EFFECTIVE APPLICATIONS OF E-COMMERCE TECHNOLOGIES IN CONSTRUCTION SUPPLY CHAIN: CURRENT PRACTICE AND FUTURE IMPROVEMENT

Patrick X.W. Zou, Dr.
Faculty of the Built Environment, University of New South Wales, Australia
email: P.Zou@unsw.edu.au

Youngsin Seo,
Faculty of Built Environment, University of New South Wales, Australia

SUMMARY: The development of e-commerce technologies in relation to construction management have been improved significantly in the recent years and are perceived as a mainstream to improve productivity and information flow as well as communications. However, until now, not much evident research has been conducted to pursue successful applications of e-commerce technologies to the construction supply chain. This research aims to understand the current state of e-commerce technologies applications in the construction supply chain and provide recommendations for future improvement. Both survey and semi-structured interviews were conducted with the construction supply chain members to obtain sufficient and useful research data. The results showed that while everyone agrees on the importance of implementing e-commerce technologies in the construction supply chain, the major barriers lies with the reluctance or inability of the subcontractors/suppliers to adopt the technologies and lack of in-house technical expertise as well as lack of integrated information management systems. The results also showed that increased awareness of company's objectives and more user-friendly, cost-reduced, standardised and integrated e-commerce systems, together with a positive organisational culture on top management supporting continuous IT training and learning and knowledge-sharing are needed in order to promote better use of e-commerce technologies.

KEYWORDS: e-commerce, construction supply chain, challenges, learning and training, knowledge-sharing, process.

1. INTRODUCTION

The construction industry is faced with the ongoing challenge to enhance current work practices and become more client-oriented. This trend is influenced by a number of factors, including greater performance expectations by clients, globalisation of the economy, increased competitions between contractors, continued restructuring of work practices, industrial relations, and industry's need to implement information and communication technologies (Love and MacSporran 1996 cited in Weippert, Kajewski and Tilley 2003). Despite the unique and individual nature of any construction project, it requires involvement by many participants, such as clients, designers, consultants, contractors, subcontractors, and suppliers, as an entity to perform various roles and responsibilities (Goodman and Chinowsky 1996). Sharing up-to-date information between participants leads to reduction of errors and time delays and consequently facilitates more effective and efficient productivity and ultimately improve collaboration and teamwork. However, current construction industry is facing costly progress delays due to inaccurate and untimely communications amongst project team members. Often vital information is 'lost' to the degree that information needs to be re-entered, or hardcopy manuals and drawing documents need be re-produced to have rapid access to the required information to perform some of their tasks (Weippert, Kajewski and Tilley 2003).

The rapid development of Worldwide Web (WWW) technologies, Internet, and Information and Communication Technology (ICT) have generated the evolutionary on-line business solution and electronic-commerce (e-commerce) both of which are to provide support for both information and workflow control, and process management as well as enhance the communication. E-commerce technologies are perceived as a mainstream to improve productivity and information flow and communications.

However, until now, not much evident research has been conducted to pursue successful applications of e-commerce technologies to the construction supply chain. For this reason, this research is focused on the current applications of e-commerce technologies across the construction supply chain. The specific issues being investigated include the objectives, reasons/benefits, barriers of using e-commerce technologies. This research also investigated the encouraging factors and the need for learning, training, and knowledge sharing for better applications of e-commerce technologies and provide suggestions for better utilisation of such modern communication and management tools.

2. LITERATURE REVIEW

2.1 E-Commerce Technologies in Relation to Construction

E-commerce can be defined as the conducting of buying and selling of goods and services as well as business communication and transactions over computer networks and through individual computers linked to the Word Wide Web (Key IT Solutions, 2005). The potentials of e-commerce technologies applications in the construction industry include: E-marketing; E-selling/e-procurement of goods and services; E-collaboration; E-finance; and E-customer services and relations (Veeramani et al., 2002). The necessary technological solutions for e-supply chain systems are readily available in the current market. Some of the fundamental issues for successful e-commerce in construction, such as signature exchange (Pederson, 1999; Asokan et al., 2000), secure payment (Shamir et al, 1998; Bellare et al., 2000), and fair contracting models (Coscia et al., 2000; Rohm & Pernul 2000; Liu et al., 2001) have already been addressed in broader business-to-business (B2B) projects. E-commerce applications have enhanced the development process operations of a project, and promoted integration and operation through the shared information network system to diverse participants in the construction supply chain (Jones & Saad 2003).

2.1.1 Benefits of E-Commerce Technologies to Construction Supply Chain

Use of e-commerce technologies in the construction processes has generated primary and secondary effects. Primary effects are more efficient information-related activities such as creation, retrieval, delivery of information and effective communication, which assisted increasing productivity. Secondary effects are activities related to efficient material-handling in information processing through the use of information technology where it contributes to inventory reduction and decrease in the number of rebuilding with accurate design information and production of energy efficient buildings (Bjork 2002).

TABLE 1: Potential benefits of e-construction to supply chain members (Source: McIntoish, 2005).

Branch of construction supply chain	Potential Benefits of E-construction (e-commerce applications)
Owners/Developers	▪ Improved project efficiency ▪ Reduced construction costs, chance of errors, and the need for rework ▪ Compressed construction programme
Designers	▪ Time savings ▪ Improved communication ▪ Increased accuracy and speed of specification
Contractors and subcontractors	▪ Lower administration and communication costs ▪ Tendering and procurement efficiencies ▪ Time savings ▪ More project control and security ▪ Enhanced project communication
Builder merchants	▪ Lower inventory and real estate costs ▪ Lower cost of serving customers
Manufacturers	▪ Reduced channel costs ▪ Improved access to information ▪ Cost-effective access to actively purchasing and specifying customers

Through applications of e-commerce technologies in the construction supply chain, organisations/participants can benefit from lower transaction costs; reduced staffing requirements; shorter procurement cycles; decreased inventory levels; higher degree of transparency; provision of information on demand which promotes more frequent and intense use of it; connection to operations across organisational boundaries; enlargement of the span

of effective control and co-ordination; improvement in the quality of decision-making processes; and enhanced communication and collaboration between supply chian members/organisations (Davila et al., 2003; Turban et al., 2002; Osmonbekov, Bello and Gilliland 2002; Carter et al., 2000; Tucker et al., 2001).

Table 1 shows that the use of e-commerce technologies in the construction industry can provide distinctive benefits to each branch of a construction supply chain, which produces the potential for enhanced performance of the entire supply chain (Salin 1998).

2.1.2 Challenges of E-Commerce Applications in Construction Supply Chain

Despite the benefits of e-commerce technologies to the construction industry, there are many challenges in its applications. In many instances, the potential of e-commerce technologies has yet been fully and properly utilised, as many companies are simply utilising various technologies to automate existing processes without analysing the company's objectives and realistic needs. In addition, significant people and culture issues need to be addressed to overcome resistance to change and achieve radical revision (Elliman & Orange 2003).

Information management systems: In the form of email, websites, and Internet services, advancement of e-commerce technologies has generated an enormous wealth of data which leads to information overload. The sharing and transferring of information governs supply chain participant's activities, which serves as a core function of the supply chain (Cheng et al., 2001). However, due to fragmentation of information from various communication channels, effective logistics of information management to have the purposeful information accessible when required have become labourous and time-consuming activities, and inefficient management of information have reduced the benefits of using e-commerce technology. In addition, the potentially enormous data collected from both internal and external communication points involves significant information management load in security, filtering, consistency checking, data cleaning, storing, knowledge discovery, and knowledge integration, which resulted in rather challenging for information management and knowledge integration (Badii and Sharif 2003).

Organisational policies and management: The introduction of new infrastructure such as e-commerce systems can affect all operations of organizations significantly, and this requires adaptation of a new underlying operation and management philosophy. This changes affects core component of organizations both management and employees, such as goals, technology, vision, training, policies, culture, mission, and business strategy. The implementation should be undertaken in a top-down hierarchical approach. Commencing from top management, further implementation must move to the middle management, then to lower management. Subsequently, change operation can be introduced to influence all the employees to support the new mindsets and the application of e-commerce technologies (Cheng et al, 2001; Mukherji and Mukherji 1998).

Human resources and culture: An organization may not possess appropriate skills to manage new innovation technology, which may not be embedded with an underlying supportive culture. Organisational culture contributes a significant part in implementation of innovation that involves different professionals working together to meet the project objectives and enhance performance, which requires 'no-blame' culture to encourage people to experiment with new concepts (Ling 2003). Furthermore, contribution by staff in task execution and management is crucial and their performance can significantly affect the success and failure of the organization (Cheng et al., 2001). It is impossible to implement new work process into an organization when the current working environment is not ready for it (Alshawi and Faraj 2002). When adapting e-commerce technologies, it needs careful and critical evaluations to decide the degree of change which includes the internal efficiency of the business, budget, availability of highly skilled people, economical situation, market conditions, political systems, capability of internal staff, and regulations with external partner.

Training, learning, and knowledge sharing: Training staffs can assist to improve resilience, trust, and pride by them, because without the commitment of staff, innovative technology cannot be aligned with the organisation's goals and objectives (Cheng et al., 2001). Knowledge sharing is recognised as a channel for industry to address its need for innovation and improved business performance. However, frequently, organizations rely heavily on people and assume that they will transfer their learning and experiences to other employees, which can make organizations vulnerable if and when there is a high staff turnover. People-based knowledge transferring system may not incur much cost commitment to organizations, but such approach is considered ineffective, unproductive and expensive when compared with the loss of knowledge that is inevitable when liable staffs leaves the organization, resulting in possible difficulty in case of expansion (Kamara et al., 2002). Walker (2004)

further comments that current information and communication technology such as knowledge repository can provide great value, but it is essential that employees have competent skills to fully utilise this application.

