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Construction Management (AFH10)
A DECISION FRAMEWORK FOR ADVANCED CONSTRUCTION TECHNOLOGY ADOPTION

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Abstract

The construction industry generally has a conservative attitude towards adopting innovations. Previous studies extensively focused on explaining the working of new technologies, and how they can be implemented. However, the process of adoption of new construction technologies by companies for transport infrastructure construction projects such as tunneling is totally unexplored. The purpose of this paper is to present a framework for the adoption process of new advanced technologies in transport infrastructure construction. The framework consists of eight stages that a company passes through in adopting a new technology. A semi-structured interview (SSI) protocol was developed and used to understand the underlying multiple objective decision-making process, and the various stages of the adoption process. Ten construction industry practitioners including railway, tunneling and earthmoving contractors discussed a total of twenty one technologies ranging in cost from $0.75M to $45M, including drilling rigs for bridge construction, blind bore shaft drills for rail development and advanced tunnel boring machines (TBM). The data obtained was analyzed using thematic analysis, and axial and selective coding techniques. The model proposed in the paper – referred to here as construction technology adoption framework – incorporates the identification of solutions, the purchase decision, and the implementation. The novel framework will assist technology policy makers and vendors to better understand the adoption process, and predict customers’ decision behavior in order to facilitate and speed up the adoption process in the heavy infrastructure construction industry.

Keywords: Construction management, Transport infrastructure, Tunneling, Advanced technology, Tunnel boring machine.
INTRODUCTION

The construction industry is generally risk averse to adopting new technologies thus it has a lower rate of new technology adoption than many other industries (1, 2). A variety of new technologies such as expensive tunnel boring machines, drilling rigs, and track layers are increasingly being introduced to heavy construction projects. The question arises how contractors make decisions to adopt new technology for heavy infrastructure construction, a decision which poses new risks and affects the success of the project in terms of on-time delivery, quality and safety. Another question is whether the adoption process for advanced technologies is different to that for conventional technologies such as earthmoving equipment. For example, how does a construction company make the decision to purchase a tunnel boring machine which might be the major cost for a particular roadway project? Most complex transport infrastructure projects (e.g., underground, highways and railways) need to employ complex plant and equipment (e.g. tunnel boring machines, or multiple core drilling rigs).

While the technologies themselves have been studied in the literature, the process of how a construction company makes the decision to adopt these technologies is largely unexplored. Several studies have focused on technology selection or prediction of performance for a particular technology such as cranes (3), earthmoving machinery (4, 5), or concreting equipment (6) utilizing different methods, such as the analytical hierarchy process approach (7). For example, Ulubeyli (8) suggests that the selection of a new concrete pump is mainly based on distance pumped. In addition, they suggest a selection method considering five different criteria (e.g. selling price, operating cost per day, technical services). However, the result of each of these studies is an algorithm for technology choice based on limited factors or technology features. The unfamiliarity of the technology for a construction company, vendor issues, or dynamic factors such as previous performance of both vendor and technology are often ignored. In addition, such studies assume that the technology selection occurs in a single stage, akin to an impulse purchase (8), rather than a multi-stage decision making process, which sometimes takes more than a year in the construction industry, particularly for tunneling. Furthermore, they assume that only a certain group of individuals such as the engineer is going to make the selection whereas usually the decision is driven by more than one person with more than one objective.

The originality of this paper lies in the examination of the dynamic relationship between the customer and the vendor throughout the multi-stage process. In doing so it considers factors related to the nature of the customer organization, issues regarding the vendor, and project characteristics, and not just factors related to the technology itself. This paper helps to fill a gap in the literature of advanced technology by considering the process a customer passes though, beginning with recognizing the need to adopt a new or advanced technology for use in transport infrastructure construction projects. The findings of the paper will assist vendors to understand the technology adoption process, and facilitate adoption of their technology. Inexperienced contractors can use the process described as a template for their own companies.

In this paper, first the literature of technology adoption is reviewed. Then, a novel framework considering both customer and vendor viewpoints is presented. Third, the exploratory research method used for collecting and analyzing data is presented. Finally, the results of the study are presented and discussed.

