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EMERGING ICT TRENDS IN CONSTRUCTION PROJECT TEAMS: A DELPHI SURVEY

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EDITORS: K. Ruikar & S. Emmitt

Dr Graham Brewer
University of Newcastle, Callaghan, NSW, Australia
Graham.Brewer@newcastle.edu.au

Thayaparan Gajendran
University of Newcastle, Callaghan, NSW, Australia
Thayaparan.Gajendran@newcastle.edu.au

SUMMARY: *This paper describes the design, implementation and findings of a project funded by the Chartered Institute of Building(CIOB) in Australasia to investigate the evolving use of Information and Communication Technology (ICT) in construction projects. It describes the context provided by literature relating to ICT-enabled project team performance and proposes an on-line, modified Delphi methodology based on the Blackboard educational delivery platform to facilitate the asynchronous participation of a panel of experienced practitioners in the generation of data. The paper closes by reporting the study findings and their implications for professional practice, concluding that clear leadership in the fields of ICT standardisation and ICT-mediated project procurement could foster supply chain integration. Such leadership has the potential to optimise project outcomes, but only if a clear potential for all stakeholders to increase their levels of profitability is demonstrated.*

KEYWORDS: *Delphi, ICT, Construction Projects*

1. INTRODUCTION

The construction industry has frequently been described as fragmented, information intensive and adversarial (e.g. Cox and Townsend, 1998). Ng, Chen, Mc George, Lam and Evans (2001) explained many of the industry problems by reference to the quantity and complexity of the shared communication. Faraj and Alshawi (1999) highlighted a need for common data exchange standards, suggesting that these could address the questions of information and communication technology (ICT) uptake and widespread adoption, leading to shared common business processes (e.g. Williams, Esper and Ozment, 2002). The New South Wales Government (1998) stressed both the complexity of the problem and the potential benefits arising from its solution. Alshawi and Underwood (1999) foresaw project teams using shared electronic workspaces, which would produce multiple benefits. However Egan (1998) and Finch (2000) observed that these costly investments had yet to fulfill their potential.

Downward cost pressures, increasing specialisation and technical complexity of projects created a demand for an integrated approach to ICT across the construction sector (Brown, Rezgui, Cooper, Yip and Brandon, 1996). However the 'islands of automation' first identified by Kartam in 1994 remained common, leading to a significantly low level of ICT integration across the various industry sectors compared to other industries.

A number of factors were identified to explain these disappointing results including:

- Failure to deliver promised returns (Shafagi and Betts, 1997);
- "Backing the wrong technology" (Shafagi and Betts, 1997);
- Lack of standard protocols for inter-organisational communication and transfer of data (e.g. Yu, Froese, and Grobler 1998);
- Failure to integrate ICT into the core business processes of the organisation (Sarshar, Betts and Ridgeway, 1999);
- Inability of the organisation to re-engineer business processes to align with those of their trading partners (Shafagi and Betts, 1997).
- Inability to measure the benefits accruing from the use of ICT (Schwegler, Fischer, O'Connell, Hanninen and Laitinen, 2001);
- Difficulty of keeping IT investments up-to-date (Shafagi and Betts, 1997).

Implicit in most of these factors was the recognition that the best intra-organisational ICT deployment would fail to deliver optimal returns if attention to inter-organisational issues was sub-optimal. This in turn linked the issue to the individual organisation's relationship with its trading partners.

Early commentators anticipated the integration of ICT across all sectors of the construction industry triggering revolutionary changes in the ways firms relate to each other, curing many of the industry's ills as a result. Rivard (2000) sought evidence across a series of surveys of ICT usage (Doherty, 1997; Howard and Samuelson, 1998; Futcher and Rowlinson, 1999, Samuelson, 2002). Nevertheless, the evidence for such a dramatic change remained hard to find, with later commentators suggesting that revolutionary change was not possible in the current climate where business leaders remained sceptical about the full range of potential benefits touted by ICT promoters (Brewer, 2008). Key to this scepticism was the difficulty in ascertaining the nature and extent of the benefits gained from ICT investments, fuelled by the prevalent project-centric focus (Love and Irani, 2001). The diversity of ICT systems and business processes within the industry, the amount of time, effort and resources that had to be devoted to realigning an organisation's business processes with those of the rest of the temporary project organisation (TPO) were all seen as impediments to achieving full benefit (ConstructIT, 1998).

The "Picturing Success" study conducted by the Cooperative Research Centre for Construction Innovation (CRC-CI) investigated the attitudes and behaviour of individuals and firms operating in the construction industry in Australia. It paid particular regard to the "softer" issues that impacted upon the likelihood of successful deployment of ICT in project team environments (Brewer and Gajendran, 2006). The study revealed clusters of issues emerging from collective experience, which were found to be critical to its successful use. These clusters, or critical success factors (CSFs) were:

- Organisational Commitment
- Organisational Attitude To Communication
- Rights And Duties Of Organisations
- Investment Drive
- Risks Related To ICT Usage (Brewer and Gajendran, 2006).

Davis and Songer (2008) explicitly linked personal attitude to intention via Ajzen's work (1985, 1991). They further introduced the potential for less than fully rational attitudes towards technology and change. This affected the way in which an individual could be expected to embrace I(C)T, providing a link to personal motivation as a significant factor in its adoption. In doing so they opened up a human dimension to the assessment of risk related to ICT usage indicated by Brewer and Gajendran (2006), thus adding a new dimension to be explored when considering it's use in a project team setting.

