables. In contrast to other exhibitions such as electronic mini-devices, software or ordinary tools, AIMEX and CME do not immediately generate transactional information such as price, terms, discounts, promotions or other financial information. Furthermore, the survey at CME Perth showed that vendors extensively support the decision maker using strategies through meetings and exchange contacts. In turn, vendors inform potential consumers, who are in the third decision node, about hire rental or trial offers for further practice evaluation. As an example, in the interview a vendor said that they were willing to loan the equipment for a while to a potentially serious buyer for testing its reliability. Different factors related to vendor and technology attributes are analysed in the following section.

7. Analysis and Results

In the first part of the analysis the relationship between observed variables is discussed. The Exploratory Factor Analysis (EFA) is used to identify the key factors that vendors use to support visitors in the purchase decision process. EFA is used to reduce the number of variables (Tipping and Bishop, 1999), pattern recognition, explaining co-variational factors (Haig, 2005). EFA has an important role in theory generation. The analysis reveals that there is strong relationship between stand feature and design, vendors' representatives and exposed technologies. For example, the variable "number of sales persons at booth" has a strong relation with booth feature (correlation is 0.863), Conversation room (0.879), Visual Learning Tools (0.835) and real exposed technologies (0.823). Furthermore, exposing capability and compatibility of the technology in real samples has strong relationships with booth characteristics (0.601-0.786); number of sale persons (0.823); function of staff (0.772), knowledge and informative posters (0.838) and written knowledge (0.811) as shown in Table 2.

Table 2: Rotated Component Matrix and the Results

No	Variables	Component		
		Factor 1	Factor 2	Factor 3
1	Vendor's exhibit area (EXA)	.517		
2	Closed stand area (CST)	.764		
3	Media type (MDA)	.784		
4	Stand feature and design (STD)	.879		
5	Exhibited technology worth (WRT)	.530	.510	
6	Maturity of the technology (MTC)		.832	
7	Number of exhibited technology line (ETL)		.746	
8	Number of vendor's technology line (VTL)		.888	
9	Brand (BRD)		.819	
10	Product exposure (PDE)	.609	.582	
11	Number of personnel at booth (PRB)	.697	.538	
12	Learning tool (LTL)	.819		
13	Knowledge (KND)	.871		
14	Persuasion (PRB)	.798		
15	Socialization (SCL)	.703		
16	Demonstration (DMN)	.642		
17	Trial (TRL)			.891
18	After sale support (ASS)			.607
19	Relationship (RLN)			.713
	Factor Loading (Rotation sums)	12.485	1.563	1.087
	Rotation Sums % of Variance	37.006	25.372	17.276
	Rotation Sums Cumulative %	37.006	62.378	79.654

F1: Dissemination Approach

F2: Maturity

F3: Service and Relationship

The use of EFA is suitable for this data set as correlation coefficients of all variables are more than 0.7 (well above 0.3). The result of the EFA in Rotated Component Matrix using Varimax with Kaiser Normalisation shows that the observed nineteen variables were grouped into three main factors.

Analysis of the data indicates that those variables revolving around technology and vendor attributes, respectively called X5 and X2, were the two main groups of decision variables of the model shown in Figure 3. As shown in Table 2, 12 variables grouped as the F1 Dissemination Approach, account for 37% of variance. F1 includes elements such as the vendor's exhibit area, closed stand area (CST), stand design and features (STD), media type (MDA) for generating awareness and presentation and also demonstration of the technology (DMN). As shown in Figure 5, visitors pause in front of the booth which is the potential start point for communication with Caterpillar at AIMEX 2011. Experts and technicians from high technologies or heavy equipment such as Caterpillar or supplier companies are ready to identify the best solution.

Figure 5: Social Activities and Live Performance at Caterpillar's Booth

Another factor – F2 Services and Relationship includes trial, after sales support and making relationships with the consumer. It accounts for 25.3% of variance. Three other variables - the number of product lines, brand and product maturity which vendors stressed at the show - are grouped as F3 and account for 17.2% of variance. The variables and factors influencing the two main categories (X5) and (X2) are shown in Figure 6 which is supposed to positively impact on the intention to use.

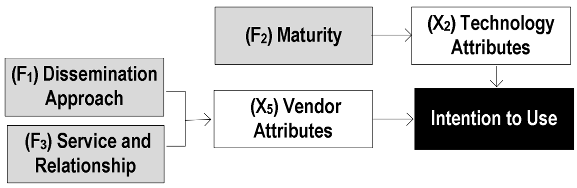

Figure 6: Factors Influencing Two Main Constructs of CTAM

8. Conclusion

The decision making process to purchase and deploy new construction-related technology introduces a variety of factors and functions. Good communication between vendors and interested customers companies as well as between "early "and "late adopters" is one of them. This paper presents the preliminary results of a study on the marketing strategies applied by vendors of various technologies modelled as part of the initial phase of the adoption process. Here, both vendor and potential customers interact and communicate with each other to find the best solution for the customer. In fact, the paper offers the Construction Technology Adoption Model (CTAM) where vendor and potential adopter pass through three stages: "Solution Finding, Decision Making, and Implementation".

The work focused on assessing the difference of how vendors attract visitors to an exhibition on mining and construction equipment. It was quickly found that several key features cluster the vendor companies: 1) stand design, 2) use of electronic communication media, 3) paper based information, 4) brand advertising, and 5) integrated marketing levels. A factor analysis classified nineteen variables such as Media Type (MDA) and Vendors Exhibit Area (EXA) in three main factors called "Dissemination, Maturity, Services and Relationship."

Heavy equipment vendors such as Caterpillar, Toshiba and Hyundai use a wide range of (expensive) marketing activities. For example, they use attractive booths overseen by professionals and staffed by welcoming marketing staff ready to take interested visitors into a special meeting room. They prefer face-to-face exposure, advanced audio-visual programmes, hands-on activities, food, live performance and live entertainment.

As the solution finding phase is completed, future work will focus on validating the model concerning Decision Making, and Implementation. This work will investigate the decision making process and procedures followed by companies related to the construction industry.

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