Diffusion Pattern Recognition of Technology Vendors in Construction

Samad M. E. Sepasgozar¹, Steven Davis²

¹ School of Civil and Environmental Engineering, University of New South Wales, Australia, Sydney. Email: samad.sepasgozar@gmail.com
² School of Civil and Environmental Engineering, University of New South Wales, Australia, Sydney. Email: s.davis@unsw.edu.au

ABSTRACT

New technologies are increasingly offered by vendors in the construction industry. Several studies in the literature have examined information technology adoption at the individual level, and how administrative and process innovations are diffused through the industry. However, vendors’ diffusion strategies for tools, plant and equipment from an organisational perspective have received very little attention.

This paper explores the different patterns of strategies that vendor organisations use to influence their customers in the decision process, understanding that the customer is not usually an individual in the organisation but a much larger group of people, many of whom will not come into direct contact with the vendor’s staff. Vendors offer solutions to construction companies and support the decision makers by providing relevant information. It would be very helpful to recognise whether there are patterns in vendors’ diffusion strategies. Identifying the patterns and the basis of these patterns, such as particular technology types, would help customers predict the vendors’ role in technology adoption at an organisational level rather than at an individual level.

Data about the activities and means of product presentation of vendors at a technology exhibition provided the basis for classification, analysis and pattern recognition. The identified patterns were subsequently validated using data from a second exhibition. The finding of the fuzzy analysis resulted in clustering the vendors into five classes according to three groups of technologies each with unique characteristics of behaviour. The presented classification pattern contributes to understanding the supportive strategies used by vendors to influence the decision of potential users.

INTRODUCTION

Demand to improve productivity while accommodating new standards of safety, quality and the pursuit of sustainability have greatly increased the complexity of performing construction tasks. The introduction of sophisticated technologies is an attempt to find solutions to the challenges facing today’s construction industry. A considerable amount of research has reported that new technologies have a greatly beneficial effect on overall productivity in construction (Ioannou and Liu 1993, Allmon et al. 2000, Astebro 2002, Schexnayder and David 2002, Goodrum and Haas 2004, Zhai et al. 2009, Li and Gerber 2011). However, the whole industry continues to be stagnant in technology adoption and is generally averse to change (Bowden et al. 2006, Nikas, Poulymenakou et al. 2007, Harty 2008, Milliou and Petrakis 2010, Li and Gerber 2011, Bygballe and Ingemansson 2014).

The successful commercialising of inventions and technology transfer by vendors relies on an understanding of the process that customers follow in
technology adoption (Vessey et al. 2002). Vendors will use this understanding to
guide their strategies for influencing their customers. While some scholarly papers
have been published dealing with the positive impact of technology use in
construction (O’Connor and Yang 2004, Kang et al. 2008, Goodrum et al. 2009,
Wang, Chen et al. 2013, Fulford and Standing 2014), there has been no
consideration of vendors’ strategies, or recognition of the patterns inherent in
technology groupings regarding the adoption process in the construction industry.

Previous research into technology adoption tends to focus on Information
Systems (IS) technology rather than on technology related to the technical aspects
of construction. Generally this is based on the Technology Acceptance Model
(TAM), which has passed through several versions (Davis et al. 1989, Venkatesh
and Bala 2008). The structure of the TAM models shows that the technology
attributes are a significant component of the models, being designed to anticipate
the intention of individuals to use the technology. However, the technology
attributes covered in TAM are significantly different to the relevant aspects of
construction technologies such as fuel consumption, carbon emissions, power and
versatility.

In practice, a wide range of different technologies from mitre saws to
tower cranes are used in construction. The construction industry is complex
(Fernández-Solís 2008) and significantly different (Anderson and Schaan 2001)
from other fields such as IS. Therefore, the models, which are validated for IS
technologies such as online programmes and small electronic devices are not
applicable to the process of construction technology adoption. In this situation, the
first step for developing a new model or replicating any model for predicting the
adoption process is to recognise technology groups; and the pattern of vendors’
strategies in the way they deliver and offer the technologies and services to the
companies.

The present paper is the first attempt to classify vendors regarding
technology adoption in construction which could be considered as the first stage in
developing a model to predict technology adoption. Therefore, this paper has two
objectives. The first is to construct a pattern of vendor classifications based on the
similarities in their supporting activities for the adoption process. The second is
the inter-group pattern of vendors’ marketing strategies regarding the adoption
process.