CONSTRUCTION TECHNOLOGY ADOPTION

Technology is one of the key streams in the transport infrastructure construction literature. Various studies cover the areas of introduction or applications of a new technology in construction (9-11), technology choice and selection (7, 8, 12), acceptance (13), and prediction of performance and implementation of a certain technology (12). However, the overall process of adopting a new advanced construction technology remains unexplored in the construction literature. This section of the paper reviews existing approaches, concepts and models in adoption.
Approaches

The most detailed examination of new technology adoption has occurred in the information systems (IS) area. In this domain research has taken two perspectives: a psychological perspective (14) and a social perspective (15). The psychological perspective fundamentally relies on technology acceptance models (TAMs) (16). These models are widely used (17-19) to predict the users’ behavior to accept information technologies (ITs) and information communication technologies (ICTs). For example, Cheng (19) used TAM to study the adoption of mobile ticketing by passengers that travel by high speed rail.

Research based on TAMs typically involves survey questionnaires regarding information technologies (13, 20-22). The data is gathered using one-shot structured surveys to investigate correlations between factors. This approach is not able to obtain deep understanding of the sequential activities taken by potential adopters.

The studies that take a social perspective base their work on the diffusion of innovation theory (15), which suggests that five categories of adopters describe the technology spread in a social system: innovators, early adopters, early majority adopters, late majority adopters and laggards. These studies are mostly statistical analyses that are not set in an aggregate framework (23).

However, most of previous studies assumed that adoption is an event which occurs in one shot. In addition, these perspectives ignore the vendor side in the model. In general, existing studies of technology adoption are not well suited to the question of how an advanced technology is adopted by a construction company. There is therefore, a need to fill this gap in the literature by developing a framework for construction technology adoption in order to understand the process of adoption.

Concepts

In this paper, technology refers to any tools, plant and equipment for physical construction activities, and advanced technology refers to the latest models of such plant and equipment. Adoption of technology is defined as the steps taken in the process through which the adopter passes to reach a decision to accept or reject a new technology (15).

Proposed Framework

This paper covers all actions in the adoption process from seeking a possible solution to implementation of the technology into daily construction operations [22], in which both participants – vendors and customers – exchange information in order to move toward the adoption decision. This process may halt either temporarily (e.g., waiting for more information) or permanently (e.g., rejecting the technology) at any stage.

The proposed framework takes into consideration previous studies in domains different to construction, and deals with any limitations noticed. For example, the proposed framework uses a multistage adoption process at the organizational level, in place of the existing single-stage psychologically-based views in TAM.

In addition, the proposed framework also takes into consideration the competitive environment and role of vendors in adoption, issues which have previously been overlooked. The dyadic relationship and the interaction of both sides of the adoption – customer and vendor – are believed to be significant in the technology transfer (24, 25).

RESEARCH METHOD

In order to explore the pre-adoption process in construction, the semi-structured interview (SSI) technique was chosen (26). The SSI systematically investigates the process by recruiting preselected interviewees who are experienced and involved in adoption at their company. The data obtained through the interviews is analyzed using thematic analysis. This method is recently has
been popularized in transportation research. For examples, see (27-31). Each interviewee discussed the framework in light of a technology adoption case from their organization. In total 21 technology cases were discussed as listed in Table 1.

### TABLE 1 Data profile

<table>
<thead>
<tr>
<th>Technology cases</th>
<th>Number of cases</th>
<th>Price $000s</th>
<th>Technology class¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunnel boring machine</td>
<td>4</td>
<td>15-45000 AT</td>
<td></td>
</tr>
<tr>
<td>Tunnel boring system</td>
<td>1</td>
<td>-</td>
<td>AT</td>
</tr>
<tr>
<td>Blind bore drilling</td>
<td>1</td>
<td>6500 AT</td>
<td></td>
</tr>
<tr>
<td>Multiple core drilling</td>
<td>1</td>
<td>150 AT</td>
<td></td>
</tr>
<tr>
<td>Drilling rig</td>
<td>2</td>
<td>540-1820 AT</td>
<td></td>
</tr>
<tr>
<td>Excavator</td>
<td>1</td>
<td>120 CT</td>
<td></td>
</tr>
<tr>
<td>Eng. gunhead rotates</td>
<td>1</td>
<td>260 AT</td>
<td></td>
</tr>
<tr>
<td>Truck</td>
<td>2</td>
<td>200-370 CT</td>
<td></td>
</tr>
<tr>
<td>Mobile crane</td>
<td>2</td>
<td>750-2800 CT</td>
<td>CT and AT</td>
</tr>
<tr>
<td>Tower crane</td>
<td>2</td>
<td>200-600 CT</td>
<td>CT and AT</td>
</tr>
<tr>
<td>Concrete pump</td>
<td>3</td>
<td>90-1400 CT and AT</td>
<td></td>
</tr>
<tr>
<td>Front end loader</td>
<td>1</td>
<td>200 CT</td>
<td></td>
</tr>
</tbody>
</table>

¹AT: Advanced technology; CT: Conventional technology

Semi Structured interviews were used in order to give the interviewees the maximum flexibility to discuss what happens in their organization, rather than to be limited to preselected ideas of the researcher.