2.2 Related Past Research

Some research has been conducted on the applications of e-commerce technologies in construction as described in this section. Veeramani et al (2002), on behalf of CII (Construction Industry Institute in USA) conducted a research on "state of practice of e-commerce in the American construction industry" through literature search, survey (with 49 responses) and 19 in-depth interviews with CII member organisations plus four in-depth case studies. They concluded that the owners are leading the implementation of Internet-based technologies (such as email communication, buyer/supplier integrated e-procurement packages) with the advantages of reducing the time required to complete the various phases of procurement. However, the challenge was documentation and standardisation of purchasing processes and workflow processes. They also concluded that some organisations including many contractors have been reluctant to experiment with e-commerce because they feel there are too many uncertainties and concerns, such as lack of structured business process/system, lack of integration of new tools with existing processes, and lack of reliability of Internet-based communication. They also found that resistance to change comes from not only the internal culture but also from business partners throughout the construction industry (ie the construction supply chain).

The IT Construction Forum (2004) based in UK has conducted a survey to 373 firms with different types (contractors, specialists, designers, consultants) and sizes on "IT in construction – use, intentions and aspirations" and their head findings include: (1) It is used extensively by UK construction firms, (2) most firms use the Internet to source information about construction products: emails is used extensively for communications and additionally to order products/materials and services; about 50% of firms use online purchase; (3) speed of work is considered as the most significant benefits of using IT followed by ease of access to records, (4) most firms consider their investment in IT in recent years to be the same or better than their competitors and their purpose of future investment in IT will still be keeping ahead of their competitors and keeping pace with clients mainly in terms of communications. (5) firms need pragmatic advice on the costs and pitfalls of investing in IT, supported by advice on how to assess their IT needs.

Gyampoh-Vidogah and Moreton (2003) conducted 3 case studies (using open-ended interview method) to investigate the implementation of information management in construction in the UK and they concluded that "…poor information management has serious implications for construction companies. At the moment, information sharing is limited to paper… functional department maintain their own data structured to suit their particular needs and information is often delayed and triggers disputes… (Gyampoh-Vidogah and Moreton 2003:171)" They also commented that "…for historical, cultural and legal reasons, there is no desire to consider seriously the use of collaborative tools…. The results is that experience of implementing cooperate IT systems is lacking and it is clearly affecting the ability to examine the potential of emerging IT or appraise current infrastructure (Gyampoh-Vidogah and Moreton 2003:157)."

Using interviews and case studies, Garden and Ash (2003) carried out a research entitled "ICT-enabled organisations: a model for change management". They argued that the relatively low level of organisational benefits realised by typical strategic information technology interventions over the past decade is often a product of poor adoption and implementation practice on the part of senior managers and IT partitioners, who have failed to understand the non-linear and emergent nature of change in complex organisation. They also argued that a clear understanding of the dynamics of change at the people/technology interface and the information system and strategy is prerequisite for the successful business benefits realisation for major IT and e-business projects.

Weippert et al (2003)'s research was focused on the implementation of online information and communication technology (named ORCM – online remote construction management) on remote construction projects where they, through case studies, examined seven IT implementation perspectives of two ICPM (Internet-based construction project management) systems, trade name as ProjectCentre and e-project. Their ORCM best practice recommendations for ICT and ICPM system implementation include: use one [information management] system; provide commitment; focus on end-user and provide training.

Dooley and Purchase (2004) investigated factors influencing electronic procurement usage in Australian semi-government organisations using a web-based survey. The key factors found from their study include internal organisational support, integration with suppliers' e-systems, supplier willingness, perceived improvement to

purchasing tasks and supplier pressure. Further, their results reinforce the view that there has been a change in attitude towards electronic systems due to the overall drop in business expectations after the burst of the Internet bubble in 2001. They further commented that, to keep track of such attitude changes, future research needs to be conducted regularly to evaluate the extend and direction of those changes.

Vaidya et al (2004) proposed a balanced scorecard approach to measure the performance of e-procurement initiative in the Australian public sector where the following issues are considered: financial, internal business process, customer, project progress, innovation and learning as well as value for money outcomes.

Love et al (2001) conducted an empirical analysis of the barriers to implementing e-commerce in small-medium sized construction contractors in the state of Victoria Australia. They conducted unstructured interviews with managers from 20 contractors in Victoria to identify the financial, technical and behavioural barriers. they found that the financial barriers were the cost of system requirements and maintenance and the risk involved in such investments plus cost of training and educations; the technical barriers included: types of technologies and software that match with the organisation's business requirements, risks associated with security and authentication and lack of education and knowledge about the systems: the behavioural barriers were the fear of losing the job, reluctance to make changes in working habits and the requirement to undertake additional training and skill development as well as the degree of uncertainty that technology instil in people. Based on these findings they provide a number of suggestions, include "be clear on what kind of change is required; plan and schedule the project and do not skip [implementation] steps…; pre-empt resistance; prepare employees through training and education to develop their confidence; communicate in two-way manner; provide employees ownership – get them to help in the process; avoid complacency; and set your sights on the specific objectives" (Love et al 2001: 39).

Stewart (2001) carried out a review on historical development, drivers and benefits of adopting e-commerce and described the role of e-commerce systems for the construction industry as "while it is currently the larger companies that are championing these (e-commerce system) developments, it is clear that many stakeholders will engage with e-commerce systems in the future… (Stewart, 2001:35)".

Ekstrom and Bjornsson (2003) of CIFE (Centre for Integrated Facility Engineering) at Stanford University conducted a research on "Evaluating IT investment in Construction – accounting for strategic flexibility" through a case study. After evaluating a number of methodologies for analysing flexibility IT investment, their results show that it is possible to quantify the value of managerial flexibility for IT investment in the AEC (Architecture, Engineering and Construction) industry but that the proper method to use is contingent on the nature of the investment project.

Via surveys to 200 subcontractors, Ng et al (2001) conducted a research on the IT usage by Australian subcontractors and they concluded that the uptake of email and Internet (for work purpose) by the subcontractors was at a low level and the awareness of IT training and education is also very low. They concluded that the Australian subcontractors are not yet ready for the implementation of even rudimentary IT technology.

2.3 Research Aims

In summary, the past research reviewed in the above sections have shown that while e-commerce technologies may be perceived as important tools to construction companies, these research have been mainly focused on some perspectives as classified below: IT development perspective (Ekstrom and Bjornsson 2003, Garden and Ash 2003, Weippert 2003); government sector and client perspective (Dooley and Purchase 2004, Vaidya et al 2004), contractor perspective (Gyampoh-Vidogah and Moreton 2003); small or sub contractors perspective (Ng et al 2001, Love et al 2001) and industry perspective (Veeramani et al 2002 and IT in Construction Forum 2004). Out of these research only two had focused on the construction industry (ie the construction supply chain) and these two research were conducted in USA and UK. A supply chain is "a network of connected and interdependent organisations mutually and cooperatively working together to control, manage and improve the flow of materials and information from suppliers to end users" (Aitken, 1999). As such, a construction supply chain includes the owner (client), planner, designer, architect, engineer, construction manager, general contractor, subcontractors, material and equipment suppliers, distributors, and manufacturer. To achieve the full potentials of e-commerce technologies, it is important to understand the state of practice and perception of the entire construction supply chain towards to e-commerce technologies. Therefore, there is need to investigate the

current applications and possible future improvement of e-commerce technologies across the construction supply chain, which are the main aims and objectives of this research.

3. RESEARCH METHODOLOGY

In order to obtain broad, least-biased as well as in-depth and specific information, both survey and interviews were used in this research. The aims of the survey were to obtain industry-wide (ie from the construction supply chain) information and data regarding current application of e-commerce technologies and to seek suggestions for future improvement. The aims of the interviews were to supplement the survey questionnaire findings with some more in-depth and specific information. Both surveys and interviews were conducted in Sydney Australia during late 2004.

3.1 Survey Questionnaire Design and Sampling

To achieve the aim of this research, the survey questionnaire includes the following components: company profile; e-commerce technology current practice; challenges, barriers, encouraging factors, and training-learning-knowledge sharing. The survey questions were derived from various literatures reviewed in the previous section. 300 sets of questionnaire were posted, with a reply paid envelop, to clients, architecture firms, engineering consultants, contractors, subcontractors, suppliers, and manufacturers. 70 responses were received. However, 22 of those responses returned were with omissions that they had to be disregarded, and the remaining 48 responses were considered valid which gave an effective respondent rate of 16%. Due to the poor response rate, another survey was conducted. This time, the authors visited a number of construction sites and offices to distribute 85 sets of the questionnaire, and obtained 85 responses. However 6 of the responses were invalid, and left the other 79 responses valid. As such, the total of 127 valid responses represents a 42% responding rate, which was a logically sufficient for a valid quantitative analysis.

3.2 Semi-structured interviews

Three fact-to-fact interviews were conducted with senior management personnel who have experience in application of e-commerce technologies, two with large construction companies, and one with a medium engineering company. A semi-structured format is chosen to expand the scope for probing the interviewees by asking supplementary questions to gain more insights (Fellows and Liu 1997). Ten questions were carefully prepared to cover various issues. Among many findings, the benefits and challenges of using e-commerce technologies are presented in this paper.