From the foregoing it was evident a) that the capabilities of ICT used in the construction industry were rapidly evolving, b) that despite this there was a general dissatisfaction with the level of ICT integration achieved within project teams, and c) that the human dimension had to be considered a confounding factor. The CIOB were keen to discover what implications this had for them as an organisation representing a substantial portion of the industry and their members, and agreed to fund a study to this end. This research was therefore designed to identify any changes in the nature of ICT adoption and integration by construction project teams since Brewer and Gajendran's initial survey in 2003 (Brewer and Gajendran, 2006), paying particular regard to the role

personal attitudes might have regarding technological change, and to further explore any issues raised by the participants. The study would specifically engage with "experienced practitioners" who were defined as *those charged with implementing the use of ICT in construction project teams* (Gajendran, Brewer and Chen, 2005).

An online Delphi study was proposed given its desirable attributes and the authors' familiarity with technique: this is now explained in detail.

2. DELPHI METHODOLOGY: THEORY

A particular aspect of this research was its use of a Delphi study to explore complex links between large numbers of concepts (Kaynak, Bloom and Leibold, 1994). This had previously been found to be particularly useful in relation to matters concerning policy and procedure, be it at the level of the individual firm, the temporary project organisation, or the industry. Traditionally Delphi studies have been used for two purposes: exploration, or confirmation of a concept(s). Delphi was particularly suited to exploring complex problems that required an element of subjective analysis (Mitchell and McGoldrick, 1994), especially in industries undergoing rapid change (Jillson, 1979). According to Linstone and Turoff (2002) specific applications included the following which were appropriate to this study;

- Delineating the advantages and disadvantages associated with potential policy options
- Identifying and developing causal relationships in complex economic or social phenomena
- Distinguishing and clarifying real and perceived human motivations
- Exposing priorities of personal values, social goals. (Linstone and Turoff, 2002, pg 4)

A Delphi survey would be designed to obtain and distill the opinions of experts over a series of rounds of data collection, which moved from the general to the specific, from diversity to consensus or polarity, requiring justification from those holding dissenting positions (Delbecq, van de Ven and Gustafsen., 1986). Each round of data collection would be triggered by a set of provocative statements a copy of which would be given to each participant for comment. The responses would then be collated and summarised by the research team, and this would then be re-circulated to the participants for further comment. Inter-round feedback would increase participant awareness of issues and aid both convergence and/or polarity (Rowe, Wright and Bolger, 1991). Irrespective of the details of design, there were three aspects to a Delphi study that separated it from any other methodology, namely participant anonymity, researcher-mediated feedback, and statistical group response reflected in the drive towards majority consensus/unanimity. These mechanisms would ensure that all individual responses were reflected during the development of the final outcome (Rowe et al, 1991).

3. DELPHI METHODOLOGY: APPLICATION

This study involved invited panellists, these potentially being located in several states and overseas. The geographical dispersal made the use of asynchronous online communication desirable. The University of Newcastle's web-based Blackboard learning management system was chosen to host this because it was able to facilitate asynchronous discussion in a number of threaded discussion forums, whilst concurrently enabling automatic on-line survey data collection.

Access to a dedicated, password-protected area could be provided for the participants, each of whom would be issued with a personal account that included a unique pseudonym and password, thus ensuring their confidentiality.

Upon login participants would be able access four discussion threads where they would provide written responses to trigger statements. Figure 1 shows the entry screen to access this. The participants would post their opening statements, and would concurrently be able comment on other participants' postings, discussing differences of opinion. Figure 2 shows a representative part of the discussion board.

At a pre-defined point in time a summary of each thread would be generated by the research team, this then being posted to a new thread as the initial trigger. This process would continue until polarity or consensus was

reached. Once the final summary was posted the panel would be given the opportunity to provide final comment prior to individual participant sign off in regard to the results.

Blackboard was designed so that although the data was entered by the participants as individual postings its functionality would enable the researchers to collect the "rolled up" contributions from each forum, in a single PDF file. Individual postings would still be identifiable, and would appear in the order in which they were first posted. This offered significant advantages during the data analysis phase, where the data was to be entered in to N-Vivo, a qualitative data analysis database application. Each rolled-up discussion would then be treated as a focus group, allowing the initial demographic coding to be carried out automatically by N-Vivo, whilst concurrently allowing each of their contributions to a particular focus group to be analysed within the context of the other contributors (Figure 3).

In a separate area within Blackboard the participants would be asked to complete a 16 question online demographic/attitude questionnaire.