Interviewees were asked about the framework to see if it matched the processes used in their organization. They were then asked probing questions to get details of their typical actions. Finally they were asked about the framework again to see if their opinion had changed based on the deeper discussion.

### FINDINGS AND DISCUSSION

The analysis and results of the rich data obtained from the 12 interviewees is presented in this section.

Interview transcripts were broken down into concepts. Codes were applied to these concepts and then sorted and collected into themes [22]. Each theme was examined for meaningfulness. It was found that the meaningful themes corresponded to the stages in the framework. Thus the findings support the proposed model for technology adoption. However, differences in emphasis on different stages were found between conventional and advanced technologies.

This section will first describe the process for conventional technologies and then highlight the differences when an advanced technology is involved.

### Framework Development for Construction Technology Adoption

The findings reveal that there are groups of technologies which follow similar procedures which begin with identifying the need to implementation in a construction project. As expected the adoption process can be modelled as a multi-stage decision. The proposed model was applied to 21 technologies and found to generally fit, with minor modifications. However, the analysis reveals that the stages have different levels of importance for different technologies.

The interviewees verified that communication between both customer (contractor or construction equipment supplier) and vendor can greatly facilitate the adoption process. The investigation showed that at least one kind of communication, such as face-to-face discussion,
telephone conversation, or email exchange of information (e.g. document, drawing, specification, etc.), occurred in each stage of the process. This dyadic relationship is ignored in the adoption and diffusion literature in construction, although it is reported that vendors have a positive role in a successful adoption (32). The adoption process begins with a need. It rarely happens that a construction company purchases construction technology because of emotional reasons, (while it is reported that in some areas outside construction, such as information technology, the adopter will sometimes purchase a technology and then invent a need for the purchased technology (15)).

Following the need recognition, the potential adopter begins by identifying potential solutions (Stage 1) and studying them (Stage 2). From the other side, vendors offer potential solutions to customers, and provide knowledge about the technology and its functionality. In Stage 3, the customer compares the features, advantages and benefits of the available technologies, while the vendor tries to induce the customer towards the vendor’s own brand. After collecting the required information about the technology (both technical and commercial aspects), the customer begins to analyze it (Stage 4). At the same time, vendors continue to communicate and exchange information and negotiate terms and conditions. In some cases, the customer asks for a practical evaluation (Stage 5) such as a trial or test. The vendor will often be involved in this trial, both loaning the technology and providing personnel to help run the test. Sometimes, vendors provide references from previous customers instead. Next, the customer makes the adoption decision of whether or not to purchase the nominated technology (Stage 6).

The final stages are implementation (S7) and assessment (S8). Vendors deliver the technology, operate the technology, and train customers in the implementation of the technology, and finally help them in the assessment period by customization and upgrading the technology.

Advanced Technologies Adoption

Several differences were seen in the adoption process for advanced technologies. These differences were not about the stages themselves; rather they involve some changes to the activities conducted in some of the stages and the relative importance of various stages. Differences emerged between standard advanced technologies (SAT) and unique advanced technologies (UAT).

The SAT group of technologies is those that are manufactured as standard units. That is, the plant or equipment has already been designed, although due to unpredictable demand the manufacture may not start until an order is placed. Examples of SAT in the sample are the latest models of trucks and excavators.

UAT technologies require major customizing and thus are not usually designed until an order is placed. Examples of UAT in the sample are blind bore drilling equipment or tunnel boring machines. The process of adoption for UAT technologies (e.g. underground equipment) often takes longer than twelve months.

The interviews showed that the adoption process for the SAT technologies is similar to the basic framework as used for conventional technologies; larger differences are found in the processes of customers of UAT technologies.

The adoption process for both types of advanced technology often starts with a need, such as a request for proposal (RFP) from a client (shown in Figure 1 as 1) some months before beginning the project. This contrasts with conventional technologies where the contractor usually recognizes the need without client input or any specific demand. Decisions to investigate conventional technologies such as a truck or front end loader are not begun until after the contract is awarded. The following sections discuss the differences between the adoption processes for both standard and unique advanced technologies in each stage of the framework. Figure 1 shows a schematic of the various stages involved.
Solution Conceptualisation

The first three stages of the framework revolve around conceptualization of the solution.