4. SURVEY RESULTS AND DISCUSSIONS

4.1 The respondents' profiles

Usually, contractors are considered to be one of the most proactive participants and work in co-ordination with all other participants, such as architects, engineering consultants, suppliers, client, and subcontractors. Therefore, as shown in Table 2, contractors (38%) were mainly selected for this survey research. Similarly, 26% of subcontractors are selected due to the fact that a construction project involves many subcontractors. Nevertheless, only considering these two types of participants for survey could mean the myopic assessment of the construction industry. Thus, other supply chain members including engineering consultants, clients, suppliers, facility/asset management personnel, and quantity surveyors were also selected to provide evaluations of the e-commerce usage in the construction industry.

This survey is designed to collect the feedback of respondents working in diverse levels of the company, ranging from managers, designers/engineers to cadets/draftmen. Fig. 1 shows that 74% of the respondents have more than 3 years industry experiences and are more likely to have a reasonable idea of advantages and disadvantages of using e-commerce applications. In contrast, respondents with less than 3 years work experiences are the generation of the Internet era who already have acquired some forms of knowledge on using e-commerce, even though they do not possess strong skills in the construction industry yet. Hence, intermingle of a variety of industry experiences is expected to provide different perspectives of e-commerce technologies and applications in the construction industry.

TABLE 2: Respondent profiles

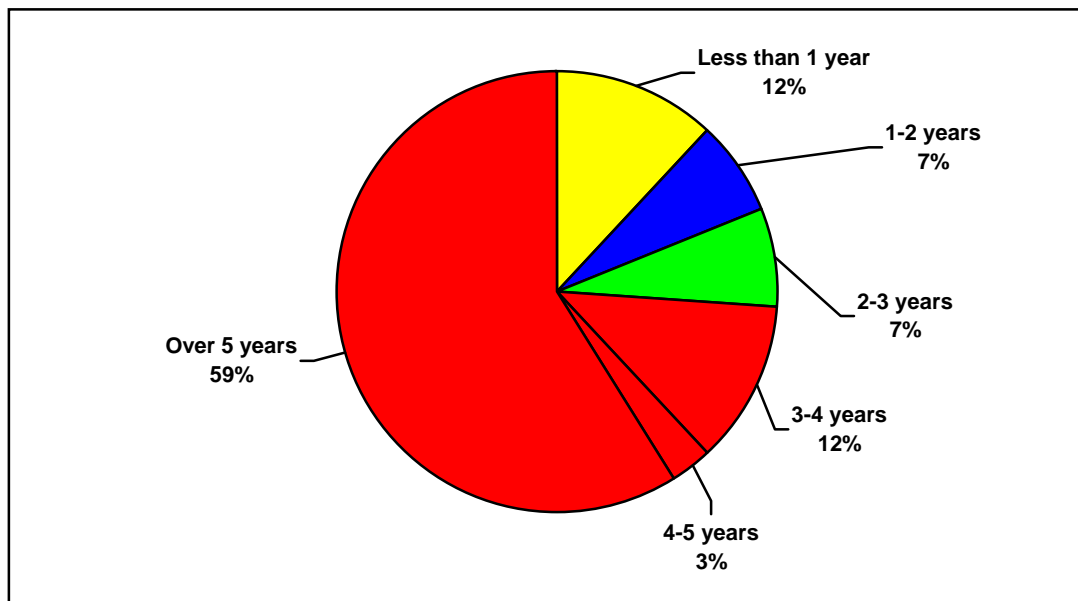| Company Types	No. of respondents	Percentage (%)
Contractor	49	38
Subcontractor	33	26
Client	15	12
Engineering consultant	12	9
Supplier	6	5
Facility/asset management personnel	6	5
Quantity surveyor	6	5
Total	**127**	**100**

FIG. 1: Respondents' experiences

4.2 Respondents' Company Profiles

E-commerce involves business communication and transaction. In the construction industry, this indicates exchanging and sharing of information across the network of organizations and participants. Therefore, the survey is targeted to encompass the variety of participants and gather their current practice of e-commerce technology. Number of permanent staffs in company directly reflects the financial capability of the company. Hence, diverse size companies' employees are selected as respondents for this survey research as shown in Fig. 2. Furthermore, as shown in Fig. 3, about half of the respondents' companies have been involved in e-commerce for 4 or more years while the other half have adopted e-commerce technology in more recent years.
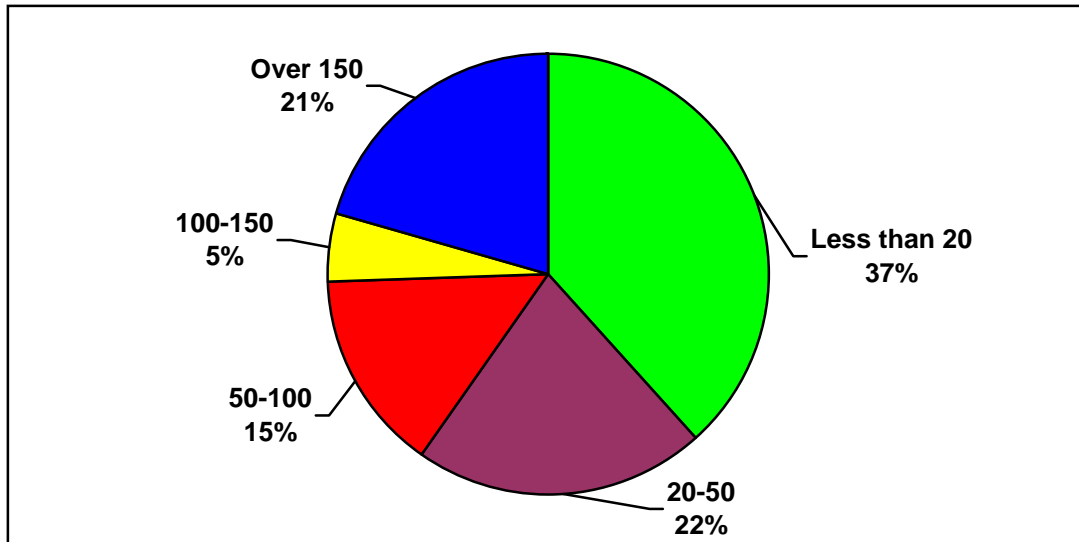
FIG. 2: Number of permanent staffs in the companies surveyed.
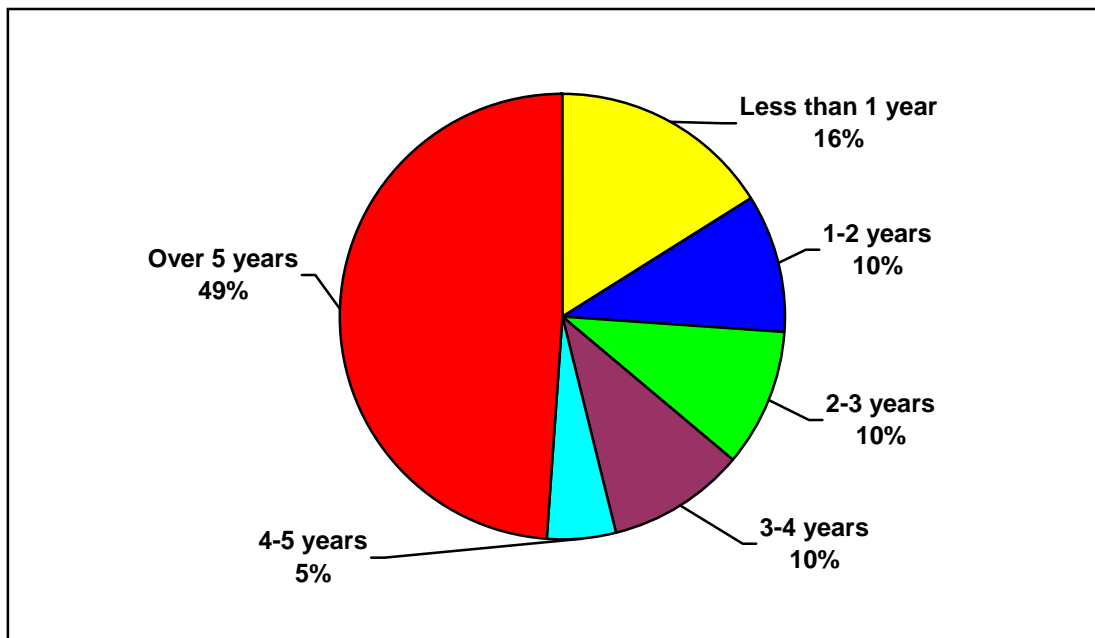
FIG. 3: Periods of companies' involvement in e-commerce technology.