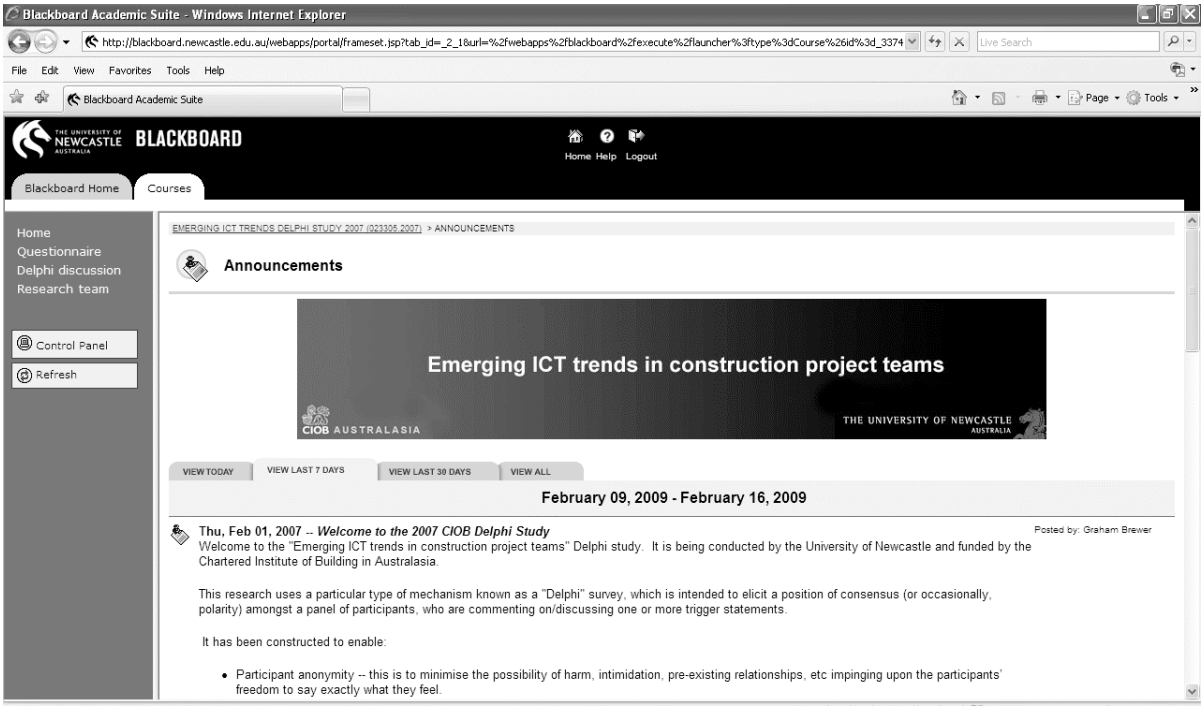

FIG 1. Blackboard Welcome Screen.

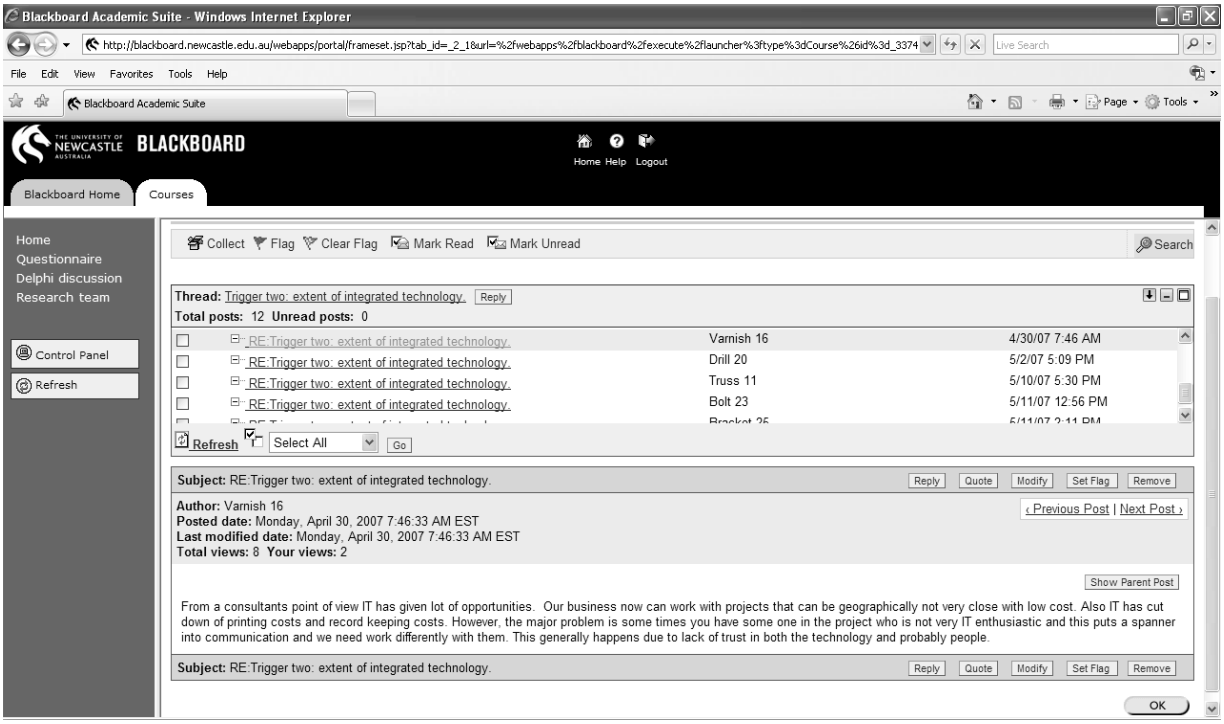

FIG 2. Blackboard Discussion Board and Posting.