Stage 1: Identification of Potential Solutions. It can be extremely important to identify enough choices during this stage, so that an organization does not get trapped into a less than optimal technology. This is particularly an issue for tunneling and underground tasks. The reason is that the construction method is dictated by the technology. For example, if a project decides to use a TBM, then the method of construction will be completely different to the method for drill and blasting. In contrast to conventional technologies, in which usually a number of competitors are available, the number of UAT vendors for specific methods is often limited. A plant manager notes: “[at this stage] if you are lucky [you have] 3 or 4 [quotes], if you are not so lucky you have only one. But that still doesn’t settle the vendor discussion; because once the project really starts what happens is that the bid team and the project execution team are not the same.”

It was found that for a nominated project (which has not been awarded to any contractor yet), different prospective contractors propose a variety of technological solutions. A TBM operator described it as “[in our project two bidders] proposed two different types of TBM and the third vendor looked at a drill and blast solution. Which technology was used was clearly defined by the construction companies.” The sales manager of the TBM manufacturer used in this project explained the vendor’s perspective: “In this process you have a number of contractors doing the same thing in parallel. We deal with all of them and they may want different solutions for the same project. Contractor A says ‘Our impression of the geology is this and the type of the machine we want is one of these’. Contractor B maybe wants another type. … There is an overlap between the capabilities of the machines. One might ask for a single shield machine, another for a double shield machine, [one is cheaper, while the other is faster] All these things start happening way back before the project starts. … Contractor A is thinking ‘I have a better bid. I can build this thing faster’. … The client would have 4-5 bids [to choose from].”

FIGURE 1 Schematic of the framework for advanced technologies.
Overall, adoption of UAT is more complex than SAT or conventional technology, because commonly multiple solutions will be identified by different prospective contractors, none of whom have actually been awarded the project yet. There is a client who has a more or less developed idea of what the need that should be satisfied is, but does not necessarily care how it is constructed. There are contractors, who based on discussions with the client, have approximate ideas of what the project needs to be and some technical understanding of how to do that sort of work. Finally there is a vendor, who from discussions with individual contractors, is trying to work out how they can provide a solution to the problem that will satisfy the needs of the client and the contractor.

Solutions are not certain or clearly defined at this stage, and most of technologies do not exist yet. The contractors are not sure if eventually they will need to buy such a technology until the client awards them the contract. However, contractors and vendors communicate to work out the technology and estimate the technology price as part of the contractor’s bidding process. Another difference is that the technology is a major part of the whole solution or construction method, and technology identification in this stage is a central part of the proposal.

**Stage 2: Study of Technology.** The interviewees verify that a customer has to collect information about potential solutions. The study at this stage is not about details, and a customer usually collects information about the technology in terms of overall functionality, capacity and the main features of identified technologies. At this stage the project details are often fairly general and unrefined (e.g. geotechnical information may be limited) and so there is not enough information to fully design the UAT anyway.

**Stage 3: Examine Potential of Solutions.** Customers usually examine the potential of each solution from various perspectives. They compare the potential of identified solutions in terms of functionality, time and cost. Customers of SATs make a short list of vendors, and examine the potential of solutions for further analysis, similar to conventional technologies. This further analysis will be made by the contractor after the project is awarded, which may be several months later.

In contrast, UAT customers examine the potentials of several solutions, and then select one to base their bid around. Thus, the initial adoption decision by the potential adopter (contractor) is being made at this stage (i.e. much earlier than for SAT). The client then makes the decision about which contractor to engage. The vendor who closely worked with the winning contractor then has a high likelihood of being engaged by the project contractor if they win the job.

UAT technologies are extremely project driven. Without the specific project there is no need for the specific technology. This is not such a factor for SAT technologies, as they may be able to be used in other similar projects.

Once a contractor is chosen by the client, then the contractor has a limited time to start the project. Therefore, the contractor moves on to analyzing information and making the adoption decision.

**Detailed Analysis and Decision**

The next three stages involve analysis, evaluation and a final decision.

**Stage 4: Information Analysis.** Given that the contractor has now been awarded the contract and has certainty that they need to do the work they will spend more effort collecting information about the technologies that they are considering for the project in order to make a better decision. This information will cover both technical and commercial aspects. The vendor responds by providing this information and precise costs.