4.3 E-commerce Applications – Current Practice

4.3.1 E-commerce Technologies Used

Fig. 4 shows that all respondents (100%) are using e-mail and a reasonable number are using Intranet and Extranet as well as third-party websites. However, 83% of respondents still use mail/fax/courier to process their works and this Figure is considered as quite high in the era of the Internet.
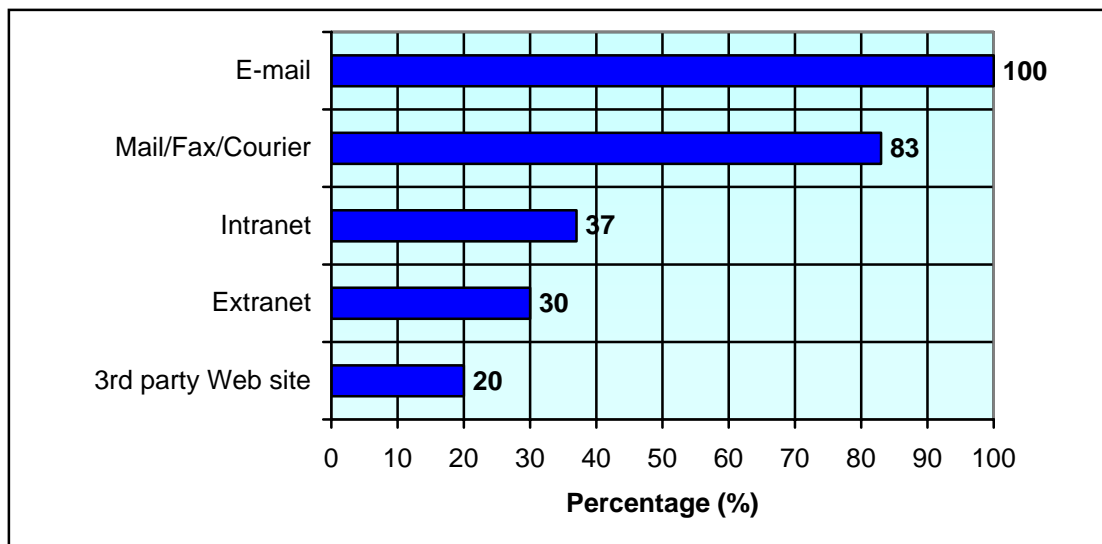
FIG 4: E-commerce technologies used to sharing/exchanging information

4.3.2 Importance of e-commerce technologies

Table 3 shows the perceived importance of various e-commerce technologies (note the responses were graded on the likeliness scale of 1 to 5 where "1" refers to most important). E-mail has been ranked the first while 'Internet connection' ranked the second, and 'online search' the third. In contrast, 'make/receive online payment', and 'make/receive quotations online' revealed the lowest level of importance and this maybe a reflection of the stagnant practice and the level of security when managing money over online (it maybe a technological issue or psychological issue). It should be noted that to realise a full e-commerce process, online payment has to be readily used.

TABLE 3: Importance of various types of e-commerce technologies in executing work

Rank	e-commerce technologies	Mean	S.D.	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
1	Electronic mail (E-mail)	**1.15**	0.42	88	10	2	0	0
2	Internet connection	**1.33**	2.37	76	20	2	2	0
3	Online search	**1.82**	0.84	41	41	12	6	0
4	Computer Aid Design (CAD)	**1.83**	1.03	46	37	10	2	5
5	Intranet	**2.08**	1.04	39	24	29	5	3
6	Computerised project management	**2.18**	1.12	34	29	24	8	5
7	Make/request online orders	**2.32**	0.99	20	46	20	12	2
8	Bid invitation/tender online	**2.37**	1.90	29	29	24	10	8
9	Extranet	**2.39**	0.97	22	29	39	7	3
10	Make/receive online payment	**2.40**	1.10	24	29	32	10	5
Legend: 1 = Very important, 5 = Not important, S.D. = Standard Deviation								

In general, taking 3 as the average value with a scale of 1 to 5, all technologies were ranked relatively important with a mean value range from 2.08 to 2.40 as shown in Table 3.

4.3.3 Reasons for using e-commerce technologies

These questions were developed based on a similar survey conducted by IT Construction Forum (2004), and various literatures. Fig. 5 shows a number of reasons (in ranking) for using e-commerce technologies in construction management. Among them, 'Better work opportunity', 'better information access and management', and 'increase in speed of working' are the main reasons for adopting e-commerce technology. These findings are similar to the findings of the survey conducted by IT Construction Forum (2004) as the top 3 reasons being 'increase in speed of working' (82%), 'fuller/easier-to-access records' (80%), and 'more flexibility in working methods' (77%). This indicated that the construction industry is moving towards 'IT-application' and

it is a reflection of the work nature, 'information intensive', and 'coordination/communication essential' when managing construction projects.
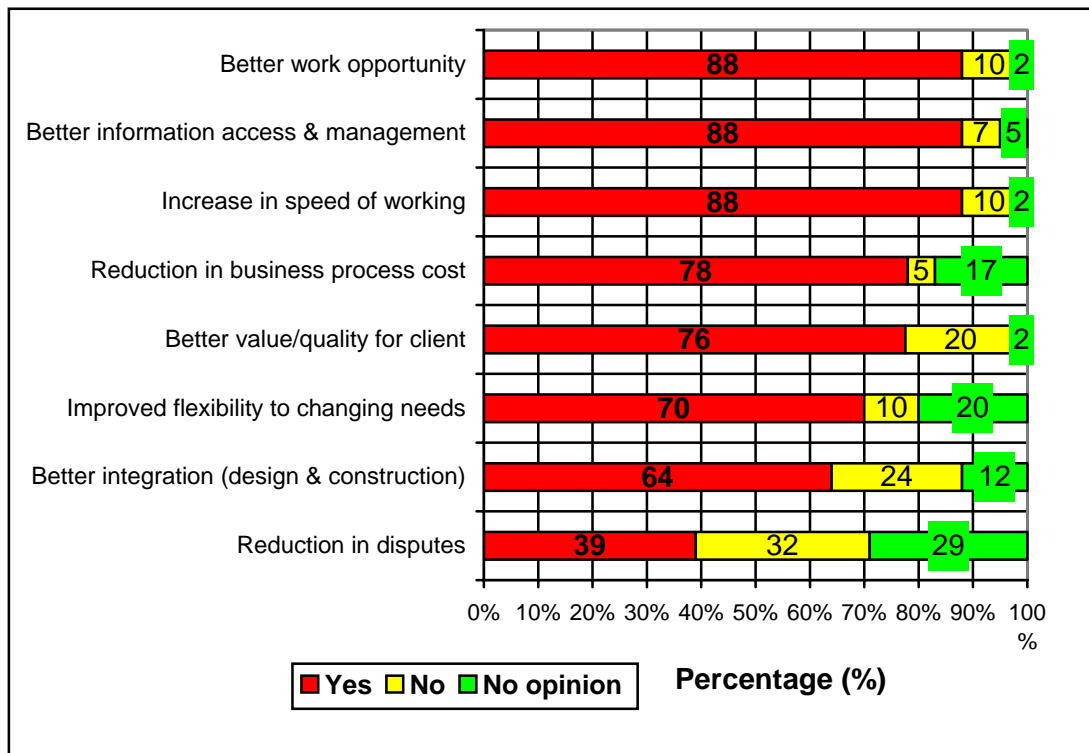

FIG. 5: Reasons for using e-commerce technologies

Considerably high percentage between 78% and 70% is also noticed for other reasons including, 'reduction in business process cost' (78%), 'better value/quality for client' (76%), and 'improved flexibility to changing needs' (70%). These figures indicate two issues. Firstly, the respondents perceive that cost, quality and time are very important objectives in construction project management, and secondly, the respondents believe that the application of e-commerce can help them reduce project cost, strive for better value and better quality, and to meet the changing need of clients and the market. On the other hand, only 39% of respondents considered that 'reduction in disputes' as a reason for using e-commerce technology.

4.3.4 Barriers of using e-commerce technologies

The barriers listed in Table 4 are derived from the US CII research report 'State-of-practice of e-commerce application in the construction industry' (Veeramani et al., 2002), and various literature. It appears that the top 5 barriers in the Australian construction industry were:

1. reluctance/inability to adopt computer technologies among subcontractors and suppliers,
2. lack of in-house technical expertise and personnel,
3. different organisational culture,
4. lack of integrated information management system, and
5. fear of implementing a business process change.

Overall, 4 of them were people-related barriers and only 1 was technology-related. Literature (eg Veeramani et al., 2002 and IT Construction Forum 2004) has also addressed people-related barriers as major challenges of implementing e-commerce technology. However despite that the technology-related issues are not imposing as significant barriers as people-related barriers it is important to recognise that continuous advancement of technology will always impose a barrier and thus, companies should constantly implement appropriate measures to overcome the technology-related barriers.

TABLE 4: Barriers of using e-commerce technologies in construction supply chain

Rank	Barriers of using e-commerce technology	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	S.D.
1 (P)	Reluctance/inability to adopt computer technologies among subcontractors and suppliers	7	24	20	37	12	**3.20**	1.67
2 (P)	Lack of in-house technical expertise and personnel	17	20	10	37	16	**3.18**	1.37
3 (P)	Different organisational culture	15	20	12	41	12	**3.17**	1.29
4 (T)	Lack of integrated information management system	15	15	23	37	10	**3.10**	1.23
5 (P)	Fear of implementing a business process change	10	22	27	34	7	**3.09**	1.11
6 (P)	Lack of individual and collective learning system	10	17	27	46	0	**3.08**	1.00
7 (P)	Lack of pressure from competitors	10	29	20	31	10	**3.06**	1.18
8 (T)	Lack of software that meets the needs of the construction industry	12	22	27	27	12	**3.05**	1.21
9 (C)	Difficulty in making Return-On-Investment (ROI) justification	17	17	29	22	15	**3**	1.27
10 (M)	Lack of commitment	17	22	12	44	5	**2.98**	1.23
10 (M)	Lack of strategic management	15	17	24	41	3	**2.98**	1.14
10 (P)	Lack of trust	15	29	15	26	15	**2.98**	1.31
10 (C)	High cost demand	12	29	17	27	15	**2.98**	1.29
10 (T)	Security concerns	12	34	15	22	17	**2.98**	1.31
15 (P)	Significant number of irregular clients	22	15	24	29	10	**2.93**	1.30
16 (M)	Lack of clear vision and objectives	12	22	37	29	0	**2.80**	1.00
17 (M)	Lack of corporate executive level support	17	27	24	27	5	**2.77**	1.16
18 (P)	Short-term and adversarial relationship and rigid contractual arrangement	17	39	22	15	7	**2.52**	1.16
19 (P)	Lack of demand from customer/client	24	37	22	12	5	**2.36**	1.14
LEGEND: 1 = Not a barrier, 5 = Strong barrier, S.D. = Standard Deviation								
P = People-related, T = Technology-related, C = Cost-related, M = Management-related.								