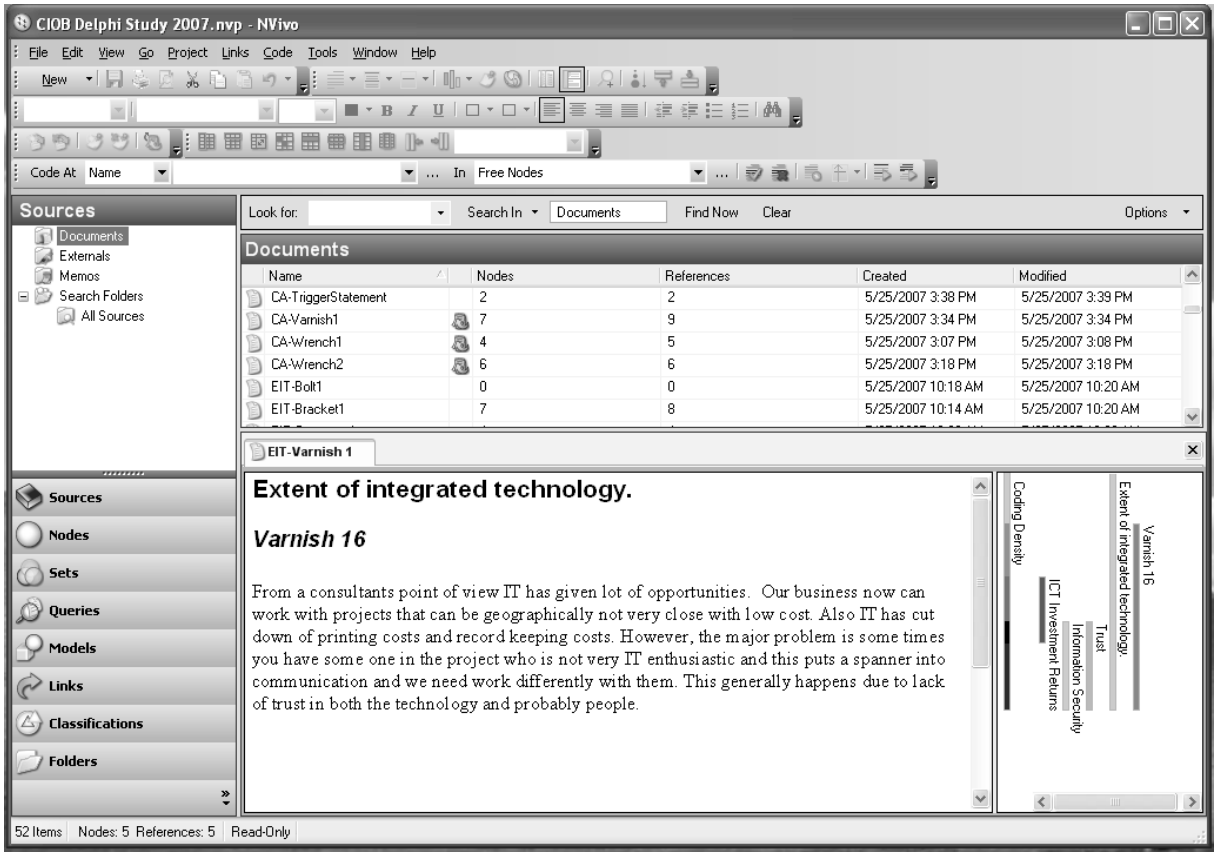

FIG 3. N-Vivo Work Environment.

4. DELPHI METHODOLOGY: IMPLEMENTATION

In this study the invitation to participate was issued through publicity releases from the Chartered Institute of Building and affiliated professional bodies. This resulted in 22 expressions of interest in participation. The Blackboard site became active at the beginning of April 2007 and the last participant sign-off on the project cam in mid-August.

At completion the study retained 15 active panelists. The final panel included two project managers, two quantity surveyors, a services engineer, a trade subcontractor, three government representatives at (inter)national, state and local levels, two architects, two ICT consultants (developer and systems engineer), an estimator and a mechanical services engineer.

The participants responded to four trigger statements abstracted from a review of the relevant literature, which were grouped to assist achieving the stated aims of the study. These are contained in table 1.

The panel contributed 71 discussion items evenly distributed across the four discussion forums, the average size of each contribution being about 100 words. These were analysed by the authors on an ongoing basis in order to generate round summaries and study conclusions. In the event consensus was reached after two rounds, and the process of data analysis by which this was achieved is described next.

5. DATA ANALYSIS

The principle underlying qualitative analysis of textual data is to communicate an understanding of it that would be similar to that generated by other researchers with similar training and background. This is comparatively easy when dealing with factual data such as demographic information (Richards and Richards, 1995) but far more challenging for referential data that deals with description or interpretation (Miles and Wietzman, 1994).

TABLE 1. Trigger Statements

Discussion thread	***Trigger statement***
Process integration	***"The integration of ICT into business processes can occur at many levels, beginning at the intra-firm level (e.g. integrated materials and accounting systems), through process alignment with others in the project team (e.g. shared CAD models to facilitate design and costing), right up to the development of industry-wide standards and procurement protocols*** To what extent do you find these levels of integration reflected in the real world? What factors affect the extent of ICT mediated business process integration? How might procurement mechanisms (e.g. design and construct, alliancing) or legal frameworks (e.g. ICT-specific forms of contract) be developed to increase levels of integration?
Integrated communications	***"Increasingly integrated technology systems are perceived by decision makers to variously bring both opportunities and risks: the level of technological integration between firms is determined by the lowest shared technology."*** To what extent do integrated communications present opportunities (e.g. faster, more effective communications, cost savings)? How might integrated communications be perceived as problematic (e.g. security, intellectual property, staff development issues)? What developments could assist in increasing the likelihood of integrated communications (e.g. common data exchange standards, interoperability across platforms)?
Competitive advantage	***"Latham and Egan indicated that ICT had the potential to generate competitive advantage and increased margins by fostering strategic, value-adding relationships."*** To what extent do you find this to currently be true? Is it realistic to expect ICT integration to trigger long-term business

	relationships or should ROI on ITC investments be based on the short term? To what extent are strategic ICT decisions reactions to, rather than attempts to beneficially shape the industry environment?
Leadership	***"Whenever ICT is first introduced into an organisation or a project team it must, to a greater or lesser extent be regarded as an innovation, the roll-out of which requires to be driven by a 'champion' empowered with both the authority and responsibility to make it work."*** Given that ICT has the ability to span the boundary between the individual firm and the project, or the project and other projects, what problems face the ICT champion? What effect does the position of the champion within the project structure have upon the success of the use of ICT? To what extent is this a case of initiating/managing change in the project as opposed to initiating change in the industry?