METHODOLOGY

A quantitative clustering methodology is selected to recognise vendors’
business behaviour patterns in the construction industry using two sets of data
gained through observation at two construction technology exhibitions (CTE). The
fundamental premise of any CTE is to provide a market place to bring together
customers and vendors, thereby encouraging and facilitating technology adoption.
Typically vendors will provide booths at the CTE and customers will visit them.
Two CTEs, one in Sydney, the Asia-Pacific International Mining exhibition
(AIMEX) and one in Perth, the Construction and Mining Exhibition (CME) were
visited in 2011 and 2012 respectively to gather data from vendors who provided a
variety of conventional as well as cutting edge technologies. Data including
photos, unstructured interviews, an exhibition directory book, the exhibition and
booth’s layout plan, technology specifications and catalogues and exhibition
papers were collected. An interdisciplinary method of understanding and
contextualising emerged from critical visual analysis that would be difficult to
generate with other forms of data (Schroeder 2005, Belk 2008). In addition to
couneractions with vendors and visitors, vendors’ web pages in the AIMEX
directory and their own official websites were visited in order to get related
information such as vendor organisation, size, type of information and product
range.

THE FRAMEWORK OF CONSTRUCTION TECHNOLOGY ADOPTION

Based on a broad literature review and practical observation, the
Construction Technology Adoption Model (CTAM) is proposed that embraces
both construction companies and vendor organisations as shown in Figure 1.
Although both sides have key roles in the adoption process, the adoption mostly
becomes possible when the construction company perceives a need, or attempts to
improve the current situation such as safety or productivity. On the other hand,
vendors compete with their marketing strategies and attempt to generate
awareness and loyalty to a new brand.

Figure 1. The framework of the construction technology adoption model

The CTAM explains how the decision process involves a sequence of
consecutive phases that a construction company passes through before
implementing the technology, and consequently taking a final decision on whether
to use or reject the technology. From the construction side the three phase of
CTAM are: 1) recognition of a need and identification of potential solutions; 2)
analysis of the solutions and selection of the optimal solution; and 3)
implementation and assessment. From the vendor side, the companion phases are:
1) diffusion, i.e. dissemination of the technology idea and awareness of their
brand; 2) proving that their solution is the best and negotiation of terms, etc., and
3) after sales services. These three phases consist of broad activities which
constitute the CTAM and can predict how a construction organization passes from
recognising a need to continuously using the technology. The present paper is
mainly focused on the first phase of the CTAM, diffusion, and is aimed at
recognising the patterns in vendors’ strategies which are designed to expose their
technology and encourage the construction company to initiate the adoption
process.

ANALYSIS OF THE VENDORS ACTIVITIES AT THE CTE

The observations at the CTEs are analysed to understand the existing
patterns of vendors’ activities aimed at supporting and influencing the customers
in the adoption process. The observations consist of field notes and visual records
and evidence such as the annotations shown in Figure 2. In order to statistically
analyse the data, a Gauge Matrix [GM] was developed to profile the behaviour of
the vendors observed. Forty one variables were identified across four indicators:
Display Configuration (DC), Communication Facilitators (CF), Technology
Attributes (TA), and Knowledge Transfer (KT) to measure the similarity and extent of the activities.

Figure 2. Indicators of vendors’ strategies at AIMEX 2011

A five level Likert scale was used for developing the $[GM]_{s,j}$, where $s$ is the scale and $j$ is a representation of the variables. For example, the scales used for four of the variables are shown in Table 1. The $[GM]_{3,41}$ was created encompassing the forty one variables for each of the 111 exhibitors at AIMEX and for each of 110 exhibitors at CME.

Table 1. The 5*5 sub-matrix of the $[GM]_{s,j}$ for CTEs

<table>
<thead>
<tr>
<th>Score</th>
<th>Booth Size (m²)</th>
<th>Designed Area (m²)</th>
<th>Booth Type</th>
<th>Number of Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$j = 1$</td>
<td>$j = 3$</td>
<td>$j = 6$</td>
<td>$j = 32$</td>
</tr>
<tr>
<td>1</td>
<td>0-35</td>
<td>0</td>
<td>Without any Design (T1)</td>
<td>1-2</td>
</tr>
<tr>
<td>2</td>
<td>36-70</td>
<td>&lt;36</td>
<td>Standard Box Scheme (T2)</td>
<td>3-5</td>
</tr>
<tr>
<td>3</td>
<td>71-199</td>
<td>37-80</td>
<td>Deluxe Decorated Design (T3)</td>
<td>6-8</td>
</tr>
<tr>
<td>4</td>
<td>200-499</td>
<td>81-100</td>
<td>Fashioned Design (T4)</td>
<td>9-12</td>
</tr>
<tr>
<td>5</td>
<td>&gt; 499</td>
<td>&gt;100</td>
<td>Unique Design (T5)</td>
<td>&gt;12</td>
</tr>
</tbody>
</table>

