IMPLEMENTING WEB-BASED COLLABORATION PLATFORMS IN CONSTRUCTION: EVALUATING THE LANE COVE TUNNEL (LCT) EXPERIENCE

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ABSTRACT : Web-based collaboration platforms present construction project teams with an opportunity to improve the efficiency of document exchange, better control project communications and enhance team collaboration. However, many construction professionals are still not convinced that these platforms, in their current form, are fit-for-purpose and yield sufficient efficiencies for the construction procurement process. In an attempt to improve the current ICT diffusion process, this paper evaluates the implementation of a web-based collaboration tool on the Lane Cove Tunnel (LCT) project in Sydney, Australia. Moreover, the paper provides strategies for achieving more effective implementation of web-based collaboration platforms in the construction sector.

Key words: information and communication technology, information exchange

1. INTRODUCTION

The majority of construction business processes are heavily based upon traditional means of communication such as face-to-face meetings and the exchange of paper documents in the form of technical drawings, specifications and site instructions. The need to increase the efficiency of these processes via exchanging massive volumes of information at high speed and at relatively low cost has been long recognized by the industry [1]. However, the use of Information and Communication Technology (ICT) in construction has not progressed to the level that can be seen in other industries [2]. This is due to a number of historical, industrial and market forces that perpetuate the industry's culture, thus affecting the extent of ICT adoption in day-to-day business processes [3]. As international competition continues to intensify, significant numbers of construction organizations are strategically investing large amounts in ICT as they seek to gain competitive advantage [4]. Despite the well-documented high expectations of improved responsiveness, efficiency and control of construction-related business operations, many of these organizations are dissatisfied by their ICT investments [5]. This dissatisfaction is in part due to the difficulty in measuring operational benefits leading to some concerns about the payoff from investments in ICT [6]. In an attempt to evaluate ICT-induced improvement on construction projects, this paper details the results of an investigation about users' perceptions of a web-based tool (InCITE) used to instantly share, visualize and communicate information between project participants on the Lane Cove Tunnel (LCT) project in Sydney, Australia. The effectiveness of the InCITE system was evaluated through a series of in-depth interviews with key stakeholders of the project (e.g. managers, engineers, architects, client etc.) across four (4) ICT-related performance perspectives. Each perspective consists of a diverse set of identifying questions (items) which focus on individual aspects where ICT-induced improvement may arise.

2. PROJECT INFORMATION EXCHANGE

The need for improved project communication is a widely documented issue in the construction industry. To facilitate the management of project information and address project communication requirements, a number of ICT tools have been used with the aim to maximise benefits and reduce cost for the entire project team. The key to project information management, though, consists of the information flows associated with inter-organisational communications. As a result, a core issue is the effective management of information, both in the form of information flows that permit rapid inter-organisational transactions between project participants, and in the form of information accumulated, coded, and stored in firm database structures.

The construction industry has for many years suffered from difficult-to-access, out-of-date and incomplete information. Until the very recent past, it would have been inconceivable to electronically control and direct information flows in construction. Documents can now be produced and transmitted instantaneously by digital transmission at fractions of their previous costs. Electronic Data Interchange (EDI) permits computers and information systems to communicate directly with other computers,

strengthening joint operations among organisations. Unfortunately, the effectiveness of utilising ICT in a construction project could be hindered by the inability to share data in electronic form between project partners. Although it is not practical to expect compatibility between all information systems in the short term, there should be more focus on the standardisation of interfaces between the different systems. ICT tools should be able to exchange digital information with other applications/systems using appropriate data exchange standards.

At the project level, which is the basic operating level in construction, project information is usually considered as the processed and presented data in a given situation, and is the data that enables effective action [7]. Information produced by many sources, at many levels of abstraction and detail and retained by the creator of that information contributes to fragmentation of the industry. Therefore, timely and accurate information is important for all project participants as it forms the basis on which decisions are made and physical progress is achieved. Wasted time and cost in construction projects can be traced back to poor coordination caused by less than optimum information handling and exchange that is inadequate, inaccurate, inappropriate, inconsistent, late or a combination of them all [3].

Traditionally, project Information Exchange (IE) between designers and contractors has been mainly based on paper documents. These documents come in the form of architectural and engineering drawings, specifications, and bills of quantities and materials. This practice has been far from satisfactory, with research showing that about two-thirds of the construction problems are being caused by inadequate communication and exchange of information and data. Research has also noted that 85% of commonly associated problems are process related, and not product related. These findings explain the growing awareness of the value of ICT to bring together the major parties in the construction process, and share project as well as industry information in a meaningful way.