4.4 E-commerce Technologies Applications – Future Improvement

This section aims to seek from the respondents on ways that could lead to more effective and efficient ways of using e-commerce technology and its future improvement.

4.4.1 Encouraging Factors for e-commerce usages

As shown in Table 5, the top 5 encouraging factors were:

1. 'Increased awareness of company's (or project's) purpose and objectives';
2. 'More user friendly systems';
3. 'Reduction in cost of computer technology';
4. 'Integrated information management';
5. 'Setting industry standards'.

Similar study conducted in UK by IT Construction Forum (2004) revealed similar results. The top 5 encouraging factors were 'reduction in cost of IT' (60%), 'more user-friendly systems' (55%), 'more training' (55%), 'improve awareness of benefits' (51%), and 'improved software compatibility' (50%). Both Australia and UK respondents agreed that 'more user-friendly systems' and 'reduction in cost of computer technology' could encourage the use of e-commerce technology.

From management point of view, it is important to have a clear aim and objective in whatever we do, including application/utilisation of e-commerce technology. It is clear that that the respondents demand 'more user-friendly systems' and their needs are directly related to 'lack of in-house technical expertise and personnel' barrier (rank 2) and 'lack of integrated information management system' barrier (rank 4) listed in Table 4. Perhaps the respondents believed that the more affordable user-friendly and integrated information management systems could provide greater savings/profits that exceed the e-commerce technology investment cost.

TABLE 5: Encouraging factors for greater use of e-commerce technologies

Rank	Factors encouraging greater use of e-commerce technologies	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	S.D.
1 (M)	Increased awareness of the company's/project's purpose and objectives	44	39	15	0	2	**1.77**	0.86
2 (T)	More user-friendly systems	51	27	15	5	2	**1.81**	1.01
3 (C)	Reduction in cost of computer technology	51	22	17	10	0	**1.87**	1.04
4 (T)	Integrated information management	34	49	12	5	0	**1.88**	0.79
5 (M)	Setting industry standards	41	32	22	5	0	**1.90**	0.90
6 (T)	Improved software compatibility	46	29	10	15	0	**1.91**	1.06
7 (P)	Integration of the construction members through network	37	34	22	7	0	**1.94**	0.93
8 (T)	Improved capability to manipulate drawings	37	37	22	2	2	**1.96**	0.94
9 (P)	Client's active leadership and participation	34	47	10	7	2	**1.97**	0.96
10(T)	Increased security	39	32	17	10	2	**2.04**	1.08
11(T)	Use of portable wireless computer and other devices to access information anywhere at anytime	41	23	27	7	2	**2.08**	1.08
12(P)	Increased trust	32	29	27	12	0	**2.18**	1.01
13(P)	Re-engineering firms' core business operation	22	32	36	10	0	**2.33**	0.92
14(P)	Establishment of partnering agreement	17	34	39	10	0	**2.42**	0.88
LEGEND: 1 = Very important, 5 = Not important, S.D. = Standard Deviation P = People-related, T = Technology-related, C = Cost-related, M = Management-related								

4.4.2 Training, learning, and knowledge-sharing

Construction projects involve many independent organisations and the effect of inefficiency in any organisation can reduce the overall efficiency and productivity of the construction project and the industry at large. Fijitsu centre (1998) claimed that even 1% improvement in productivity could contribute considerable benefits to the construction industry. Clarke and Wall (1998), and McCreadie and Rice (1999) cited in Cheng et all, 2001 emphasised that continuous/life-long training can provide construction companies with new skills, technology, and knowledge in meeting the future demands. Therefore it is important to provide training for the employees to learn IT. This section aims to identify the constraints and encouraging factors in learning, training and knowledge sharing of e-commerce technologies.

Importance of continue training: 49% of the respondents believed that continuous training in e-commerce technologies is very important and the other 49% believed important while only 2% rated not important. Furthermore, the second barrier listed in Table 4 confirms that the respondents are desperately seeking the right level of knowledge and training to operate today's highly sophisticated softwares.

Frequencies of training: Fig. 6 shows that in total 61% of the respondents have received training in recent 3 years. However, a surprising figure of 27% respondents have never received any training and this result shows that companies are not fulfilling the need to provide learning and training facilities for their staffs. Markus and Benjamin's (1997) (cited in Gardner and Ash, 2003) used 'magic bullet' analogy to criticise the tenancy of IT practitioners naively assuming that by developing a powerful technology and shot into the problem location, desirable changes will occur in human and technological fabric of the company. Is appears that from this finding this tenancy occurs in Australian construction companies.
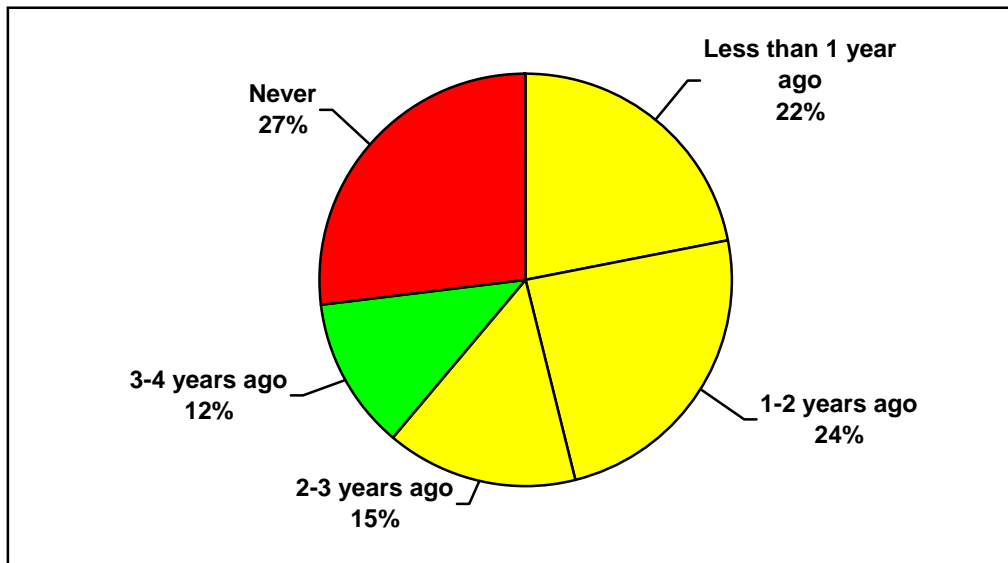
FIG. 6: The most recent e-commerce technology training respondents received/attended

Importance of collaboration between industry and academia: 'Construction 2020 A vision for Australia property and construction industry' produced by national Corporative Research Centre (CRC 2004) states that Australian leadership in research and innovation is the paramount in accomplishing the world's best practice construction industry. Thus, this question aims to understand the respondents' perception on the research and innovation and how it contradicts or agrees with the national Corporative Research Centre's vision for 2020. Majority of the respondents shared a similar mind-set as shown in Fig. 7 with 85% of the respondents strongly agree or agree on "collaboration between industry and academia is required if the industry is to properly benefit from university ideas and expertise". This was improved by approximately 38% compared to the results (approximately 47%) of 'Innovation in the Australia Building and Construction Industry 2002 Survey Report' produced by PricewaterhouseCoppers (2002).
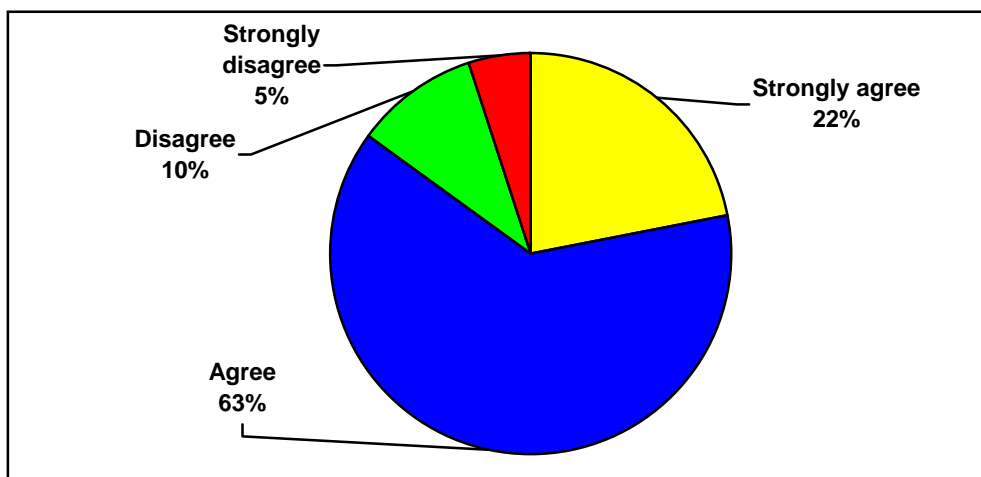

FIG. 7: Importance of collaboration between industry and academia – for proper benefit acquirement by the construction industry from ideas and expertise of universities.

