LIFTING AND HANDLING EQUIPMENT: FROM SELECTION TO ADOPTION PROCESS

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ABSTRACT

Advanced technologies are increasingly being introduced to the construction industry. Several studies in the literature have examined the diffusion of advanced communication technology, however the adoption process for handling and lifting equipment (e.g. advanced cranes and lift trucks) from an organizational/project perspective has received very little attention. This paper presents the handling and lifting equipment adoption model including key stages of the process from seeking a potential solution to utilisation. The paper also intends to identify whether different construction companies follow the same procedure or have different technology adoption behaviours due to the differences in their organization characteristics. In doing so, a total of 22 in-depth interviews were conducted to investigate how contractors make decisions to adopt a piece of handling and lifting equipment, and to gather information about their feedback on technology implementation. The findings show that the model consists of six main stages (i.e. required activities) such as 'seek potential solutions', 'comparisons', 'evaluation', 'negotiation', 'evaluation', and 'assemble and operate', which are navigated by customers and vendors as they pass through the adoption process. It was also found that there are three main groups of decision makers in the sample which are called 'leader corporations and large firms', 'mid-sized leaders' and 'followers' which pass through the adoption process differently in terms of being either innovative, developing new market technologies, or exhibiting conservative behaviour. Future study should evaluate the model in different contexts and market settings.

Keywords: handling and lifting equipment, Technology Adoption, Cranes, Lift Truck

INTRODUCTION

Building construction is becoming increasingly modernized and industrialized. There is an interest in shifting from traditional and in situ construction to modularized and off-site prefabrication methods. Consequently, handling and lifting equipment (HLE) such as cranes and lift trucks will be critical for improving productivity and safety in modern construction. However, the current crane literature focuses on the process of crane selection but there is virtually no published work explaining the holistic crane adoption process.

Several technology adoption studies focusing on information technologies show: consensus on the importance of understating the process to ensure successful uptake; and the need to investigate the market place where technology diffusion and adoption occurs (Kale and Arditi, 2005; McCoy et al., 2010; Sepasgozar and Bernold, 2012 ; Sardroud, 2014; Sepasgozar and Davis, 2014; Sepasgozar and Davis, 2015b). According to Arts et al. (2011), understanding the whole process gives a critical insight for managers involved in marketing innovation. However, an open question concerns consideration of the range of key factors influencing adoption decisions by which construction companies select and operate new HLE for their projects. According to Manley (2008), many construction companies are not aware of the best practice approaches to implementing innovations and whilst this comment is primarily for Australian projects, the same is thought to be true of many other countries as well. Therefore, the need to study technology adoption topics in construction is particularly important as it has been generally slow in uptake across the construction industry (Sepasgozar and Davis, 2015a; Sepasgozar et al., 2016).

Previous studies have provided different models for crane selection, such as Adaptive Probabilistic Neural Networks (Sawhney et al., 2000) and geometrical characteristic based algorithms (Al-Hussein et al., 2001). However, these current studies only consider project specific variables as distinct from the broader based organisational needs that clearly impact on customer decision making. There is therefore, a need to investigate the industry practice of crane usage in a local area to better understand organisation level adoption strategies.

The present paper develops a framework for HLE adoption in three main steps. First, the relevant literature was reviewed to identify the key area where current knowledge is lacking in HLE adoption and to distinguish between selection and adoption processes. Second, the research method to investigate the adoption process in the HLE industry is presented. Third, presentation of findings which includes an HLE adoption framework consisting of three main themes; and three customer groups who pass through the process in different ways. This is followed by a comparison to

understand differences between each customer group in the adoption process.

FROM CRANE SELECTION TO CRANE ADOPTION

The contextual complexity of the construction industry coupled with the uniqueness of the crane business in terms of sensitive technology and safety, compel us to seek a more comprehensive framework to assist in HLE adoption decisions. The existing studies present crane selection models such as Decision support for tower crane selection (Marzouk and Abubakr, 2016), Adaptive Probabilistic Neural Network-based (Sawhney et al., 2000) and a geometrical characteristic based algorithm (Al-Hussein et al., 2001), predominately relying on crane geometry and technical factors. For example, Al-Hussein et al. (2001) presents an algorithm that takes into account the lift dimensions, weight capacity, and the location distance (that should be covered), all technically feasible lift settings. These attributes should satisfy all specified clearances between the crane, the lift, and all adjacent buildings.