A vendor manager notes: “We do refinement of specification, getting down line by line description of what makes the TBM. What is the major components, pumps, hoses, cutter head, etc. [This is done in] huge detail … [The contractor] derives a list, issues the time; quality is sacrificed sometimes, because of time. … We start the process with them, we call pre-design in advance of the award, and we start the engineering design process”
Stage 5: Practical Evaluation. Given that adoption of advanced technology will probably have a large impact on the outcomes of the project, customers usually require assurance at this stage that the technology will be appropriate for the project. Preferably they would like to see the technology working first hand.

In the conventional technology case the vendor will usually loan the equipment to the potential customer for a few days for the contractor to try it out. In the SAT case, if equipment happens to be available the vendor will organize a demonstration for the customer, otherwise they may organize for the customer to see the equipment in operation at another customer’s site.

In contrast, with UATs it is not possible for the customer to test or practically evaluate the technology, since it does not yet exist. This problem is dealt with by providing customers with a list of references from previous customers. This list and what the previous customers say are critical in this stage. A plant manager reported: “in some cases we are not able to have references from other projects and we just call up plant engineers: What they did for you? Where they ok or not? … If anybody says that they [vendor] left us in the lurch that usually is the end of it. That is very important – the support – and making sure it all works … is an extremely important aspect for us.”

Stage 6: Adoption Decision. This stage has been recognized as one of the most important stages for all technologies. Not reaching this stage is effectively deciding to not adopt any technology. At this stage the customer may negotiate for more after sales services, and add penalty clauses to the contract. In some cases they try to transfer all risks related to performance of the technology to the vendor. A plant manager of a tunneling contractor notes: “all these projects have quite massive penalties for exceeding the finishing dates or one of the bad penalties to start with, if you are running a site like this, you might have running cost, the cost of people and keeping them one day … you have a quite massive cost. The daily cost is much more than $100 000 …”

On the other hand, vendors resist accepting such risks as they may be associated with unknown ground conditions or other project attributes over which the vendor has no control. Customers and vendors meet to negotiate to get agreement about the commercials aspects of the agreement, and contract terms and conditions.

The interviewees were in agreement that this stage is more complex and critical for a UAT customer than for a SAT or conventional technology customer, and often takes a much longer time. Sometimes this stage overlaps with the two previous stages.

Implementation and Assessment

The technology adoption process is not complete when the decision to adopt a specific technology is made. The organization still has to implement the technology for itself and assess how it works.

Stage 7: Implementation. In this stage the contractor uses the technology on the project. In the time between the awarding of the contract and delivery of the technology the customer will be preparing to use the technology through training of its personnel and possibly inspection and testing of the technology as it is being built. When the technology is built, then the vendor will test it before delivery. Other activities at this stage include transportation, modification of other aspects of the project to be compatible with the technology, assembly and set up at the site, dry or wet testing, and commissioning. A plant manager of a tunnel boring machine (TBM): “we shift the machine to Australia, and when the TBM arrived in Australia we unpacked and assembled it underground at [the site].”

Since the implementation stage is the whole point of the adoption process, it has a large impact on all of the other stages. Implementation of a new technology is often difficult because staff from the organization have not used the technology before. This may be at the higher level of it being a completely new technology that the organization is unfamiliar with, or at a simpler level, that the new machinery is different to machinery that they have used before and has new quirks and
idiosyncrasies. Furthermore the organization will often need to modify systems or set up new systems to accommodate the new equipment and it may take a while before these systems function smoothly.

Therefore at all of the earlier stages questions will have been asked such as: Does the technology deliver the functionality? Does the vendor train our operators? How reliable will the machine performance be? How does the vendor service the machine (e.g. solve technical problems, repair break downs, provide spare parts)? The decision maker has to consider how the decisions in each stage would affect the outcome of the adoption process and finally the implementation, and the probable impact of the delivery in terms of time and cost.

Stage 8: Assessment. The interviewees pointed out the importance of regularly assessing the technology. Previous studies define adoption as being successful if the adopter fully and continuously uses the technology (15). This definition needs to be modified somewhat for advanced technologies because customers usually change some components of a unique advanced technology such as TBM or blind bore drilling equipment during implementation on site. The reason for this is that the operating team usually was not available during the early stages of identification of solutions or pre-design. In addition, the job conditions such as geology may be different to that expected, and this new information will require customization of the machine. In this case, the technology as whole is implemented, while some components of the machine, which are technologies themselves, are rejected. It rarely occurs that a huge TBM is rejected. However, during implementation vendor support usually includes modifications to increase speed or productivity. This kind of customization and modification rarely occurs for standard advanced technologies such as the state-of-the-art of mobile cranes. A plant manager of a contractor for an infrastructure company notes: “We designed and built a drill rig, … to design and build it was something near the $65 million mark. I wouldn’t say that is entirely the complete sum, because we had to add parts along the way as we went through a commissioning and installation phase.”