Barriers in e-commerce training, learning and knowledge sharing: Currently, construction industry practices of poor training, learning and knowledge sharing are hindering effective implementation of e-commerce technology. Therefore, identifying the barriers is significant as it will assist in developing appropriate measures to enhance the effective implementation of e-commerce technologies. Table 6 demonstrates 12 barriers in training, learning, and knowledge sharing. The top 3 barriers, 'lack of understanding on how to get started and what to do', and 'lack of understanding the potential benefits of training, learning and knowledge sharing' and 'insufficient time allocation' indicated that employees and companies do not initiate or motivate training,

learning and knowledge sharing for they simply do not understand how to commence and what trainings to provide.

TABLE 6: Barriers in training, learning, and knowledge sharing

Rank	Barriers in IT training, learning, and knowledge sharing	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	S.D.
1	Lack of understanding on how to get started and what to do	7	20	16	37	20	**3.41**	1.21
2	Lack of understanding the potential benefits of training, learning and knowledge sharing	7	20	12	51	10	**3.40**	1.12
3	Insufficient time allocation	7	20	27	29	17	**3.28**	1.16
4	High cost demand	10	22	19	32	17	**3.25**	1.24
5	Mistake-intolerant work environment	10	17	22	46	5	**3.20**	1.07
6	Lack of support by corporate executive level	15	20	19	29	17	**3.15**	1.31
7	Lack of commitment	12	29	12	27	20	**3.13**	1.34
8	Pressure of high expectation from management	7	27	24	32	10	**3.13**	1.12
9	Lack of a clear understanding and documentation of company's business procedures and processes to guide users	7	34	12	32	15	**3.12**	1.25
10	Insufficient funds allocation	10	27	22	29	12	**3.07**	1.20
11	Lack of incentives	17	15	31	27	10	**2.98**	1.20
12	Internal competitions	22	39	24	10	5	**2.35**	1.07
LEGEND: 1 = Not a barrier, 5 = Strong barrier, S.D. = Standard Deviation								

The forth and fifth barriers, 'high cost demand', and 'mistake-intolerant work environment' suggest that companies are reluctant to invest on employees training. 'Pressure on high expectation' and 'lack of commitment and support from management', ranked around the middle. These indicate that there is a room for management to promote the culture of learning e-commerce technology. In addition, it seems useful to provide detailed guidance to allow employees to understand the company's business processes and procedures, and incorporate e-commerce as a tool into their daily tasks.

It is positive to note that 'incentive' and 'internal competition' was not seen as barriers. These results maybe explained in two ways. Firstly, the internal competition is not so strong within the company, and secondly, the culture may have shifted from competition nature to collaboration nature.

TABLE 7: Factors that encourage learning, training and knowledge sharing

Rank	Encouraging factors	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	S.D.
1	Continuous learning, training, and knowledge sharing	56	39	2	3	0	**1.51**	0.66
2	Supportive environment	46	39	7	8	0	**1.75**	0.87
3	Develop a robust plan to introduce e-commerce technology across the company	32	49	17	2	0	**1.90**	0.75
4	Establish networks for companies to share non-sensitive technological advances and new ideas	31	37	20	12	0	**2.13**	1.00
5	Company to pay for staffs to attend national and international seminars, conferences, and trainings	27	44	17	12	0	**2.14**	0.96
LEGEND: 1 = Very encouraging, 5 = Not encouraging, S.D. = Standard Deviation								

Factors that encourage learning, and knowledge-sharing: As shown in Table 7, 'continuous training, learning, and knowledge sharing' is rated the number one factor that the respondents think will help in improving their e-commerce skills, followed by 'supportive environment'. With a positive supportive learning

environment and culture, it naturally requires 'a robust organisational plan and a network to support employees to learn and show that they have learned'. It is interesting to note that the respondents do not see 'pay for staffs to attend national and international seminars, conferences, and training' is a major motivator. This may be due to their commitment to work and they require more 'practical' knowledge of e-commerce rather than 'theoretical' components. This may also indicate that work-oriented learning is more effective than 'sit and listen' learning style.

5. INTERVIEWS FINDINGS AND DISCUSSIONS

This section presents the results of three interviews conducted with industry leaders together with some discussions that provides cross link to the survey findings.

5.1 Interview (1) - with a project coordinator of a large construction company

5.1.1 Background

Interviewee A: is a project coordinator of a large construction company and has more than 20 years experience. He is currently involved in a construction project with an estimated cost over AU$600 million. *Interviewee A's* company, being referred to as *Company A*, is one of the largest Australian construction companies with a turnover of approximately A$1 billion and work in hand exceeding AU$1.4 billion that possess capabilities to design; design-and-construct; construct-and-maintain; BOOT (build own operate transfer) and maintain the commercial, residential, defence, education, hospital, and healthcare buildings; tunnels; transport infrastructure; bridges; marine works; pipelines; dams; and water and wastewater system.

Company A has an ambition to become technology pioneer in the construction industry. It realised the benefits of using e-commerce technology, such as time and cost reductions in exchanges of information, improving quality for documentations, and enhancing communication and collaboration among project participants. The corporate management is always very committed in exploring a better technology to assist staff even if that demands higher costs and might take a long time to realise benefits from such investment.

5.1.2 Current E-commerce technology applications

Company A has been proactively investing in e-commerce technology for the last 10 years. During these years, some technologies have been used and dismissed as a result of effort by *Company A* in trying to implement newer and better technology options. On the other hand, it has not always been utilizing leading technologies for the implementation of e-commerce due to different needs and objectives which could not be easily fulfilled by simply using such cutting-edge technologies; rather it used and customised the information technologies recommended by IT consultants to best serve its unique needs.

The construction industry is moving towards managing projects through web browsers. Currently, *Company A* is using 3rd party customised web browser, *Project Centre* (it has the functions for design, manage, process payments, exchange correspondences, and manage documents and process claims), to manage over 90% of the projects. However, after the completion of this project in 2005, it will adopt a newly developed web browser system sponsored by *Optus* called, *Insight*, as all major Australian contractors have decided to cooperate in using this as a compatible system.

Moreover, about a year ago, *Company A* has adopted the *Blackberry devices* (wireless enabled Personal Digital Assistant (PDA) that combines computer, telephone/fax, Internet, Microsoft applications including Excel, and pdf) to provide advantages for projects with 24 hours a day and 7 days a week communication and information access. Currently, it is only distributed to on-site personnel for pilot-test use before further distributions are decided. If the use of this device can prove better communication and produce more efficient and effective means of executing tasks more promptly, it has high possibility to be utilised to manage all the projects in the future.

5.1.3 Challenges of implementing e-commerce technology

Purchasing a web browser system available in the market and implementing it to suit the company's needs and objectives were most difficult challenges that *Company A* faced in the past few years. Due to expensive investments for a web browser system, the committee and staffs endeavoured for a number of years to make it

beneficial for the company, but the effort only created problems to *Company A*, hence, the web browser system had to be withdrawn.

As a result, *Company A* decided to re-assess the needs and objectives of the company and the projects, and set these as a foundation to develop a new web browser system with consultations with external IT companies. Although developing a new web browser demands much higher initial investments when compared with purchasing one, it was cost effective in the long term.

One of the biggest challenges in relation to carrying out projects is leading all subcontractors to use the new e-commerce technology and approach towards the same technology level. There are approximately 500-600 subcontractors involved in the current project, and managing information and communication for a project of such size and scale through phone, fax, post mails, and converting information to the web browser system and vice versa are quite challenging tasks. However, those subcontractors have been loyal and committed to *Company A* for a long time, and contributing to increase overall values of each project, therefore it is very challenging to carry out the company's own objectives while understanding and supporting the needs and requirements of those subcontractors. Notwithstanding, a portion of subcontractors are quite enthusiastic in adapting a new technology when the advantages are realised, *Company A* is hoping for more and more of them to adapt new technologies, preferably more easily, in near future.

The e-commerce application system developed by *Company A* is unique and specifically suit its needs and objectives, and every employee was given an in-house e-commerce application training before utilising the new system. As for this particular project that the *Company A* is engaged in, the majority of the employees and workers have been newly recruited. In order to maintain the efficiency and effectiveness of the project process, those employees including part-time, temporary, and newly recruited, who were unfamiliar with the company's e-commerce application have been offered with in-house e-commerce application trainings as needed, because *Company A* believes that training will turn employees into more valuable and productive assets for the company.

5.2 Interview (2) -- with a contract administrator of a large construction company

5.2.1 Background

Interviewee B: currently works for one of Australia's largest construction companies with the estimated annual turnover AU$750 million dollars, referred to as *Company B*, which specializes in design and construction; maintenance; fitout; management, and refurbishment of commercial, retail, industrial, educational, residential, aged care, hospitality and recreation, and heritage buildings. *Interviewee B* has over 20 years of experiences in the construction industry and is currently administering a refurbishment project with an estimated cost of over AU$1 million.