An extensive research exists in the construction technology literature, which attempts to empirically understand the adoption process of information technologies through an analytical exploratory process in construction projects. For example, Mitropoulos and Tatum (1999) and Peansupap and Walker (2005) investigate factors affecting 'information systems' adoption in construction. These studies often investigate new factors (e.g. availability of skills; site engineer and foreman involvement in the process) but the differences between information technology and HLE adoption processes differ in attributes, hence limiting the ability to simply apply the same contextual variables. Therefore, a more specific framework for HLE, which is purpose built, forms the key aim this study. The equipment adoption literature is an under development area, and the current paper follows the general method of construction technology adoption model (CTAM) developed by Sepasgozar et al. (2016). CTAM shows that other factors such as down time, quick operation, ease of repair and automatic control influence the decision processes (Sepasgozar and Davis, 2015b; Sepasgozar et al., 2016).

RESEARCH METHODOLOGY

A qualitative research was conducted in order to explore the HLE adoption process in construction. It utilised thematic analyse and cluster analysis make possible using NVivo software. As mentioned, this method was employed because of the lack of understanding about HLE manufacturers and their customers' business behaviour, in regard to the adoption process. A total of 22 participants in Australia and the United States were recruited using a combination sampling strategy of 'criterion-chain' from the crane business. Some examples of the unstructured questions which

were designed to allow the respondents to explain their experiences of the technology adoption process are: Give me specific examples of technologies in your company, how many purchase decision procedures do you have in the company, how different they are. Criterion chain sampling makes use an initially identified participant who can provide additional participants via a network of supply chain contacts. For example, a crane use in Sydney can provide participants involved in crane manufacture and crane distribution.

This method of sampling was designed specifically for this study because the investigators aimed to become immersed in the construction technology market community, and also aimed to elicit facts rather than individual behaviour (Schultze and Avital, 2011). Based on chain sampling method, 22 experienced participants were purposely recruited from two regions Australia and North America. Participants from two developed countries were chosen as their feedback on technology adoption is critical to vendors before disseminate the technology in the rest of the world. Table 1 shows the participants profile.

Table 1. Selective participants' profile and business

Participant position	Experience (years)	Crane type
Dispatch manager	25	Mobile crane
President	50	Mobile crane
Safety director	12	Mobile crane
Sale manager	20	Mobile crane
Owner	28	Mobile crane
Owner	28	Mobile crane
Operator manager	20	Mobile crane
Operator management	30	Mobile crane
General manager	42	Mobile crane
General manager	22	Tower crane
State sale manager	4	Two mobile cranes
Senior project manager	10	Tower crane
Managing director	43	Mobile crane (55 and 250 ton)
Project manager	12	Tower crane
Project manager	10	Tower crane
Project manager	10	Tower crane
Managing director	12	Rail crane and tele-handler
Director	30	Rail crane and tele-handler
Managing director	27	Tower crane (310 and 330 ton)
Contract manager	16	Tower crane
Project manager	14	Tower crane
Managing director	40	All terrain and crawler crane

ANALYSIS AND FINDINGS

Themes constituting the adoption process

This section presents key themes representing the HLE adoption process observed in the interview data. For instance, Figure 2 presents the key themes and subordinate structure of parent nodes, child nodes and indicative comments which lead to three key themes of customer decision-making processes identified by the research including: Investigation (T1), Acquisition (T2) and Utilisation (T3).

Investigation (T1): T1 represents activities that a customer carries out to identify potential solutions and make comparison between competing options. This includes seeking understanding about newly available handling and lifting solutions and gaining confidence about whether or not the solutions will meet their needs. This theme shows that customers are looking for safer solutions to lift more weight. In addition, they are interested in machine control and monitoring technologies to increase performance efficiency. When the customer seeks new solutions, the local standards and road conditions and traffic legislations are mainly considered. This makes the crane industry different from other technologies such as concrete pumps or information technologies. Further, previous crane selection studies have not mentioned these factors.

Acquisition (T2): T2 represents activities that a crane customer carries out to evaluate, select and purchase a new crane. This theme represents HLE evaluation steps including functionality (e.g. Outriggers) and financial (e.g. Cost analysis) and recommendation criteria. In addition, customers negotiate to get their crane from a vendor who is trustworthy. Here, trust and relationship with the vendors are important and are intimately linked with other aspects such as negotiating lead times and the terms and conditions of contract.