The relationship between construction project participants is normally complex and involves many parameters that extend across technical, functional, business, and human dimensions. As a result, attention and focus must be given to the intensive collaboration among project participants to synchronise both the input and output of the supply chain. Undoubtedly, a key enabler to successful collaboration is the ability to communicate, and share and exchange project information in a timely and accurate manner. A European survey [8] has highlighted the need for electronic sharing of information between Large Scale Engineering (LSE) clients' information systems and those of: funding bodies in the areas of finance and accounting; consultants in the areas of modelling and calculations; project managers in the areas of project planning and QA systems & documents control; contractors in the areas of CAD drawings, materials procurement, project planning, QA systems & documents control, and communication systems; and suppliers in the area of materials procurement.

Since the Internet is a worldwide system for exchanging and distributing free-format information, it is regarded as an ideal platform for building up Information Systems. The growth and wide use of the Internet generally for electronic commerce and for communication provides a valuable tool in the areas of information sharing, file transfer, communication and reporting on associated tasks. A number of organizations have utilized the Internet in the management of construction projects, though empirical evidence is scarce.

3. EVALUATING ICT IN CONSTRUCTION

Generally, ICT investment appraisal is more difficult than other investment decisions because ICT-induced benefits are hard to identify and quantify [9]. As a consequence, more traditional investment appraisal methods such as Return on Investment (ROI), Net Present Value (NPV) or Internal Rate of Return (IRR) have been difficult to apply despite being widely understood by senior managers [10]. The ICT productivity paradox prompted calls for new approaches to evaluate ICT-related investments [11]. In an attempt to provide a balanced approach to ICT performance evaluation, ICT should be evaluated across a number of perspectives [6, 9, 12]. For the purpose of this study ICT was evaluated across four robust ICT-related performance measurement perspectives:

- *Operational Benefits Perspective*: Concerned with the impact of ICT on productivity and efficiency, cost and time (tangible & intangible).
- *Technology/System Perspective*: Refers to the hardware and software, covering issues such as tool performance, reliability, availability, security and suitability to the application/process.
- *Strategic Competitiveness Perspective*: Focuses on the long-term strategic goals of the organisation and how the newly implemented technology creates competitive advantage.
- *User Orientation Perspective*: Covers issues associated with the usage such as tool utilization rate, availability of training and technical support and satisfaction with the tool.

These perspectives and their associated indicators were customized for the specific elements of ICT and construction. The framework utilizes project-, tool- and process- specific ICT indicators designed to reflect the particular aspects where ICT implementation can improve project-based information management processes.

4. CASE STUDY: LANE COVE TUNNEL

4.1 Project overview

The Lane Cove Tunnel (LCT) project involves the design and construction of twin 3.6 km tunnels linking the M2 to the Gore Hill freeway and the upgrading of a further 3.4km of the Gore Hill Freeway. Lane Cove Tunnel Company (LCTC) has been appointed by the NSW Government to finance, design, construct, maintain and operate the LCT for 33 years, after which the tunnel will be returned to the Roads

and Traffic Authority (RTA). LCTC has contracted the Thiess John Holland Joint Venture (TJH) to design and construct the LCT and associated works. The project team comprising approximately 250 staff including engineering design, construction, urban design, environmental experts and community relations staff are based at the North Ryde project office in Sydney NSW along with 8 site offices for construction staff. Following completion, the tunnel and the two new north-facing Falcon Street ramps will operate as a toll road.

4.2 Optus InCITE

The Lane Cove ICT strategy was principally concerned with the successful implementation of the Optus InCITE web-based collaboration platform. Other software used on the project was not evaluated in this case study. InCITE is a neutral construction industry trading exchange hosted by Optus and accessed through the Internet. Thiess and John Holland Group Pty Limited are two of a group of six large construction companies that are responsible for driving the launch of InCITE. Optus InCITE currently comprises three distinct applications which are all accessed through an on-line portal by a single registered name and password. Those applications are: Document Management, Tender Management and Purchasing. Only Document Management is being used at Lane Cove. Document Management refers to the on-line management of all documents and drawings and, formal or informal communication. It supports the interactive design process within and between organizations. It manages the work flow between architects, engineers, consultants, subcontractors and the construction site and speeds up the design and feedback process. Documents are stored centrally in a secure data centre provided by Optus, so version control can be managed effectively and users can be certain that they are dealing with the latest document. The document management application improves project communication, manages all project documents and their various revisions and includes scheduling functionality to reduce design cycle times. The business case for the TJH implementing the InCITE platform was based on the following expected benefits:

- A single central repository for all project documents accessible 24hrs-a-day from anywhere;
- Reduction in paper copying costs;
- Reduction in distribution costs;
- Considerable time savings through more efficient processes;
- Increased document control;
- Increased accountability and audit capabilities;
- Increased transparency during design development resulting in earlier detection of defects;
- Reduction in the number of errors owing to out-of-date information or misinformation;
- Reduction in time for staff spent on paper and electronic document management;
- Improved project communication;
- Fostering a more collaborative approach; and

The driving force behind the implementation of Optus InCITE on the LCT project was the need to automate a large number of processes that were previously paper-based and to ensure all project information and communication was kept in a single repository. This strategy wasn't in place when InCITE was first implemented on the LCT project. It evolved throughout the first year of use on the project. The strategy can be described in 4 stages: (1) identify business processes to suit the project; (2) mapping the processes; (3) preparing a training strategy; and (4) implementing the training. The Project Director of the LCT project made the use of InCITE mandatory for all employees. Use of other methods of document exchange was not recognised. The use of email outside of InCITE was banned. Clauses have been written into subcontractors and design consultants contracts stating that InCITE is the only recognised vehicle for document and drawing exchange. A full-time trainer and one full-time InCITE staff member was provided to support staff on InCITE. All the processes that are managed through InCITE are mapped onto flow charts, documented and incorporated into the Project Quality Manual. Training involves an initial three-hour introductory session.

4.3 Research method

The case study was conducted at the LCT project site office in North Ryde in November 2004. The research method comprised of two principal stages. The first stage involved mapping the newly implemented ICT-based processes and developing appropriate questions to examine them and the second stage was concerned with conducting interviews with key stakeholders. The first stage commenced with a half-day workshop with the InCITE Manager and LCT ICT Manager with the purpose to: identify the ICT technologies that have been implemented; identify the business processes that are directly affected; design project specific indicators for each perspective of the balanced scorecard framework; and agree on the open-ended interview questions. From this workshop, 36 questions were developed across the four ICT-related performance perspectives described previously. It should be noted here, that all four perspectives are interdependent and need to be considered to assess the ICT strategies overall performance. Each question was designed to compare the effectiveness of each process operated through Optus InCITE to a Business As Usual (BAU) approach using a five-point Likert scale, namely, (1) significant detriment; (2) some detriment; (3) no change; (4) some improvement; and (5) significant improvement. The open-ended part of the questionnaire was designed to give respondents the opportunity to provide more in-depth responses relating to the good/poor elements of the technology and its' implementation. In total, the project stakeholders were asked 14 questions about InCITE and the associated implementation strategy. Fifteen interviews were conducted with project stakeholders representing different elements of the procurement process.

4.4 Part A: ICT performance evaluation

In total, thirty-six (36) indicators were developed across the four perspectives and are presented in Table 1. Due to confidentiality requirements, the ICT performance scores for these indicators cannot be presented.

Table 1. Quantitative survey indicators

Code	Indicator Description
Operational Benefits Perspective (OB)	
OB-a	IT-enhanced coordination and communication
OB-b	IT-enhanced decision-making process
OB-c	Reduced unnecessary site visits
OB-d	Reduced number of Quality Assurance non-conformances
OB-e	IT-enhanced user/stakeholder accountability
OB-f	Time savings due to efficient document management
OB-g	Reduced multiple handling of documents
OB-h	Realised cost savings
OB-i	Optimise staff utilisation (*resourcing of staff*)
OB-j	Streamlining of processes
OB-k	Improved client satisfaction
OB-l	Access for availability and searching of documents
OB-m	Reduced errors on site due to accessing latest documents
Technology/System Perspective (TS)	
TS-a	Reliability of ICT tool (accessibility, etc)
TS-b	Appropriateness for application/function
TS-c	User friendliness
TS-d	Improved quality of output
TS-e	Effective system security
TS-f	Suitability for site conditions (on site use)
TS-g	Performance of ICT Tool (response time etc)
TS-h	Scalability (max no of users at any one time)
Strategic Competitiveness Perspective (SC)	
SC-a	Improved staff computer literacy
SC-b	Enhanced organisational competitiveness
SC-c	Enhanced organisational image
SC-d	Project alliances forged through electronic means
SC-e	Ability to attract clients
SC-f	Access to project knowledge learning
SC-g	Ability to satisfy business obligations
User Orientation Perspective (UO)	
UO-a	Satisfactory level of IT training
UO-b	Frequency of IT training
UO-c	Satisfactory level of IT support
UO-d	Responsiveness of IT support
UO-e	Effective IT utilisation pertaining to job responsibilities
UO-f	User satisfaction (user, client, other)
UO-g	Easy to navigate (e.g. menu structure in *alphabetical order*)