For this interview, *Interviewee B* decided to provide a specific response on challenges and pitfalls of 'e-commerce' applications based on his experiences with a number of large construction companies in Australia, including *Company B*.

5.2.2 Challenges of implementing e-commerce technology

The use of e-commerce technology has provided benefits, such as time saving in processing; Requests For Information (RFI); and responding, as well as cost reduction in rework; travelling; and project overheads. However, the use of e-commerce technology has created different types of problems as follows.

Problems with Email: The construction project involves many participants and the most common way of exchanging information by these participants is emails. However, the benefit of being able to send information to numerous recipients simultaneously with a single attempt has created chaos with the number of the incoming emails. In numerous instances, emails as general information are forwarded to many, often including people who do not need such emails, by Carbon Copy (CC). As a result of massive incoming e-mails that range from vital to completely irrelevant which, generally, is up to and around 60%, people have to spend a significant amount of time, especially at the start of the day at work, checking, classifying, and deleting e-mails that have arrived within one day. Due to overwhelming volume of incoming emails, in many instances, people select each email by only reading the Subject Heading which may not represent the content of the email since such Subject Heading can be quite subjective, roughly skim through the email content, and disregard the information, not to mention that many rests are left not being read in time or not being read at all before its deletion. This whole spontaneously-created symptom increases the chances of missing and misunderstanding the crucial information

and delay in response time, which could, and often does, result in a huge delay to overall project progress. These are also the biggest disadvantages of e-commerce network that *Company B* has been experiencing at the moment, however no solutions are provided to alleviate the problems.

Problems with World Wide Web access: Although Internet services are introduced to staffs for productive execution of the work, web access restrictions are producing counterproductive results at times. Consequently, companies utilize e-commerce technologies, but no single company knows exactly how to control access and restriction to such Internet related technology to improve and ultimately optimise benefits from its human resources and technology in use. In order to avoid unproductive web surfing activities, many companies restrict access to various websites, or even allow web-browsing only within a set time period, such as lunch time. On the other hand, site activities involve proactive contact with tradesmen and subcontractors, and access for products information, which online searches can provide with the most convenient and productive search results. However, in some companies, firewall restricts access to vital sites that can provide such results such as white pages, yellow pages, and other companies' websites, and as a result, staffs and other workers are left to have to spend much longer time to physically find the same information in a very unproductive way.

Problems with archiving and retrieving project information: As a construction project proceeds, staffs and workers should file the relevant documents for each respective task they are responsible for, under the project code. However, in many instances, companies do not realise the significance of maintaining an efficient filing system but heavily rely on its system to archive files according to the generic standards such as dates and age of each document without a customized set of rules to categorise-archive each document for convenience of future usage such as retrieval. As a result, problems with retrieval of relevant information can easily occur, especially when new staff takes over a continuing project. Files are not categorised and simply stored in the computer system, which makes it almost impossible to retrieve a specific file from the archived information, even with some key words, without having to spend a very significant amount of time and effort, in many or most cases, reviewing most of the archived files until it is found.

Every project has a legal responsibility to retain all project documents for 7 years. In the event of any legal claims, files should be readily available, being able to retrieve each file effortlessly. However, in the absence of a filing system and its procedures to categorise information, significant inputs of time, effort and money will be required to locate a single file that may not be made available in a limited time restraint as required. Archiving a file is one of the staff responsibilities, but, often, they delay the archiving process until the completion of the project, as they need to access files frequently but archiving system without categorisation prevents retrieval of relevant information. During the construction of a project, numerous drawings are created and revised, and these drawing files are exchanged through e-mails. Depending on the format and set-up, drawings require high memory spaces and problems will occur when the number of staffs does not archive the files, which can disable the computer system.

Problems in IT learning, training and knowledge sharing: Often, there is no proper form of training available, and new staffs are expected to achieve enough knowledge from a training conducted by other non-technical staff who have been using the system for a longer time. Many companies provide about an hour of informal and verbal trainings on the work procedures and utilised computer technology and systems. Such trainings do not consider the minimum time required providing each trainee to understand and absorb the information, but the trainee is expected to exercise 100% of the provided information and materials after training. Learning manuals maybe provided, but understanding and absorbing the information within the manuals are not guaranteed which is why trainings are given. Without thoughtful consideration on what is required to provide best opportunity to learn from the materials and each training, trainings can become a significant waste of time, effort and money.

Due to this kind of improper learning and training system, when new staffs are faced with technical problems, they inevitably refer them to their peer staff or senior staff for further assistance. However, internal competitions and reluctances of sharing knowledge and information prevent such assistance from being available, without proper system to provide it. As a result, new staffs are reluctant to ask questions, and instead will spend longer hours to learn about using e-commerce technology which may limit his/her experience in benefit of e-commerce technology. Consequently, the company will also experience the limited benefits of human resources and its system.

Furthermore, some companies have different attitudes in training permanent employees and contract employees. Even when both kinds of employees are expected to execute the same tasks, such companies will be willing to pay only for permanent employees' IT training due to its limited budget for training. Trainings are provided to contract employees only when they are absolutely necessary for adapting work procedures, not for improvements in such as e-commerce technology.

5.3 Interview (3) - with a design coordinator of a medium engineering company

5.3.1 Background

Engineering design co-ordinator, *Interviewee C* works for a nation-wide engineering company, being referred to as *Company C*, with over 35 permanent staffs in Sydney office. *Company C* provides services in design, maintain, and build for retail, commercial, educational, residential, industrial buildings and hospitals. *Interviewee C* has gained close to 20 years of professional experiences in the industry and currently manages an engineering work for one of the biggest shopping centre projects in the state of New South Wales.

Company C always follows the technology trend in the construction industry, and 3 to 4 years ago, it started to fully exchange data online. Both *Company C* and the employees had to adopt the technology as architects, designers, and other professionals started to produce drawings using advanced technologies and they preferred to work for companies which use similar cutting-edge technology systems. Also, a few projects demanded compatible technology requirements in the contracts.

Above all, to remain competitive in the construction industry, *Company C* had to adopt e-commerce technology. Further advantages such as ease of exchanging documents, issuing engineering drawings, and exchanging design details are realised only after the adoption of e-commerce technology. *Company C* believes that its current e-commerce capabilities, including personal computers, a server with large storage capacity and speed, Intranet, A0 size printers, and engineering drawing softwares meet all the demands and requirements of the current construction industry, therefore, it expects no further investment requirement for newer technology in the next 3 years.

5.3.2 Challenges of implementing e-commerce technology

The biggest challenge is learning and training a new technology which is new to almost everyone. The most recent training that *Company C* provided to its staff was 3-4 years ago when it first adopted a new e-commerce technology. Since then, the staffs became involved in large projects and faced to have to use extranet to share and exchange project information, but no one has received training on the extranet, including its e-commerce applications. The e-commerce applications were not too difficult to use, but it required a high IT experience and capability from the users to understand and adapt the e-commerce operation procedures to their daily tasks, which made it quite difficult for those without much IT background knowledge and skills, hence, losing its full benefits.

Some of the *Company C* staffs who have been newly recruited since the last training in the past 3 –4 years have never been trained to use the e-commerce applications, or any work related applications. However, due to the internal staffs learning supports with their keen and self-motivated attitude on learning the e-commerce technologies and other work related applications, *Company C* was able to increase the overall productivity without providing further trainings.

However, internal learning support was not sufficient for those who had basic or no computer knowledge and these employees did not fulfil the *Company C's* performance expectations in using e-commerce technology and work related software. As a consequence, some of senior staff were dismissed from *Company C* in the past. *Interviewee C* believes that it was such a loss for the *Company C* to dismiss such highly skilled senior staff who could not meet only the expectations with their IT skills, which was often expected without proper training.

5.4 Discussions of Interview Findings

These interviews have provided the employees' attitudes and opinions on application of e-commerce technologies in construction project management. The main reasons for adopting e-commerce include "time and cost reduction, remaining competitive in the market, improve project document/information quality and meet the client/market demand and requirements". The challenges of implementing e-commerce technology were somehow different between he three companies: *Interviewee A* had difficulty in implementing purchased web

browser system to suit the company's needs and objectives but the biggest challenge has been leading all subcontractors to adapt the new e-commerce technology and approach towards the same technology level. this echoes to the findings of the survey. The research by Love et al (2001) and Ng et al (2001) draw similar conclusions. *Interviewee B* has been having problems with a number of issues: (1) massive incoming emails that range from vital to completely irrelevant; (2) uncontrolled web access restriction which led to lower productivity; (3) inefficient information management and information storage for project information archiving and retrieving; and (4) adversarial internal nature and no training provision. These problems should be taking into consideration by top management in establishing IT aims and goal. *Interviewee C* has not been receiving training for the new e-commerce applications in the past 3 years and the company was facing a problem of practical skills versus IT skills for senior and experience employees. These provide insight to the importance of IT training-learning-knowledge-sharing as found in the survey.

In these interviews, the importance of learning and training was strongly emphasized as it determines the attitude towards new and beneficial technology itself, and this result was very consistent with the findings of the survey. Furthermore the major barriers of using e-commerce technology found from the interviews, 'lack of in-house technical expertise and personnel' and 'lack of individual and collective learning system' and "IT-inability of subcontractors", are consistent with the results drawn from the survey findings.