Utilisation (T3): T3 represents activities that a customer carries out to operate, maintain and ensure the HLE works appropriately on their projects. The interviews show that this theme was very important to customers and formed a key part of their purchase decision process. Customers were concerned about crane tests including safety test, HLE maintenance and spare parts availability. In this sense, they look for simple technology and not complex HLE. They are also mainly concerned about down time (i.e. how long and how frequent), particularly where the likes of a small sensor on a complicated HLE becomes burnt-out or broken, and can cause significant delays. Customer feedback was crucial for new customers. As they talk to each other using different communication channels (e.g. industry workshops), networking and word of mouth affect HLE diffusion in the longer term.

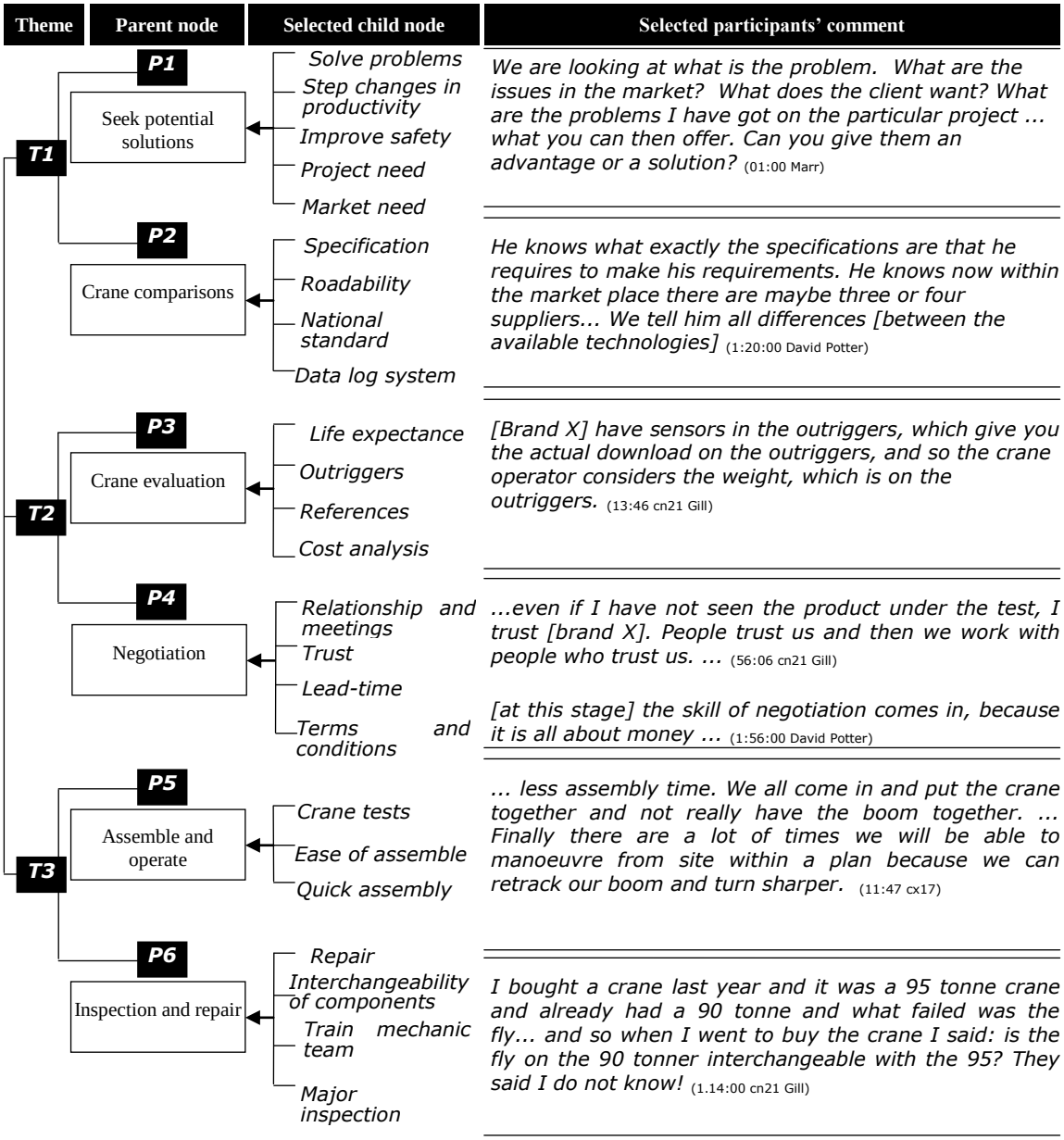

Figure 1. Diffusion process tree representing diffusion process of T1 (investigation), T2 (acquisition) and T3 (utilisation) behaviours.

