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Implementation Processes of Virtual Reality in Construction Companies

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Abstract
The use of virtual reality (VR) in the construction industry is seen as a major transformation from two dimensional drawings. It is currently used in many design companies to present architectural perspectives and helps the owner to obtain an ideal image of the final construction project. However, few construction companies have applied VR in simulating construction methods. In fact, the use of VR can assist all project participants to understand the sequence of construction activities and reduce the potential conflicts among project teams. This paper presents a case study of VR implementation processes in three large Thai construction cases. The six stage of IT implementation from literature is used as the framework in this study. It aims to identify the factors and barriers that occur throughout these implementation stages. The interview is used as a research technique to collect the quantitative data. The finding found that few construction companies were applied VR for simulating their construction methods. VR was used to simulate construction methods in special complex projects. The initial adoption of VR is driven by the project manager who is interested in VR while site engineers and draftsperson can encourage on the success of implementation in the following stages. In addition, this project manager establishes a team for developing and implementing this VR. All participants agree that the use of VR provides benefits in communication and coordination. The understanding of implementation processes can benefit to other contractors who are interesting in adopting VR in their organization.

Keywords
IT implementation, Graphic Simulation, Construction Methods, Virtual Reality

1. Introduction

The use of virtual reality (VR) in the construction industry is seen as a major transformation from two dimensional drawings. It is widely used in many design companies to present architectural perspectives and helps an owner to obtain a picture of the final construction product. Many research studies illustrated the potential use of VR in construction. Aouad *et al.* (1998; 1999) pointed that many software related to VR and 4D-CAD have been developed to improve efficiency in construction processes. Some emphasized that three-dimensional (3D) object drawing provides potential for information integration. Furthermore, this object-based drawing concept further helps information integration over time to produce four-dimensional (4D) modeling (Koo and Fischer 2000; Sriprasert and Dawood 2002. In addition, it helps with visualizing constructability such as providing sufficient workspace for building services and integrating structural data to build a walk-through visualization of the design.

Although the benefits of using VR in construction are obvious, few construction contractors have applied VR in simulating construction methods. Whyte & Bouchlaghem (2002) studied the top 20 house-building companies in the UK and found that there was only one company that was an early adopter of virtual reality systems. They reviewed the strategic adoption of the system and categorized its implementation approach as being either 'strategic' or 'ad hoc'. The 'strategic' approach considers software introduction based on long-term corporate strategy. The development of software involves top management support, user involvement, and a software developer. On the other hand, the 'ad hoc' approach was developed on a sub-strategy that depended on a special department's needs and short-term benefits. Under this approach, introduction of software needs the resource and policy support from a middle manager rather than from top management. Thus, although strategic adoption can be viewed as 'early adoption', an organization may still choose an 'ad hoc' innovation adoption approach.

Mitropoulos and Tatum (1999; 2000) explored criteria that forced organizations to adopt new IT such as 3D-CAD and EDMS. They concluded that these criteria are: a perceived need for competitive advantage; external requirements; technological opportunity; and finding solutions to process problems. They noted that organizations that tend to be early adopters are driven by competitive advantage or internal problem-solving processes. They also discovered that an external requirement such as a client's needs does not significantly influence their early adoption of innovations. Technological opportunity, therefore, appears to have a low impact on early adoption due to the high cost of technology and lack of required skills. Thus, the early adoption decision may be most significantly influenced by competitive advantage or need to solve process problems.

Further research attempts are to study the practice of VR implementation. Bouchlaghem *et al.* (2000) pointed that technical problem of VR use can hinder its implementation and cause the low level of its use. Based on the literature review, the implementation of VR can be defined as two main phases: adoption decision and implementation. However, few studies have been explored the adoption and implementation of VR in construction organization. Thus, the review of IT adoption and implementation in construction organization is essential to provide lessen learned to our research. Thus, the review in the following section will focused on barriers of IT adoption and implementation and also the framework of IT adoption and implementation.