6. CONCLUSIONS

In summary, this research has found that majority of the respondents considered the e-commerce technologies, such as e-mail, Internet connection, online search, computer aid design, and intranet are fundamental to execute construction management work. The reasons for using e-commerce technologies include gaining benefits such as 'better work opportunity', 'better information access and management', and 'increase in speed of working' and remain competitive in market place. While 34% of respondents have used e-commerce for more than 4 years, the other 66% have less than 4 years experience. The respondents' limited experience highlights the need for IT training, learning and knowledge sharing. The barriers and challenges in using e-commerce technologies mainly come from 'reluctance/inability to adopt computer technologies among subcontractors and suppliers', 'lack of in-house technical expertise and personnel', and 'different organisational culture' as well as 'lack of suitable systems that meets the company's needs'. Therefore in order to encourage greater use of e-commerce technology it is necessary to 'increase awareness of the company's/project's purpose and objectives', 'develop more user-friendly systems', 'reduce the cost of the technology' and provide more 'information about e-commerce benefits', and 'information assessing your company's/project's needs'. Nevertheless, continuous learning, training and knowledge-sharing in e-commerce technologies is important to ensure better use and improve e-commerce technologies applications in the construction industry.

In conclusion, we are in the era of ever changing technology with continuous improvements made to existing technologies with the focus on convenience, productivity, benefits of their usage. Therefore each company should first define clearly its business aims and objectives, then develop a strategy to most effectively use e-commerce technologies to help realize these objectives, then invest suitable amount of money into purchasing the e-commerce infrastructures and applications as well as providing sufficient top management support and sufficient IT skill training to employees together with a suitable performance measurement and cultivation of IT learning/knowledge-sharing culture.

7. REFERENCES

Aitken J.M. (1999). Supplier Associations, A Methodological Opportunity in Supply Chain Research, *proceedings of the 8th International Annual IPSERA Conference*, Belfast and Dublin, United Kingdom and Ireland, 13-22.

Alshawi M. and Faraj I. (2002). Integrated construction environments: technology and implementation, *Construction Innovation*, Vol. 2, No. 1, 33-51.

Asokan N., Shoup V. and Waidner M. (2000). Optimistic fair exchange of digital signature, *IEEE Journal on Selected Areas in Communication*, Vol. 18, 593-610.

Badii A. and Sharif A. (2003). Information management and knowledge integration for enterprise innovation, *Journal of Logistics Information Management*, Vol. 16, No. 2, 145-155.

Bellare M., Garay J. A., Hauser R., Herzberg A., Krawczyk H., Steiner M., Tsudik G., Van Herreweghen E. and Waidner M. (2000). Design, implementation, and deployment of the iKP secure electronic payment system, *IEEE Journal on Selected Areas in communications*, Vol. 18, 661-627.

Bjork B. (2002). A formalized model of the information and materials handling activities in the construction process, *Construction Innovation*, Vol. 2, 133-149.

Carter P., Carter J., Monczka R., Slaight T. and Swan A. (2000). The future of purchasing and supply: a ten year forecast, *Journal of Supply Chain Management*, Winter, 14-26.

Cheng E.W. L., Li H., Love P. E. D. and Irani Z. (2001). An e-business model to support supply chain activities in construction, *Logistics Information*, Vol. 14, No. 1/2, 68-78.

Coscia E., Nicolodi S., Doyle R., Slade A., Ginty K., Shamsi T. A., Ioannou L. and Chrissohoos P. M. (2000). The e-entry web-based e-commerce platform: an advanced infrastructure supporting tendering, bidding and contract negotiation.

Davila A., Gupta M. and Palmer R. (2003). Moving procurement systems to the Internet: The adoption and use of e-procurement technology models, *European management Journal*, Vol. 21, No. 1, 11-23.

Dooley K. and Purchase S. (2004). Factors influencing electronic procurement usage, *13th Annual IPSERA conference paper*.

E-commerce. [online] (2004). Available: http://www.keyitsolutions.com/e-commerce_ecommerce.htm [2004, September 30].

Ekstrom M.A. and Bjornsson H.C. (2003). Evaluating IT investments in construction – accounting for strategic flexibility, Centre for Integrated Facility Engineering (CIFE) *Technical report #136*, Stanford University, 23 pages.

Elliman, T. and Orange G. (2003). Developing distributed design capabilities in the construction supply chain, *Construction Innovation*, Vol. 3, 15-26.

Fellow R. and Liu A. (1997). *Research Methods for Construction*, Blackwell Science Ltd, Great Britain.

Fijitsu Centre. (1998). *Information Technology in the Building and Construction Industry: Current States and Future Directions*, A report for the National Building and Construction Committee Department of Industry, Science and Resources, Australian.

Gardner S. and Ash C.G. (2003). ICT-enabled organisations: a model for change management, *Journal of Logistic Information Management*, Vol. 16, No. 1, 18-24.

Goodman R.E., and Chinowsky P.S. (1996). Managing interdisciplinary project teams through the Web, *Proceedings of the 3rd Conference on Computing in Civil Engineering* - American Society of Civil Engineers in New York, USA, 452-458.

Gyampoh-Vidogah R. and Moreton R. (2003). implementing information management in construction: establishing problems, concepts and practice, *Construction Innovation*, Vol. 3, 157-173.

Hampson K. and Brandon P. (2004). *Construction 2020: A Vision for the Property and Construction Industry*, Corporative Research Centre for Construction Innovation, Brisbane Australia.

Jones M. and Saad M. (2003). *Managing Innovation in Construction*, Thomas Telford Limited, London, UK.

Kamara J.M., Augenbroe G., Anumba C.J. and Carrillo P.M. (2002). Knowledge management in the architecture, engineering and construction industry, *Journal of Construction Innovation*, Vol. 2, 53-67.

Ling F.Y.Y. (2003). Managing the implementation of construction innovations, *Journal of Construction Management and Economics*, Vol. 21, 635-649.

Liu P., Ning P. and Jajodia S. (2001). Avoiding loss of fairness owning to failures in fair data exchange systems, *Decision Support Systems*, Vol. 31, 337-350.

Love P.E.D., Irani Z., Li H., Cheng E.W.L. and Tse R.Y.C. (2001). An empirical analysis of the barriers to implementing e-commerce in small-medium sized construction contractors in the state of Victoria Australia, *Construction Innovation*, Vol. 1, No. 1, 31-41.

Mackay D.R., Altmann G.L., and McMichael H. (2003). How intimate are Australian e-business retail supply chain? *Logistics information management*, Vol. 16, No. 1, 48-55.

Mukherji A. and Mukherji J. (1998). Structuring organizations for the future: analysing and managing change, *Journal of Management Decision*, Vol. 36, No. 4, 265-73.

Ng S.T., Chen S.E., McGeorge D., and Lam K.C. (2001). Current state of IT usage by Australian subcontractors, *Construction innovation*, Vol. 1, No. 1, 3-13.

Osmonbekov T., Bello D. and Gilliland D. (2002). Adoption of electronic commerce tools in business procurements: enhanced buying centre structure and processes, *Journal of Business and Industrial Marketing*, Vol. 17, No. 2/3, 151-166.

Pederson T. P. (1999). *Signing contracts and paying electronically*, Lecture materials on Data Security, Springer-Verlag 1561, Berlin, Germany,134-157.

PriceWaterHouseCoppers Pty Ltd. (2002). *Innovation in the Australia Building and Construction Industry 2002 - Survey report*, [online] Available: www.acif.com.au/dwn/20104_Proposal_V5 2 col.pdf [2004, December 10].

Rohm A. W. and Pernul G. (2000). COPS: a model and infrastructure for secure and fair electronic markets, *Decision Support Systems*, Vol. 29, 343-355.

Salin V. (1998). Information technology in agri-food supply chains, *International Food and Agribusiness Management Review*, Vol. 1, No. 3, 329-334.

Shamir G., Ben-Or M. and Dolev D. (1998). A safe and scalable payment infrastructure for trade of electronic content, *International Journal of Cooperative Information Systems*, Vol. 7, 331-354.

Stewart P. (2001). The role of e-commerce systems for the construction industry, *The Australia journal of construction economics and building*, Vol. 1, No. 2, 24-36.

The IT Construction Forum (2004). *Survey of IT in Construction Use, Intentions and Aspiration*, [Online] Available: http://www.itconstructionforum.org.uk/publications/publication.asp?id=1168 [2004 September 30].

Tucker S. N., Mohamed S., Johnston D. R., McFallan S. L. and Hampson K. D. (2001). *Building and construction industries supply chain project (Domestic)*, CSIRO - Department of Science and Resources. June BEC Doc 01/214, 1-51.

Turban E., King D., Lee J., Warkentin M. and Chung H. (2002). *Electronic Commerce 2002: A Managerial Perspective, Pearson*, New Jersey, USA.

Vaidya K., Callender G., Sajeev A.S.M. and Gao J. (2004). Towards a model for measuring the performance of e-procurement initiatives in the Australian public sector: a balanced scorecard approach, *Australian electronic governance conference*, Centre for Public Policy University of Melbourne.

Veeramani R., Russel J.S., Chan C., Cusick N., Mahle M.M. and Roo B.V. (2002). State-of-practice of e-commerce application in the construction industry, *CII Research Report, 180-11*.

Walker D.H.T. (2004). The competitiveness of having a knowledge advantage, *The Building Economist*, June, 26-29.

Weippert A., Kajewski S.L. and Tilley P.A. (2003). The implementation of online information and communication technology (ICT) on remote construction projects, *Journal of Logistics Information Management*, Vol. 16, No. 5, 327-340.