Clustering customers

In order to identify whether there are groups of customers who follow the adoption process differently or have different concerns, a cluster analysis method was employed. In doing this, the clustering method inherent in Nvivo was utilised. For instance, this method categorises words with similar meaning together around different customer behaviours. The researchers were then able to view the individual groups and inductively derive names for each different type. Figure 2 shows the result of the analysis including the three main clusters of customers identified. Each shows that three clusters exist in the sample: 1) Leader corporations: keen to be the first in utilising advanced cranes earlier than other local companies; 2) Mid-sized leaders (hirers or subcontractors): keen to have

an updated fleet with advanced cranes to rent them out to the contractors; and 3) Followers (small or medium sized family business companies): keen to utilize proven cranes based on the lessor's feedback.

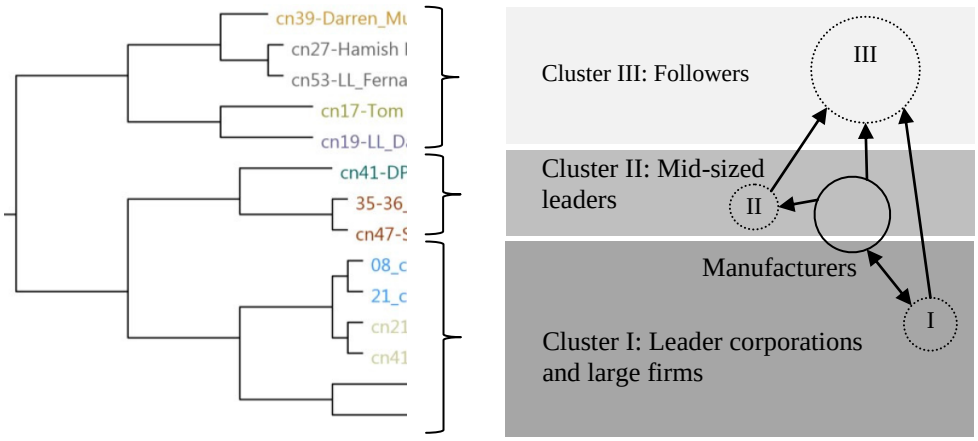

Figure 2. Customer classification based on their adoption behaviour

Comparing customers across themes

This section compares three clusters across three key themes discussed previously (i.e. T1, T2 and T3) with a view to characterising, profiling and distinguishing different types of HLE customers. Table 2 presents a matrix, where the three clusters are shown in columns and themes T1, T2, and T3 are shown in rows.

The previously presented findings are interesting in so far as they provide a more holistic view that goes beyond the HLE selection process (as an isolated purchase decision) and looks at the broader adoption approach (which links the purchase decision with ongoing actions required to holistically take up the technology). For instance, a participant stated that the decision to use a new crane is a "*big decision as [cranes] have a lot of components and different configurations*". This means the customer also takes the complexity of maintenance and availability of after sales services into account during HLE adoption analysis. This finding is separate from current customer behaviour perspectives in the crane literature which primarily focus on purely crane selection criteria. Rather, the study presents a model which refers to a process from seeking a potential solution to utilizing the technology including inspections and repair as requirements of technology adoption decisions.

Table 2. The matrix of cluster characteristics across each stage of the process

Theme	Cluster I (leader corporations)	Cluster II (mid size leaders)	Cluster III (followers)
Investigation (T1)	• Seek to solve problems and/or look for a step change in productivity • Collaborate with a manufacturer to modify their product	• Develop new market by increasing lift capacity • Actively seek new crane and updated	• Get the job done by using a proven crane; • Actively investigate what pioneers do to solve the same problem
Acquisition (T2)	• Decision being made in a longer process; • Owners not involved; • Many persons are involved in the decision • Premium price	• Informal and relatively quick process; • Decision being made in a shorter process; • Mainly the owner involved in the decision	• Informal and relatively longer process-financial problem (affordability); • Mainly the owner involved in the decision; • Price sensitive decision
Utilisation (T3)	Concerns about: • Complexity of assembly; • Availability of spare parts; • Resale value	Concerns about: • Complexity of maintenance; • Availability of support even remote services	Concerns about: • Any complexity; • Availability of spare parts; • Availability of technicians; • Maintenance cost

CONCLUSION

The aim of this study was to understand the process of handling and lifting equipment (HLE) adoption decisions in the construction industry. Understanding of the process requires a major shift from an 'HLE selection' modelling to 'HLE adoption' process perspective. This new perspective provides many more factors and variables to accurately predict customers' intentions towards adopting new equipment. This paper presents a proposed conceptual framework for HLE adoption which contributes to the body of knowledge by identifying three themes of activity representing the whole process of HLE adoption including investigation, acquisition, and utilisation. Common sub-features pertaining to each theme are provided (e.g. inspection and repair considerations are a subset of Utilisation). Further, customers can be seen in terms of how they respond to the above process by reflecting three differing degrees of customer driven leadership Here, the paper identifies new groups of HLE users in the industry called 'leader corporations and large firms', 'mid-sized leaders' and 'followers' which

pass through the adoption process differently in terms of being innovative, intending to develop a market by new technologies, and being conservative respectively.