2. Barriers of IT Adoption and Implementation

One potential problem that is likely to occur that inhabits an organization from moving beyond awareness is that the organization becomes reluctant to adopt and invest in the required IT initiative. Early innovation adopters may fear that they are taking an unacceptable risk due to adoption uncertainties (Mitropoulos and Tatum 1999) while late adopters may fear losing competitive advantage benefits through offering novel services after others have offered those benefits (Love et al. 2001).
IT implementation management should play an essential role in creating a proper fit between organizational needs and user requirements (Korunka et al. 1997). In fact, IT implementation has been recognized as the one of the most difficult tasks and with several problems. Johnson (1995) found that 53 per cent of 3,682 IT projects in 365 companies were faced with costs-and-budgets overrun problems and 31% were cancelled. Korunka, Weiss & Zauchner (1997) found that inadequacy in managing IT implementation led to project cost overrun. Griffith, Zammuto & Aiman-Smith (1999) assert the root cause of IT failure is the 'invisibility problem' of implementation such as overestimation of a new IT initiative's value or lack of concern for people-related issues. They suggested that project managers should focus on implementation-related issues such as funding, support, and realistically estimating an initiative's technology benefits.

Two main approaches can be pursued to understand IT implementation: (1) a factor approach and (2) a process approach (Fichman 1992). A factor approach is focused on understanding the factors, variables or criteria that influence successful IT implementation. The aim of this approach is to predict and measure likely IT implementation success. A process approach focuses upon understanding key activities or stages of IT implementation so that the way in which the IT implementation can be understood and optimized depends on the nature of the prevailing circumstances. This paper focused on the process approach because we attempt to learn from the case studies on how the construction organization adopt and implement VR to their organization.

3. Framework of IT Adoption and Implementation

It can be argued that different organizations have their own specific processes and culture, which in turn, cause inconsistent outcome of IT implementation. As the implementation of IT deals with several technological and social variables, it could be argued that simple management of IT implementation may not be adequate. It is necessary that the organization should provide intensive managerial support and to monitor the organizational IT implementation. As the result, the success of IT should be considered both IT adoption and implementation stages. Carlopio (1998) argued that the concept of innovation diffusion can explain the nature of innovation diffusion at organizational and individual/group level. He proposed a framework of innovation diffusion in workplace environments. He adopted Rogers' DoI model and extends the use of this model at the individual/group level. His framework indicates that the diffusion of innovation may occur at both organizational and individual/group levels as later indicated in 'Part A' of Figure 1. Peansupap and Walker (2005) support that this concept can be applied to explain the nature of IT adoption and implementation.

According to Carlopio (1998), the organizational innovation diffusion process as a cyclical loop beginning with knowledge awareness then moving through matching and selection, decision, implementation, and confirmation. In addition, the implementation at the organization level consists of replicated sequences of innovation diffusion, but with innovation diffusion occurring at individual/group levels. At the individual/group level, innovation diffusion is focused on members who are expected to adopt it. This is similar to identified different behaviors between dependent and independent adoption aspects discussed in the previous section. The adoption decision of technology within organizations is usually authorized by a group of senior managers and therefore the key question of ICT adoption should be focused on how to make expected users accept and use ICT in their work processes. Several concepts explain users' acceptance, such as the technology acceptance model (TAM) (Davis 1989), technology planned behavior (TPB) (Taylor and Todd 1995), and diffusion of innovation (DoI) (Rogers 1995). These can be considered as traditional innovation adoption models because they have been argued to explain an individuals' intentional behavior in adopting technology in which the individual has independently adopted or rejected technology (Fichman 1992). Gallivan (2001) argued that traditional innovation adoption models may not be applicable under mandated adoption, dependent on multiple adopters, and extensive training to upgrade users' skills.

As traditional adoption models rely on voluntary adoption decision by individuals, they may be less suitable in explaining complex organizational adoption decisions (Gallivan 2001). Success in technology adoption within organizations needs top-level implementation support and encouragement of expected users to individually adopt and use the technology. To overcome the traditional innovation adoption approach, Fichman (1992) recommended integrating DoI with other theories such as critical mass (Markus 1987), absorptive capacity (Cohen and Levinthal 1990), and organizational learning (Attewell 1992). Similarly the adoption of technological innovation into organizations can be seen as a change initiation process affecting the way people work. The rate of technology diffusion adoption can be predicted by technological characteristics, communication channels, and social systems (Rogers 1995). In addition, traditional innovation diffusion within an organization requires change management to facilitate and encourage people to adopt ICT initiatives. Organizations can do this through: motivating staff; providing appropriate training and technical support; and ensuring supervisor support for an open-discussion sharing environment (Senge et al. 1999).