Vendors’ activities were separately scored for each variable and all of the variables weighted before analysis. Then cluster analysis was applied to identify patterns in the sample of vendors and technologies.

CLUSTERING ALGORITHMS AND THE INDICATOR MATRIX

Modelling the technology adoption process in construction requires an understanding of the variety of vendors and the patterns in the strategies they use. The patterns allow us to identify the variety of technologies and group them based on their characteristics. In the present paper, the Fuzzy c-means (FCM) clustering algorithm (Bezdek 1981) was used to find out whether different vendors in each cluster shared activities that might account for the adoption strategies associated with that cluster. Then, the vendor’s membership matrix ($\mu_{ic}$) was employed to numerically indicate the similarity of vendors’ behaviour between clusters.

In the first stage, the FCM clustering method is employed to classify vendors into c disjoint subsets $c_k$ ($i = 1, 2, \ldots, c$) in which separation distance within the cluster is small. The FCM is seen as a widely used method in fuzzy pattern recognition. The FCM is based on minimizing an objective function called the c-means functional $J$. It is defined as
\[ J_m(U,V) = \sum_{k=1}^{C} \sum_{i=1}^{N} (\mu_{ik})^m \|v_i - c_k\|^2 \]  

Here, \( \mu_{ik} \in [0,1] \) is the membership coefficient of the \( i^{th} \) vendor in the \( k^{th} \) cluster, \( m \) is the fuzziness coefficient greater than 1 that controls the fuzziness of the resulting clusters, \( v_i \) is the \( i^{th} \) vendor, \( c_k \) is the \( k^{th} \) cluster centre, \( C \) is the number of clusters, and \( N \) is the number of vendors. \( v = \{c_1, c_2, \ldots, c_N\} \), \( c_i \) is the centre vector of \( c_k \) cluster. Here, the notation stands for Euclidian distance between vendors and the cluster centre. The \( \mu_{i,v} \) is employed to numerically indicate each vendor class membership and the similarity of vendors among the classes in a matrix called \( \mu_{i,v} \). The element in the \( i^{th} \) row and \( k^{th} \) columns in \( \mu_{i,v} \) indicates the degree of membership function of the \( i^{th} \) vendor with the \( k^{th} \) cluster. The Fuzzy Matrix \( \mu_{i,v} \) for vendor classification is as follow:

\[
\mu_{i,v} = \begin{bmatrix}
I_{v1,C1} & I_{v1,C2} & \cdots & I_{v1,Ck} \\
I_{v2,C1} & I_{v2,C2} & \cdots & I_{v2,Ck} \\
\vdots & \vdots & \ddots & \vdots \\
I_{vN,C1} & I_{vN,C2} & \cdots & I_{vN,Ck}
\end{bmatrix}
\]

Here, the \( \mu_{i,v} \) represents how closely the \( i^{th} \) vendor is located to the \( k^{th} \) cluster. Using FCM, the vendors’ business behaviour and similarity of their behaviour among different classes were analysed. Matlab R2012b was used to perform the analysis and the results of classification are presented in the following section.

RESULTS AND VALIDATION

**Fuzzy Classification of Vendors**

Setting the fuzzy clustering algorithm to find three clusters resulted in clusters that roughly correspond to heavy equipment (e.g., drilling rigs and loaders), light equipment (e.g., pumps and mini backhoes) and small tools (e.g., hand tools and brick saws). Setting the algorithm to find five clusters discovered that the heavy equipment cluster was made up of two distinct strategy patterns and so was the small tools cluster. The two heavy equipment clustered were labelled A and B, the light equipment cluster was labelled C, and the two small tools clusters were labelled D and E. Setting the algorithm to find other numbers of clusters did not result in meaningful clusters.
Figure 3. Contour plot showing the distribution of vendors according to booth size and position. Many of the dots represent multiple vendors.