Approaches to coding text – assigning consistent labeling to text holding similar meaning – can vary widely from the linear (e.g. Strauss and Corbin, 1990) through to the emergence of meaning via the interplay between data, notes and codes (Glaser, 1992). Morse and Richards (2002) distinguished codes from topics in the way that codes would reappear in multiple pieces of data. Developing an ecumenical perspective from these widely differing approaches it is possible to establish a number of methodological principles:

- Data should be revisited.
- Codes should also be revisited and revised/extended where appropriate during the analysis.
- Codes and coding structures develop with the ideas that gave rise to them in the first place – they are shorthand for the researcher's ideas.

Morse and Richards (2002) also indicated that this last point would be formalised by the generation and inclusion into the data of the researcher's own notes/memos.

Standards of consistency and repeatability can be increased in a number of ways. Firstly the competent researcher should be aware of his/her propensity for subjectivity (Klein, Moon and Hoffman, 2006), developing a keen self-awareness to aid objectivity (Cohen and Daniels, 2001). Secondly, it is desirable to use multiple coders (Morse and Richards, 2002), working autonomously, then sharing/comparing/resolving anomalous coding at face-to-face meetings. Lastly, whilst by no means essential, it is nevertheless useful to use a qualitative database application in order to store, code and interrogate the data. N-Vivo 7 is recognised as peerless in this regard.

It is important to understand that coded data of itself sheds no further light on the phenomenon under investigation without the interpretation of the researcher, and the explanation of this interpretation to others. This process of abstraction can be undertaken from a number of different philosophical perspectives including the dialogical, individual, hermeneutic and empirical (Ramberg and Gjesdal, 2005), and whilst the two last of these were considered appropriate for this research it is necessary to provide an explanation why hermeneutic abstraction was ultimately rejected.

Hermeneutic is the development and study of theories that have been developed to interpret and understand texts. It was initially concerned with the "accuracy" of scriptural interpretation, subsequently being extended into other areas of contemporary philosophy (Cohen and Daniels, 2001). Hermeneutic enquiry acknowledges the researcher's prior knowledge and experience, and the propensity that this has to influence their interpretation. Adler (1997) eschewed "method for methods sake" and did not advocate the development of a step-by-step method or analytical requirements. By contrast, empirical phenomenology requires similar standards of methodological design as would be familiar to a positivist, quantitative researcher, namely:

- An emphasis on commonality that is present in the many diverse appearances of the phenomenon.
- Reliance on the actual words of the participants.
- Explicit this about the design and the steps taken to obtain the findings.

- Characteristics leading to verifiability and ability to be replicable.
- Emphasis on rigour of the approach rather than on creativity (Cohen and Daniels, 2001)

Importantly, empirical phenomenology also accepts that hermeneutic activity (interpretation) it is an intrinsic part of this approach, something that the authors instinctively recognized.

The following protocol was established for the project utilising the foregoing principles:

- Multiple analytical passes of the data would be required to extract the fullest understanding.
- The first pass would consist of note/memo writing for each piece of data, which would be read in isolation. This was to be a "sense-making" exercise, and the notes/memos would therefore become a legitimate part of the data to be analysed by the study.
- The second pass would interrogate the researchers' notes/memos themselves in order to identify emergent recurring theme codes, as differentiated from isolated topics.
- The third pass would revisit the participants' contributions, utilising the code list developed in the previous step to assign particular meaning to text passages. The theme codes would be modified where necessary during this stage, with addition, extension and deletion of codes being permissible.
- Abstraction would be undertaken in order to explain the appearance of various theme codes, which could potentially span both discussion group boundaries and, ultimately the theme codes themselves.

The application of the process described above to the participants' responses resulted in the hierarchies of theme codes shown in Table 2 after the second pass. This was then used to inform the coding of individual participant contributions in the third pass.

TABLE 2. Initial Codes After Review of Notes/Memos

Primary code (by forum title)	***Secondary codes***	***Tertiary codes***
Process Integration	Current levels of integration	
	Factors affecting levels of integration	Procurement Legal framework Trust
Integrated Communications	Opportunities created by integrated communication	
	Threats presented by integrated communication	
	Potential enablers of integrated communication	
Competitive Advantage	Business case for ICT in project environment	
	Return on investment	Long-term Short-term
	Competitive disadvantage	
	Geographical location and dispersal of firms	
	Limited impact of ICT on low level subcontractors	
Leadership	Intra-firm	
	Inter-firm	
	Leadership in the industry	

The application of this coding hierarchy to the data required the development of explanatory annotations for each theme code, recording the researchers' shared understanding of the meaning of the code. By this process it was possible to increase the consistency of each code's application to the text. By way of example -- the code "Integrated communications: opportunities created by integrated communications" was annotated thus; *Technical or descriptive statement of the beneficial application of ICT to particular tasks/processes within a project team setting. Includes technical or business process descriptions. Excludes financial benefits (see ROI).*

The application of the code described above was deemed appropriate by both researchers to the underlined section in following passage from a transcript:

> "From a consultants point of view IT has given lot of opportunities. Our business now can work with projects that can be geographically not very close with low cost. Also IT has cut down of printing costs and record keeping costs. However, the major problem is some times you have some one in the project who is not very IT enthusiastic and this puts a spanner into communication and we need work differently with them. This generally happens due to lack of trust in both the technology and probably people."

Elements of this passage were also assigned the codes "Trust", "Threats presented by integrated communication", and "Current levels of integration".