According to Cooper and Zmud (1990), the model of organizational adoption and its implementation consist of six stages: initiation; adoption; adaptation; acceptance; routinization; and infusion (Figure 1, part B). This stage model has been used for measuring technology adoption maturity based on the characteristics of each stage (Damsgaard and Scheepers 2000). This framework is also applied to explain the practice of web-based project management adoption and implementation within construction organization. Thus, this model can be argued as applicable to VR adoption and implementation using the same management processes.

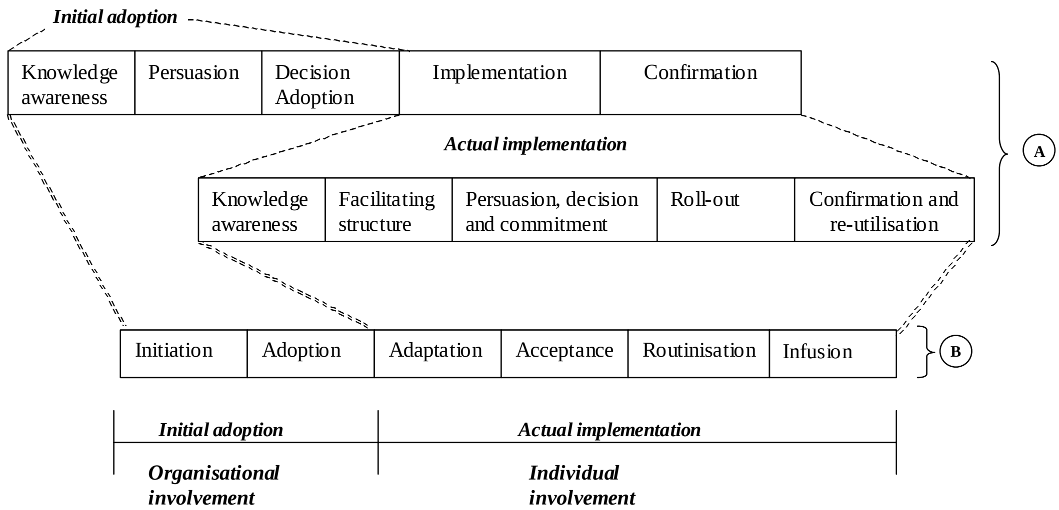

Figure 1 Stage model of technology diffusion adapted from Rogers (1995) [A], Carlopio (1998) [A] and Cooper and Zmud (1990) [B]

4. Research Methodology

The research methodology was classified as a qualitative research approach (Yin 1994). A semi-structured interview approach was used to collect data from users and senior engineers who experienced the use of VR in each three large Thai construction organizations (two main contractor companies and one consultant company). Interviewees were nominated by key contact people within the IT department who understood the research aims to identify VR users were already using VR in their work so that a better understanding of how these organization approached VR adoption and learning. Thus the sample is not a random sample but a purposeful one drawn from VR users, in major construction companies that principally operate in Thailand (Table 1).

Table 1. Interviewee in three cases

Interviewee type	Case A	Case B	Case C
Project managers	2	2	1
Site/Senior engineer	1	1	2
Foreman/Draftsman	1	1	2

The focus of the study was on the organization and the way that it adopted VR initiative. The research question is directed at understanding how and why observed behaviors took place in adopting and learning VR initiative. It concentrated upon the VR innovation facing major construction companies and the aim was to gain a better insight into how several of the major local Thai companies in this industry sector approaches VR innovation. It was anticipated that the study would allow through comparing and contrasting the organizations, better business practices to be identified and the deeper mechanisms underpinning these to be unearthed and understood. While lessons learned may be offered for general acceptance or adaptation, the results are not intended to be seen as a general factual status either within the organizations concerned or as being representative of all the top tier contractors under study. The findings will highlight on current practice in the VR adoption and implementation mechanism. The six stage of IT implementation from literature is used as the framework in this study. It aims to identify the factors and barriers that occur throughout these implementation stages.