Surprisingly, the results illustrate five separate clusters whose centres are quite far from each other as shown in Figure 3. However, some of vendors are not close to the centre of any particular cluster and may be seen to have a combination of strategies. This illustrates the fuzzy nature of the clusters.

Table 2. Profile of vendors’ classification based of fuzzy c-means results

<table>
<thead>
<tr>
<th>Cluster</th>
<th>&gt;0.33</th>
<th>Average</th>
<th>Vendors (v_i)</th>
<th>c_k for Booth Size (Z_i)</th>
<th>c_k for Booth General Type (Z_o)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
<td>10.19</td>
<td>Earthmoving vendor 111, 01, 04, and 107</td>
<td>5.29</td>
<td>5.49</td>
</tr>
<tr>
<td>B</td>
<td>22</td>
<td>19.42</td>
<td>Heavy equipment vendor 06 and 105, Earthmoving vendor 15</td>
<td>3.91</td>
<td>4.07</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>26.52</td>
<td>Construction tool vendor 55, concrete pump 08, Monitoring vendor 24</td>
<td>2.77</td>
<td>2.94</td>
</tr>
<tr>
<td>D</td>
<td>38</td>
<td>27.46</td>
<td>Solar equipment 30, Pump vendor 11, Tool vendor 12</td>
<td>1.68</td>
<td>2.06</td>
</tr>
<tr>
<td>E</td>
<td>38</td>
<td>27.41</td>
<td>Green tool vendor 13; Hand tool vendor 14</td>
<td>1.05</td>
<td>1.09</td>
</tr>
</tbody>
</table>

In the analysis, the membership coefficient matrix $U = \mu_{i\alpha k}$ was computed based on the $\mu_{i\alpha k}$. A part of the fuzzy matrix $U$ is shown in Table 3. The table reveals that the strongest possibility is that Earthmoving vendor 107 and Earthmoving vendor 111 belong to cluster A, while there is a weaker possibility they belong to other clusters. Heavy equipment vendor 105’s marketing strategies are not totally similar to cluster A, meaning that Heavy equipment vendor 105 has some strategies similar to cluster B. Some vendors in cluster C have similarities with cluster B such as Construction tool vendor 55, while others have similarities with cluster D and even cluster E such as Monitoring vendor 24. Vendors in the two last clusters have some similarities in marketing strategies such as SBS and Orion Solar.

**Validation**

The second set of the CTE’s data from CME 2012 was employed to validate the vendor patterns found in the first CTE. Similarly, five clusters of
vendors provide the most meaningful results. Once again, cluster A is more distinct than the other clusters.

Table 3. Fuzzy matrix $\mu_{ik}$ for some of the AIMEX vendors

<table>
<thead>
<tr>
<th>Vendors (vi)</th>
<th>P(A)</th>
<th>P(B)</th>
<th>P(C)</th>
<th>P(D)</th>
<th>P(E)</th>
<th>Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthmoving vendor 107</td>
<td>0.7373</td>
<td>0.1090</td>
<td>0.0540</td>
<td>0.0498</td>
<td>0.0500</td>
<td>A</td>
</tr>
<tr>
<td>Earthmoving vendor 111</td>
<td>0.7833</td>
<td>0.0863</td>
<td>0.0457</td>
<td>0.0423</td>
<td>0.0424</td>
<td>A</td>
</tr>
<tr>
<td>Heavy equipment vendor 105</td>
<td>0.3212</td>
<td>0.3205</td>
<td>0.1275</td>
<td>0.1151</td>
<td>0.1156</td>
<td>A, B</td>
</tr>
<tr>
<td>Construction tool vendor 55</td>
<td>0.0727</td>
<td>0.3439</td>
<td>0.2117</td>
<td>0.1853</td>
<td>0.1863</td>
<td>B, C</td>
</tr>
<tr>
<td>Monitoring vendor 24</td>
<td>0.0340</td>
<td>0.1547</td>
<td>0.2795</td>
<td>0.2655</td>
<td>0.2663</td>
<td>C, D, E</td>
</tr>
<tr>
<td>Solar equipment vendor 30</td>
<td>0.0166</td>
<td>0.0674</td>
<td>0.2676</td>
<td>0.3255</td>
<td>0.3229</td>
<td>E, D</td>
</tr>
</tbody>
</table>

DISCUSSION

The finding that there are five clusters of vendor behaviour is important because it reinforces our knowledge of vendor types used for modelling technology adoption in the construction industry. In addition, it has useful strategic managerial implications for construction market players. To understand the adoption process in construction, we need to identify a pattern of existing vendor attributes influencing the adoption process. The two objectives of this paper are: (i) identifying patterns of vendor activities which support adoption decision-making; (ii) investigating the differences of vendors’ business behaviours between the clusters in terms of facilitating the technology adoption process.