It is important to note that the researchers' use of the codes breached the boundaries of each focus group, meaning that codes originated in the text of one discussion could, through the process of abstraction appear in the analysis of several others. By this means the data could surface theme codes that might not otherwise have emerged in their own right. By way of example the issue of return on investment, and specifically the period of time over which this should be planned for, were surfaced in the discussion on competitive advantage whilst appearing in the coding of entries in the process integration forum, thereby linking the two discussions. The additional concepts thus surfaced were:

- Capability of the individual firm within a project team
- Power position within the project team
- Fee competitions/documentation to fee
- Technology driven change/rapid rate of change
- Responsibility/liability for information re-used by third parties
- Industry fragmentation as a barrier to knowledge transfer
- Ownership/protection of intellectual property
- Cost/risk transference
- ROI linked to technology lifecycle

Incorporation of the additional concepts into the theme codes resulted in the consolidated code list shown in Table 2, in which it is apparent that there is no longer any trace of the original primary codes (forum topic titles), nor a hierarchy of codes – all theme codes now assumed to have equal stature.

TABLE 3. Consolidated Theme Code List

Client needs	Cost of mistakes	Geographic Technology
ICT agility	ICT Capacity Gap	ICT Firm Size
ICT Investment Returns	ICT strategies	Industry Culture
Industry Standards	Industry Structure	Information Security
Interoperability	Leadership Challenges	Leadership direction
Leadership Role	Legal Status	Level of integration
Minimum Technology	Procurement	Profitability
Relationships	Technological Change	Technology Unfriendly
Trade based ICT	Trust	Unaffordable

The following section details the finalised abstraction of the coded data. This was posted to the Blackboard site, and subsequently obtained the participants' sign-off as an accurate summation of their consensus position.

6. RESULTS

6.1 Competitive Advantage

6.1.1 Business Operations and Client Needs

When considered from the perspective of ICT use in a project environment some firms do not experience any form of competitive advantage through its use as a collaborative communication tool. These firms are typically trade subcontractors who view their competitive advantage as being derived from their trade skills, which

provide their clients with timely, cost competitive and quality services. However they do not discount the benefit arising from the use of ICT to automate their in-house administration, for example inventory control, payroll, invoicing and so on.

The firms operating in project teams that do derive specific competitive advantage from the use of ICT are typically specialist subcontractors and consultants. By using the technology to enable them to work in geographically dispersed teams, to provide fast exchange of communication, and to be resource efficient (particularly in terms of printing and courier costs) these firms are able to provide their clients with a speedier, higher quality service at a lower cost.

The key issue in explaining the different benefits that these two groups experience is the nature of the product exchanged in a business transaction. On the one hand the trade subcontractors predominately deliver a physical artefact based on the completed design of others, whilst on the other hand those who are involved in generating the design of (part of) the building are essentially transacting information. Moreover, generating or modifying a design requires an intense two way exchange of data to ensure design integration: this is in contrast with the trade subcontractors, where the flow of data is predominantly in one direction.

6.1.2 Industry Standards

Competitive advantage in the construction industry is related to scale. The overwhelming majority of firms operating in the sector are small to medium-sized enterprises that generally operate in broadly similar ways using broadly similar technologies. For them the existence of industry-wide standards might not be viewed as being of great assistance in generating competitive advantage. However, when viewed as an industry competing in an international market, the existence of a limited number of shared standards and protocols could be seeing as generating a competitive advantage for the industry when compared to its international competitors.

Such a competitive advantage could well be geographically sensitive, in that locally developed systems might not be globally compatible. Careful consideration should be made before implementing a particular system to ensure its alignment with the business processes of both domestic and international trading partners.

6.1.3 ICT Agility

Some firms from different levels in the industry have achieved competitive advantage through their flexibility in adapting to the technology demands of clients. By agreeing to use the systems proposed by various clients they have developed the ability to work on multiple ICT platforms.

6.1.4 ICT Capability versus Organisational Requirement Gap

In many cases the extent of ICT enabled collaboration is dictated by the technological capacity of the least capable project team member. For ICT to be used to maximum effect in a project team setting it is desirable to first conduct an assessment of the ICT capability profile of potential trading partners. This is of maximum importance in information-intensive clusters of firms.

6.1.5 Return on Investment and Profitability

The return on any ICT investment and its impact on profitability are paramount considerations. If the firms do not see an explicit, tangible benefit (to improvement in their bottom line) they will not invest in ICT. Although a case is made by some firms for long-term commitment resulting in intangible, hard-to-quantify benefits, standard cost-benefit figures are easy to calculate in short term and tend to drive the majority of ICT investment decision-making.

In a competitive project-based industry some firms view staff development as a net cost. This is explained because staff members frequently change employers. Consequently, the cost of training and the hours of lost work during training are seen as loss of productive work time and the skill bases of trained workers in the construction industry in long run may belong to the industry sector and not to particular organisations. This may discourage organisations to spend on training in non-regulated areas, since in the medium- and long-term these skills may not ‘be owned by’ their organisation.

Furthermore many firms in the industry do not see the benefit of investment specifically targeting ICT integration in projects. They perceive they will never be key project participants and therefore lack the positional power or authority to influence changes that would enable them to influence project ICT use to increase their

profitability. Indeed the cost involved in overcoming internal resistance, changing the firm's work culture, and attempting to obtain favourable data exchange protocols with trading partners in various projects are often seen as substantial barriers to high level ICT investment.