4.5 Part B: Interviews

Part B of the study involved conducting in-depth interviews with fifteen (15) members of the LCT project team representing various roles within the project. These interviews were conducted over a one-hour period and included the following team members: civil reviewer, civil construction manager, community relations officer, condition surveyor, document controller, design engineer, design constructability reviewer, environmental engineer, human resource manager, independent verifier, consulting engineer, quality assurance officer, safety manager, tolling manager and tunnel construction manager. In total, fourteen questions were asked, as follows:

1. What has gone well?
2. What has not gone well?
3. Describe any implementation problems?
4. How have these problems been addressed?
5. Would you recommend this technology on future projects?
6. How could this technology be more effectively implemented in the future?
7. What do you see as the main barriers of implementation?
8. What are the main drivers of implementation?
9. What is your overall view of the technology itself?
10. Does it work?
11. How has it helped you to do your job?
12. What changes would you make to improve it?
13. Is it user friendly?
14. What would you do if you were responsible for implementing this kind of technology in the future?

A number of positive factors contributing to critical success factors can be deciphered from the open-ended questions and are summarized below.

- The majority of stakeholders recommended the use of this technology on future projects;
- The majority of stakeholders stated that InCITE was helping with their jobs;
- The majority of stakeholders understood the benefits for the project by implementing an ICT platform such as InCITE and were committed to its continued use;
- The majority of stakeholders acknowledged that management have reacted to problems raised with the initial roll-out of InCITE; and
- The majority of stakeholders stated that the level of training and support was very good.
- The main drivers to implement InCITE were found to be: remote accessibility; all information in the one resource; accountability, traceability, permanent records; a paperless office where all your records are instantly available on line; and long term ease of retrieval and storage of documents for completion.

4.6 Summary

In summary, the results indicate there have been many successes with the system, including, dynamic document archiving, more efficient design management processes, improved document exchanges, more project accountability,

improved document exchange, reducing communication costs; paperwork; storage requirements; transactions times and costs; quicker response on project progress and achieving increased information exchange; quicker access to project data; strategic competitive advantage; improved focus on client requirements; improved information version controls; improved filtering of information, legal audit trail and electronic records suitable for client handover for operations. On many projects implementing this type of technology, many stakeholders are reluctant to change from their existing work practices. This did not appear to be the case on this project. This was possibly a symptom of the top-down approach applied by the project director and good communication between the project team. It was remarkable that many of the stakeholders understood the value of introducing an ICT platform like InCITE and were committed to its future success.

5. MOVING FORWARD

From the TJH LCT project, ten Critical Success Factors (CSF) were identified for helping construction firms to more effectively implement web-based collaboration platforms in a construction environment. These factors include: (1) organizational commitment; (2) identify business processes to suit the project; (3) mapping business processes; (4) preparing a training strategy; (5) implementing the training; (6) provide appropriate infrastructure; (7) plan staged roll-outs; (8) upload policies are issued; (9) business analysis is carried out; and (10) a communication strategy formulated. Each of these CSFs are described individually in the following sections.

5.1 Organizational commitment

To ensure the success of the use of InCITE on the LCT project, the Project Director mandated the use of InCITE. Stakeholder commitment was vital to InCITE's successful adoption and use and various statements from staff and consultants confirmed that the majority of stakeholders: (1) understood the benefits for the project from implementing an ICT platform such as InCITE and are committed to its continued use; (2) acknowledged InCITE helped with their jobs; (3) appreciated the level of support and training provided; (4) would recommend the use of InCITE on future projects; and (5) acknowledged that management have reacted to any problems raised.