The result of $\mu_{ik}$ indicates that cluster A and cluster B vendors disseminate mostly similar technologies such as backhoes, dozers and dump trucks and, in some cases, components, power generators and secondary product lines. However, Table 3 provides the probabilities for five of the companies being in each cluster and reveals that Earthmoving vendor 107 strategies are exclusively associated with cluster A ($U_{107,1} = 0.7833$) in which the strategies were unique at AIMEX such as live performances during the CTE, providing simulators and digital media to transfer knowledge, demonstrating cutting edge technologies, and more than 10 booth staff. At the same time, one unanticipated finding was that Heavy equipment vendor 105 employed similar strategies to both cluster A ($U_{105,1} = 0.3212$) and cluster B ($U_{105,2} = 0.3205$), while there are weaker similarities with cluster C ($U_{105,3} = 0.1275$), cluster D ($U_{105,4} = 0.1151$) and cluster E ($U_{105,5} = 0.1156$). Observations show that the Heavy equipment vendor 02 exhibited a series of technologies in AIMEX as shown earlier in Figure 2. This is not similar to CA, although they mainly focused on their brand and claimed innovativeness and leadership. Therefore, the vendors’ behaviour in support of customers was most likely affected by the character of their technology.

At the same time, the result obtained FCM membership classes shows that cluster D and cluster E presented mostly similar types of solutions such as tools, electronic devices, wear parts, attachments and accessories. They mostly have small booths, less digital information, and demonstrate the technology in a less ostentatious way, employing only one or two sale persons. However, there are differences within this group such as the advertisement, brand maturity and after sale services. Observations show that most cluster D vendors simply show their
products in a basic booth. Most local vendors who serve a limited geographical area are associated with this class of technologies such as Green tool vendor 13.

The findings suggest that vendors set their strategies based on the technology characteristics which facilitate its adoption. However, there is abundant room for further progress in determining the relation between the strategies and the duration of the process which a potential adopter passes through before making the decision to purchase the technology.

**CONCLUSIONS**

This paper has investigated the vendors’ marketing strategies to explore the pattern of vendor clusters which exist in the construction market. The strategies are aimed to facilitate and pace the adoption process. At the same time, the strategies are utilised to support and influence construction companies as they pass through different phases of the purchase process. The paper presents the results of a study which attempts to understand the differences between five recognised compartmentalised clusters of vendors, some of whom may have multi-marketing strategies. The present paper takes the first step of gaining an understanding of the adoption process to elaborate the CTAM by recognising vendor marketing patterns.

The current findings add substantially to our understanding of vendor clusters in the construction market by a providing a pattern of five classifications. The paper has shown that cluster A and cluster B vendors disseminate mostly similar technology types such as heavy equipment and plant and in some cases machine components and secondary product lines. However, groups of vendors in each class employed different strategies because they provided different models of technologies at the CTE. Similarly, cluster D and cluster E vendors offered generally similar types of technology that could be considered together as a group in order to study the adoption process. Another important finding was that cluster D and cluster E vendors displayed totally different business behaviour compared with the first two classes of vendors at the CTEs. This difference inspires a new assumption that the variety of the vendor strategies is compelled by the technology’s character. In this case, each group of technologies probably demands specific strategies by vendors to display, offer and support construction companies after the sale to introduce the technology at the construction site. Hence, the vendors’ business patterns allow us to identify the variety of technologies and group them based on their characteristics which assist us to model and predict more accurately the technology adoption process in the construction company.

These findings provide the following justification into this on-going study. The features and characteristics of the technology affect the vendors’ marketing strategies and the customers’ decisions. The findings of this study have a number of important implications for innovators, manufacturers, and exhibition organisers in understanding the variety of vendors and their business behaviour in supporting decision makers in the adoption of new technologies. Furthermore, industry policy makers could use the results of the study in order to strengthen the technology adoption process so that it eventually enhances the productivity of the construction sector and consequently boosts the prosperity of the economy.

Ongoing work is looking at validating this pattern through the use of interviews with industry practitioners.

**REFERENCES**