6.2 Extent of Technology Integration

6.2.1 Size and Business of the Firm

The nature of the firm's core business has a strong influence on the type and extent of ICT systems that it naturally uses. The lower tiers of trade subcontractors within the industry focus most of their ICT effort on automating their internal administration, making efficiency gains in the process. However those firms at the higher tiers, predominantly engaged in design and construction coordination have to communicate, to a greater or lesser extent, with their project partners using electronic communication channels that are potentially the most efficient. Paradoxically they also have the potential to be the most problematic, thereby negating all of the benefits. It could therefore be advantageous to profile the nature of both the business process and ICT capability of potential trading partners before engaging with them in project teams.

6.2.2 ICT Capability versus Organisational Requirement Gap

In most construction projects the full functionality of the available ICT systems are often not used. This may be explained by either a general lack of capability, or alternatively to fit in with the ICT capability of the least capable member of the project team.

A mismatch in ICT capabilities among a project team can sour working relationships as a result of time delays. Moreover, team members with a low ICT capability may request changes to the communication process e.g. sub contractors without the facilities to print A0 drawings may want the drawings to be printed and sent in hard copy. Therefore where this is not mandated by a contract, service agreements should specify the expected mode of communication when mandating ICT enabled communication.

There is common agreement that PDF formatted documentation suits the data exchange needs of most ICT users. This is in part because PDF documents provide some level of security with their lock/privilege features, rendering modification and copying of shared documentation far more difficult.

6.2.3 Information Security

The security of information is, to a greater or lesser extent, a concern for all firms in the construction industry. Many firms demand security guarantees of electronic communication systems, especially when the communicated or stored information is commercially sensitive or contains valuable intellectual property. The security of drawings and other information in portals managed offshore is an extreme example.

Three important issues recur with regard to information security:

- The availability of technical security features embedded in the ICT tools e.g. data encryption, levels of password protection etc.
- The availability and level of awareness of intellectual property rights, and their preservation during electronic data communication.
- The perception of the users – the extent to which they have trust or faith in the ICT systems they are expected to use.

6.2.4 Return on Investment and Profitability

When it comes to assessing the financial benefit of ICT there are three main schools of thought:

- Short term ROI – ICT is purchased and deployed for a specific project and, as with any other job-specific tool, it is expected to pay for itself within the project for which it was purchased.
- Long-term ROI – ICT investment is a strategic decision that will begin to pay for itself immediately but benefits will only be fully realised after a prolonged period: crucially, these might include difficult-to-quantify benefits such as strategic relationships with trading partners, effectiveness gains, and quality improvements.

- Strategic disadvantage – ICT investments are a necessary evil that prevent the firm being marginalised/losing business as a result of not having ICT capabilities.

6.2.5 ICT Investment Strategies

ICT investments are made with the expectation of increased profitability. However proactive investment in ICT adoption is not widely evident in the industry. Investment in ICT tools made without adequate understanding of their use and benefits are most likely to be a failure. Moreover, as staff turnover is commonly expected in construction firms employers may perceive it to be unproductive to invest in training that is not explicitly critical for operations.

ICT strategies can also be based on business opportunities. If a long term collaborative partnership is expected investments in the specific ICT platform are seen as being more viable and practical.

6.3 Leadership

6.3.1 ICT Agility

Some small firms have developed ICT agility to work in multiple platforms and this is indicative of good leadership of such firms. However, demanding ICT agility by powerful members of a project from the small members at the cost of the small members may not show a good leadership direction by powerful members.

6.3.2 Size of a firm and exercising of influence

Large organisations with large numbers of employees have the opportunity to influence the way the business is done and may demonstrate leadership in the process. This is especially true of government clients who are best positioned to initiate change: by way of example some local government organisations are pioneering electronic tendering methods. However it is unreasonable to expect small firms to take a leadership role since they do not have the power position to initiate changes in the industry.

6.3.3 Industry Structure and Culture

It is believed that trust is an important part for collaborative arrangement. Trust can deal with aspects that are beyond contractual binding. It is also suggested that achieving the culture to work in a collaborative manner is not that easy due to the structure of the industry.

Whilst it may be easy to identify leaders in individual organisations (generally through its formal authority structure) leadership in the wider construction industry is more difficult to conceptualise. In a project organisation the combination of varying contractual arrangements and the evolution of relationships over time means that leadership may not arise from the formal organisational structure of the project. As a consequence ICT leaders may emerge at different stages of a project from different parts of the temporary project organisation.

6.3.4 Leadership Challenges

Champions of successful ICT implementation in individual organisations may have difficulty in projecting this leadership into a temporary project team. This challenge arises within the project context due to relative power positions within the team, rendering the costs of exerting (or attempting to exert) leadership higher than the benefits that it would produce, especially for those from firms located within lower tiers of the project structure.

6.4 Process integration

6.4.1 Geography and Technology

Although there are number of universal ICT protocols and standards, construction work process are very much influenced by geographical region and local culture. Therefore use of standard process developed elsewhere may not be appropriate for deployment in domestic contexts.

6.4.2 Cost of Mistakes

The construction industry has traditionally experienced difficulties in producing complete, well-integrated production documentation. ICT is one of the technologies that ought to assist in improving the integration of

production information. However, currently ICT tools alone are largely unable to deliver such integration, largely as a result of contractual strictures and control of intellectual property.

6.4.3 Industry Structure

Competitive tendering remains the predominant method of procurement in the construction industry. This results in a highly organic and constantly changing network of relationships between industry participants. This means that for much of the industry a high the level of process and ICT integration is rendered unachievable. However, for a select few within the industry that operate with stable supply chains integration opportunities exist, and they are quick to exploit them.

6.4.4 Industry Wide Standards

It is widely felt that adequate levels of industry regulation and standards may help to tame the proliferation of rival ICT systems, and that ongoing developments in interoperability standards are facilitating greater levels of integration.