5. Research Findings

The findings in each case are organized into two main sections. The first part will present the current practice of VR adoption and implementation based on the six stages of adoption and implementation. The adoption focused on the strategy of introducing VR in Thai construction projects while the implementation highlighted on the management processes that enhance the use of VR at individual/group level. The second part will identify drivers and barriers in each stage of adoption and implementation. The current practice of VR adoption and implementation in three cases can be summarized in Table 2. The initiation and adoption of VR in all cases is driven by the positive perception on potential benefits of using it. Based on three cases, there are two different approaches of VR initiation and adoption. First approach is defined as *top-down approach*. The initiator in case A and B is a group of senior project managers or IT senior project managers. On the other hand, second approach is described as *bottom-up approach*. The main initiation of VR is relied on staff from bottom-line.

Table 2 Summary of VR adoption and implementation in construction cases

	Case A	Case B	Case C
Initiation	*Group of senior project managers* who perceived the benefits of using VR for simulating construction methods and sequences.	Initiation of VR is proposed by *IT senior project manager* who perceived the benefits of using VR to support architectural view of construction project.	The adoption of VR started from the group in the bottom-line. Senior engineers, draftsman and site engineers are recognized the potential benefits of using VR in modeling construction process.
Adoption	Strategic adoption of VR is independently adopted in some large construction projects. Most of project will be outsourced to graphic company.	Adoption decision of VR is depended on the size of construction project and type of work, and client type.	
Adaptation	Adaptation is based on managerial support and training. The VR training is provided to new engineer and draft persons at the beginning but the training of VR is not compulsory.	The success of VR adaptation is influenced by training, self-learning, and group learning. This training is conducted by representative from software vendor.	Senior engineers observed the benefits of using VR and then learn on what the key functions of VR program.
Acceptance/Use	Acceptance in this case is comprised of experienced staff in construction and computer graphic staff from outsource company. The use of VR is relied on individual learning, VR background and sharing environment.	Draft persons are required to learn and practice on how to use VR by themselves. The acceptance of VR is based on the architectural work rather than construction work process.	Learning process of VR occurs at work group level. The staff in this team exchanged the idea on how to install the steel truss with draftsman who can develop the VR
Routinization	Site and senior engineers provided the technical knowledge on construction	The development of VR model in construction required both technical	The staff in this team exchanged the idea on how to install the steel

	processes while graphic designer from outsource company will produce VR model.	VR knowledge and practical construction knowledge.	truss with draftsman who can develop the VR modeling.
Infusion	The company did not have policy to use VR in all construction projects as it will increase the project cost.	-	The benefits of VR use is presented to other project managers. It helps to persuade the use of VR in other projects.

During implementation phases, VR adaptation in three cases was encouraged by managerial commitment. In case A and B, senior project managers provide several supports such as staff training, software and computer investment, and budget in developing VR. In case C, senior engineers involve in learning about VR functions and allocate some budget for developing VR. However, acceptance or use of VR in case B and C is different from this in case A. In case A, the main role of acceptance is relied on outsource company and internal staff who known about technical aspect of construction processes while the acceptance in case B and C is depended on internal site engineers and draftsman who be able to develop VR model. The communication between construction expertise and VR model developer is essential to the success of VR acceptance because VR model developer have less idea about construction process or methods. In contrast, construction expertise should know about VR functions so that he/she may direct developer to use full range of VR functions.

It was found that routinization occurs when construction experts transfer knowledge of construction process with VR model developer. The clear benefits among construction project teams assist the VR routinization. The benefits are learning of construction staff and coordinate between main contractors and sub-contractors. In addition, most of project teams agree that VR helps to illustrate the virtual view of construction processes. Next, the infusion process can be enhanced by presenting positive benefits to other project managers and this helps to persuade the use of VR in other projects.