5.2 Identify business processes to suit the project

Various departments within the LCT project were identified, including, safety and risk, quality management, human resources, design management, construction (tunnels and civil), community relations, condition surveys, environment, independent verification, quality assurance, tolling, etc. Staff within these work areas were asked to identify the steps in all key processes and conduct a needs analysis including an alignment with on-site processes. Stakeholders in a project process were requested to devise the processes and protocols that facilitated business process alignment, whilst, protecting the business interests and confidentiality for users of the project processes e.g. the human resource department required protection of personal details under privacy laws. It was necessary to align InCITE processes with those of its clients. At LCT, the records management system was aligned with outputs required by clients. External expertise was contracted to help design/provide help to TJH.

5.3 Processes align with the business strategy

All steps within each documented process were flowcharted and software aligned to suit these processes. Approximately 50 processes were identified at the LCT Project and twelve months was spent mapping these processes.

5.4 Prepare a training strategy

LCT management identified a training strategy which included: (1) identifying champions in the use of InCITE to assist other staff; (2) all staff trained at the commencement of their employment on the project; (3) inclusion of training into periodic staff performance reviews to identify weaknesses and devise individual action programs that overcome them; (4) one-on-one training for staff where needed; (5) records management training; (6) roving trainer; and (7) staff training programs to for each project phase.

5.5 Implement the training strategy

Stakeholders were trained prior to using the collaboration platform. This ensures the system is used efficiently, productivity is increased and the legal audit trail is easily retrievable through good records management practices. At LCT, dedicated trainers and training rooms were implemented in the LCT project office. All stakeholders were trained including TJH staff, consultants, suppliers, subcontractors, etc. A training manual was given to all trainees for later reference. Moreover, questions and answers were prepared and trainees tested for competency. A quote from the construction manager at one of the LCT tunnel sites summed up most of the staff's feedback on training: "I had training on my first day on the project. Everyone is committed to InCITE. The way the company gives you every support to utilize InCITE is as good as it gets".

5.6 Infrastructure

Sufficient infrastructure is required to achieve an adequate speed and efficiency of use. Collaboration providers specified 'line capacities' for the infrastructure depending on the number of expected users of the system. On large projects of this nature it is recommended that a minimum of a 2Mb leased line is installed. Moreover, the algorithms within the software code itself must be designed for numerous users.

5.7 Staged roll-outs

Staged roll-outs may be necessary for updates and modifications of the collaboration platform. Possible phases could include, when the design process ceases and

construction starts; or where construction finishes and maintenance commences. It is important to remove processes no longer required or add processes when needed.

5.8 Collaboration platforms upload policies

Each functional area within a construction project should submit an upload policy for approval by management. Policies should particularly address "work-in-progress" documents. In particular, consideration might be given to uploading design drawings at various stages of development e.g. 50%, 75%, 100% where multiple drawings will be produced. At the LCT project a total of 7500 drawings were produced and these were uploaded as the design progressed. Other projects have reported up to 85 re-issues on architectural plans for design/construct projects.

5.9 Business analysis

A business analyst should review the format and delivery of the information as part of the prescription of the processes. For example, where multiple sheet drawings are uploaded in adobe acrobat format into the system, the business analyst might prescribe 'that these documents will be viewed by users in one PDF file'.

5.10 Communication strategy

The diffusion and communication strategy at the LCT project included: regular briefings to inform stakeholders as to the progress being made; inclusion of InCITE issues into a monthly staff newsletter; strategy to align processes between the North Ryde site office and tunnel sites; "help-desk" support hosted on-site by TJH ICT staff; "help-desk" support hosted off-site by Optus; and recognition of champions of the system to support peers to solving any problems. A communication strategy is needed for any changes implemented within the collaboration platform to advise users of new features or changes to protocols and procedures. Personnel also need to have a means to comment on the system and associated support provisions.

6. FUTURE RESEARCH

The Lane Cove Tunnel project case study is the first of a series of case studies designed to investigate the issues surrounding the implementation of ICT on Australia's leading construction and integrated engineering projects. It is part of a wider industry directed research and education program that investigates the deployment of life cycle ICT strategies in the Construction and Integrated Engineering industry. It promotes the critical success factors that help overcome the technical & cultural barriers that are currently holding back efforts to integrate design construction and operational processes.

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