This paper identifies that the HLE adoption process is a complicated multi-stage process because customers (construction companies and HLE rentals) are professional and actively seeking new HLE technologies to increase their productivity (enabling the lifting of heavy objects faster and safer).

Understanding themes of activities and the customer's attitude toward new HLE are critical; because it enables researchers to modify the adoption decision is understood for relevant customer groups. These modifications give a better description and prediction of the HLE adoption process. By clearly delineating the current practice used in the industry, this finding enables new dealers to determine the best strategy for them to implement when disseminating their technology. Inexperienced contractors can use the process described as a benchmark for their own companies. The limited number of experienced professionals available for the interviews is a limitation of the current study, but future studies can use the findings as a base for a larger industry study. For instance, larger studies which would work towards improving the validity of the above findings.

REFERENCES

Al-Hussein, M., Alkass, S. and Moselhi, O. (2001) "An Algorithm for Mobile Crane Selection and Location on Construction Sites", *Construction Innovation,* 1(2), 91-105.

Arts, J. W., Frambach, R. T. and Bijmolt, T. H. (2011) "Generalizations on Consumer Innovation Adoption: A Meta-Analysis on Drivers of Intention and Behavior", *International Journal of Research in Marketing,* 28(2), 134-144.

Kale, S. and Arditi, D. (2005) "Diffusion of Computer Aided Design Technology in Architectural Design Practice", *Journal of Construction Engineering and Management,* 131(10), 1135-1141.

Manley, K. (2008) "Against the Odds: Small Firms in Australia Successfully Introducing New Technology on Construction Projects", *Research Policy,* 37(10), 1751-1764.

Marzouk, M. and Abubakr, A. (2016) "Decision Support for Tower Crane Selection with Building Information Models and Genetic Algorithms", *Automation in Construction,* 61, 1-15.

McCoy, A. P., Badinelli, R., Koebel, C. T. and Thabet, W. (2010) "Concurrent Commercialization and New-Product Adoption for

Construction Products", *European Journal of Innovation Management,* 13(2), 222-243.

Mitropoulos, P. and Tatum, C. (1999) "Technology Adoption Decisions in Construction Organizations", *Journal of Construction Engineering and Management,* 125(5), 330-338.

Peansupap, V. and Walker, D. (2005) "Factors Affecting Ict Diffusion: A Case Study of Three Large Australian Construction Contractors", *Engineering, Construction and Architectural Management,* 12(1), 21-37.

Sardroud, J. (2014) "Perceptions of Automated Data Collection Technology Use in the Construction Industry", *Journal of Civil Engineering and Management,* 21(1), 54-66.

Sawhney, A., Vamadevan, A., Marble, J. and Mund, A. (2000) "Internet Based Interactive Construction Management Learning System" in *Construction Congress Vi*, 280-288.

Schultze, U. and Avital, M. (2011) "Designing Interviews to Generate Rich Data for Information Systems Research", *Information and Organization,* 21(1), 1-16.

Sepasgozar, S. M. and Davis, S. R. (2015a) *A Decision Framework for Advanced Construction Technology Adoption,* translated by.

Sepasgozar, S. M. and Davis, S. R. (2015b) *Modelling the Construction Technology Implementation Framework: An Empirical Study,* translated by Heikkilä, R., Oulu, Finland.

Sepasgozar, S. M. E. and Bernold, L. E. (2012) *A Technology Pre-Adoption Model for Construction,* translated by Sydney.

Sepasgozar, S. M. E. and Davis, S. (2014) "Diffusion Pattern Recognition of Technology Vendors in Construction" in *Construction Research Congress 2014*, 2106-2115.

Sepasgozar, S. M. E., Loosemore, M. and Davis, S. R. (2016) "Conceptualising Information and Equipment Technology Adoption in Construction: A Critical Review of Existing Research", *Engineering, Construction and Architectural Management,* 23(2), 158-176.