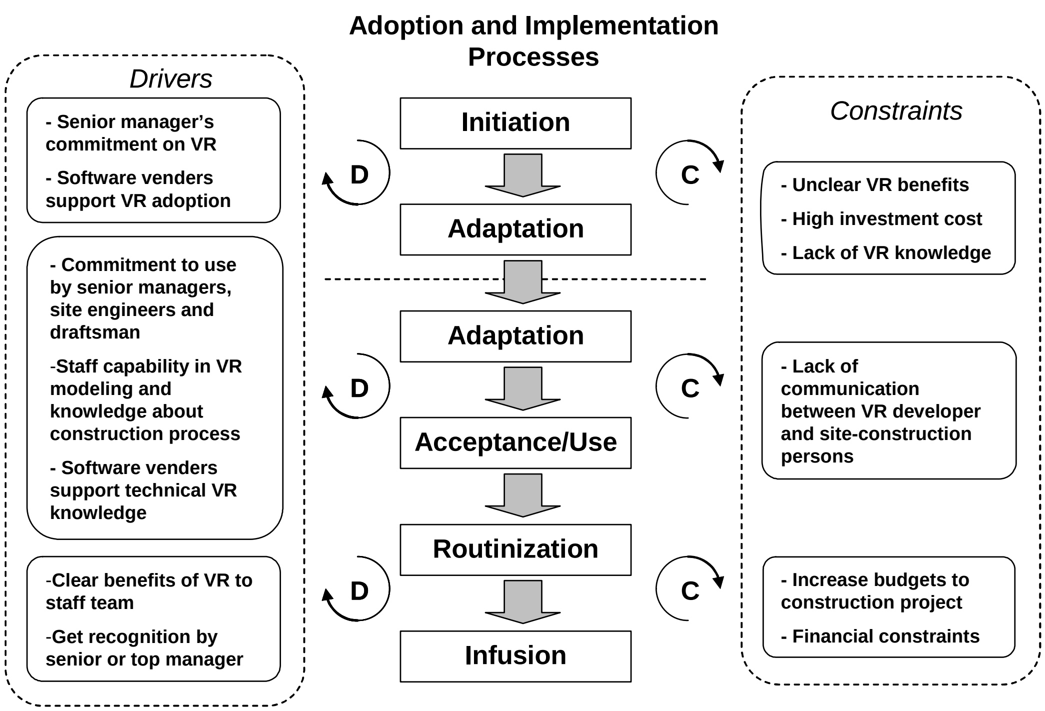

Figure 2 Drivers and barriers during VR adoption and implementation processes

However, there are some barriers of adoption and implementation of VR to develop construction processes. These are limited budget of construction project, unclear understand the benefits of VR use, lack of knowledge about developing VR, lack of knowledge about construction process, commitment to use by senior managers, site engineers and draftsman, and recognition of VR team development.

6. Research Discussion and Conclusion

The finding found that few construction companies were applied VR for simulating their construction methods. VR was used to simulate construction methods in some complex work processes. It is more likely to be used in large construction project. The initial adoption of VR is driven by the project manager who is interested and committed in VR investment and adoption while site engineers and draftsperson can encourage on the success of implementation in the following stages. In addition, this project manager establishes a team for developing and implementing this VR. All participants agree that the use of VR provides benefits in communication and coordination. The understanding of implementation processes can benefit to other contractors who are interesting in adopting VR in their organization.

The case study illustrated different drivers and constraints of VR during processes of adoption and implementation. At the initial and adoption stage, gatekeeper who introduced VR into a construction project is the key driver. The gatekeeper may be senior managers or senior projects who perceived the benefits on VR use. However, the constraints at this stage may be unclear VR benefits, high investment cost, and lack of VR knowledge. These constraints can hinder the VR initiation and adaptation.

During the implementation stage, the key driver is moved forward to implementer who plays essential role in encouraging and supporting VR use into a construction project. Implementer needs to work with group of VR users. Two strategic approaches of VR implementation can be internal group and outsourcing team to develop the VR model. Outsourcing team was claimed to provide benefit when the local staff have no experience on VR modeling. It is also useful approach when the use of VR modeling is required in some construction projects. On the other hand, the internal group is suitable when top manager perceive the benefits of VR use and attempts to encourage VR use among users. However, the implementation of VR by internal group is required a lot of resources, time to learn, and financial support.

As the result, it is difficult to convince benefits at the initial stage. To overcome these problems, organization should establish specific teams to implement the VR use for some construction projects. As the VR model here is applied to simulate construction processes, VR modelers need to understand about construction processes. Therefore, both approaches are required the sharing and communication construction processes from construction experts to VR modelers (internal group or outsourcing team). This sharing is also needed to transfer VR modeling knowledge from VR modelers to construction experts for ensuring the use of full benefits. Several participants understood that the implementation of VR model may impact on high cost of construction project. The main reason is that VR modeling is under developing in construction industry. However if the VR modeling is simpler in the near future, this constraints may reduce.

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