6.4.5 Procurement Path

Non-traditional procurement methods are more naturally conducive to increased levels of ICT integration. Design & Build projects break down boundaries between the consultants and contractors are less formal, and as a consequence information relating to a project may be exchanged with less restriction.

6.5 Summary

This section has outlined the detailed sub-themes themes recorded in memos as developed during data analysis, relating them to the major thematic groups identified during the first pass data analysis (section 4). Issues of Professional Leadership, Supply chain integration, ICT-mediated procurement strategies, Standardisation, and Value creation/Return-on-investment have been identified as central to the optimisation of ICT usage by individual firms and the temporary project organisations they necessarily have to join in the course of their business.

7. CONCLUSIONS

This final section reviews both the approach to the research and its findings, closing with implications for further research.

Firstly, from a methodological perspective it is instructive to reflect upon the mechanics of the technique used in this research. The Blackboard website creation process, excluding the intellectual input required in creating the initial discussion threads and demographic survey, but including the creation and allocation of pseudonyms and passwords took about 15 hours. There was a time allocation required for distribution of login details to potential participants in response to their requests to be involved in the study, typically less than 10 minutes per participant.

Positive aspects of the process were the absence of any paper communication, postage costs and delays, and the ready-made generation of text data in a format suitable for direct entry into the N-Vivo system. At no point during the study was negative feedback regarding the research/data collection mechanisms used in this study received from any of the participants. Indeed several were complimentary about the experience, valuing the venue to discuss issues in an environment that provided anonymity.

Moving on to the research itself, the primary purpose of this study was to identify those issues concerning industry practitioners working with ICT within project teams, with the intention of informing the CIOB in regard to possible future action in support of the professionals they represent. The outcomes arising from the results in the previous section are now summarised with reference back to the literature where appropriate.

The overarching issue is that of leadership and the role it has to play in driving the creation of ICT-enabled value and competitiveness (Brewer and Gajendran, 2006). These attributes are attainable at many different levels, first and foremost at the level of the individual firm, thereafter across a project team, and potentially for the entire industry. However the achievement of this potential is tempered by the fragmentation inherent in most construction industry contexts (Cox and Townsend, 1996). The challenge of overcoming fragmented and

adversarial project environments is one that is best met through strong, well positioned and well informed leadership. Whether this is provided by peak bodies, expert client organisations, or experienced practitioners is of secondary importance, though coordinated effort is preferable, with client satisfaction through increased value delivery being the ultimate objective. This is the province of the first tier firms in the project supply chain.

The issues associated with first tier ICT integration are the most clearly understood by the industry participants in temporary project organisations (Fischer et al, 1998), since they are ultimately responsible for the level of value delivered by the project (Peansupap and Walker, 2005). However this value is not created by them alone; the lower tiers in the project supply chain have a significant effect upon the success or otherwise of the project (Sarshar and Isikdag, 2004). Since this is usually predicated on the involvement of firms from the lower tiers consideration should be given to mechanisms that increase their level of integration. However this should be tempered by the recognition of the nature of the product being exchanged and its eventual purpose (Hinze and Tracey, 1994). Trade subcontractors are charged with delivering a physical artefact based upon the information generated by others rather than generating information to trade, thus rendering the need to integrate communication with their customer insignificant.

It follows that the contractual relationship is a key determinant in ICT integration. Certain procurement mechanisms are more conducive to integration across a project team than others. This is especially the case where the client organisation reduces its risk by appointing a single point of responsibility, such as in Design & Construct contracts. When considered from the client's perspective this is often determined by their overall procurement strategy, part of which might be the desire to maximise value delivery over the constructed assets life cycle (Walker and Hampson, 2003). This is highlighted where the client has an ongoing interest in optimising the management of its new facility -- ICT can play a pivotal role in doing this.

Fragmentation is a barrier to closer alignment between trading partners, and systems incompatibility is a symptom of this. Organisations wishing to drive higher levels of ICT integration across temporary project organisations must demonstrate their commitment to the development of harmonised standards and documentation conducive to use in ICT-mediated project environments (Betts, 1999). The pursuit of pan-industry interoperability through the development of industry foundation classes (IFCs) under the auspices of the International Alliance for Interoperability (IAI) is a demonstration of commitment. The investment of time and effort should flow into the development of IFC-friendly cost and contract documentation suitable for the local market.

Ultimately, innovation without reward is not really innovation at all, merely novelty for novelty's sake, a commercially irresponsible path to pursue (Cozzarin and Percival, 2006). The use of ICT to develop value throughout the project supply chain in expectation of value generation for the client is thought by some to be a comparatively low-risk strategy. However, whilst such claims are easy to make, they are difficult to quantify (Andressen et al, 2000). Professionals have a role to play in coordinating the collection of data that tracks the influence of ICT upon the efficiency and effectiveness of individual firms and the projects to which they contribute.

Lastly it is appropriate to note an issue that was raised, or remain unresolved by the research. It was tacitly accepted that integration, be it ICT- or business-related, would be understood by each participant in their own context and discussed as such – this proved to be the case. In much the same way the concept of “project success” can be defined from the individual stakeholder’s perspective and their satisfaction judged on their own terms. However, unlike project success, integration by its very definition requires close interaction and alignment with others. During the conduct of the research it became apparent that the panel contained a number of different views on the nature and extent of integration. Whilst it was possible to speculate as to the causes for these differences, it was recognised that they contained the potential for resistance to integration, arising from a lack of shared understanding/expectations of the concept. Further research is needed to clarify the concept.

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