Therefore, UAT adoption often doesn’t have a fixed price, while the cost of SATs often is estimated fairly accurately. The assessment stage commonly results in modifications to UATs features or components, while for SATs the major components that are related to the main function of the machine rarely change. However, the assessment is still useful as feedback for the vendor, which can be considered for future production.

One plant manager described the initial assessment phase for his TBM: “The first formal testing starts with a factory acceptance test. This is the performance of the machine against its design operational parameters. This is a dry test that doesn’t cut any rock and was done in Germany. … When it arrived in Australia it was assembled underground and went through another dry test to check what had been done in Germany and to ensure nothing had changed in transit. … We then went into a wet commissioning phase in rock.”

The same plant manager discussed the importance of ongoing testing: “because the machine has not been built or used before, and as we use and learn more about the machine we had to change the schedule [based on the productivity information obtained].”

COMPARISON BETWEEN CONVENTIONAL AND ADVANCED TECHNOLOGIES

The interviewees were asked to evaluate the influence of each proposed factor in the adoption decision by using a scale of high, medium, low, and not applicable. The interviewees’ were asked about conventional and advanced technologies separately. Results are presented in Table 2.
TABLE 2 Importance of technology attributes

<table>
<thead>
<tr>
<th>G</th>
<th>Factors</th>
<th>% of times ranked “high”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Conventional</td>
</tr>
<tr>
<td>1</td>
<td>Technology features</td>
<td>83</td>
</tr>
<tr>
<td>2</td>
<td>Compatibility</td>
<td>67</td>
</tr>
<tr>
<td>3</td>
<td>Versatility</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>Ease of use</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>Reliability</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>Performance quality</td>
<td>83</td>
</tr>
<tr>
<td>7</td>
<td>Model</td>
<td>33</td>
</tr>
<tr>
<td>8</td>
<td>Availability</td>
<td>83</td>
</tr>
<tr>
<td>9</td>
<td>Durability</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>Emission</td>
<td>50</td>
</tr>
</tbody>
</table>

The comparison shows that all variables are supported by interviewees as influential factors. The main differences are that ease of use and environmental aspects are more important for conventional technology customers, while performance quality is more important for advanced technology customers. However, most of the factors apparently do not have substantial differences in importance.

Importance of Stages

The study finds that a customer passes through eight stages to utilize a technology. However, further investigation reveals that there are differences in the level of importance of each stage for conventional and advanced technologies. Interviewees were asked about the importance of each stage in the process. Answers were scored as high (3), medium (2) and low (1). Results were averaged and are plotted in Figure 2.

Figure 2 shows that all stages in the process, except for Stage 5, Practical Evaluation are considered more important for advanced technologies than for conventional technologies. It is also seen that the pattern of importance is quite similar, stages that are more important for conventional technologies are also more important for advanced technologies.

This pattern is important for vendors to know so that they can decide when they should put more effort, or for which stage they should provide more resources and support for the decision.
maker. It may imply that vendor’s business behavior during the implementation period (i.e., after sales services in previous jobs) at stage 7 might be more important than their effort to induce the customer to select their product at stage 3. This finding is different to other areas such as IT and IS, in which vendor persuasion is a key step in the adoption process (15).

CONCLUSION

The presented framework provides a deep insight into the technology adoption process in construction. It offers a systematic framework that describes the stages that a construction company passes through in making adoption decisions, from identification of a solution to implementation. In addition, the framework considers the vendors’ role, and communication with customers along the adoption process. This is the first empirical study on the adoption process of advanced technologies in construction; other adoption studies do not investigate the systematic staging of adoption. Instead, they assume that the adoption occurs in a single stage or they are focused on the adoption of information technology rather than construction technology. The framework in this paper makes a novel contribution at both the theoretical and practical level. At the theoretical level, it describes the interaction between the customer and the vendor in more detail than previously. At a practical level, inexperienced customers can use the framework as a basis of their own processes, and vendors can use this understanding of customer processes to more effectively target their own efforts to influence customers to adopt their technology and support them afterward to build up their reputation.

The limitation of this paper is that the number of interviewees is rather limited, both in sample size and in the range of technologies covered. Future work will involve interviewing more people from a wider range of construction industries to see how well the results stand up and generalize.

Also a wider range of factors will be investigated including vendor and company factors and the attributes of the projects that the technology will be used.

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