Construction project supply chains and their use of ICT

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ABSTRACT: This paper describes the first stage in a much larger project, funded by the Co-operative Research Centre for Construction Innovation in Australia investigating the application of supply chain concepts in the context of the construction project to develop a model of supply chain interaction that is appropriate for investigating ICT adoption both within a single construction project and across the sector. It models the influences described in previous literature relating to ICT-related supply chain participant performance and further proposes an on-line, modified Delphi methodology to facilitate the asynchronous participation of an international panel of experts in the validation of the model. It concludes by reporting the findings from the study and directions for further research.

1 PROBLEM CONTEXT

Many observers have characterised the construction industry as being fragmented, information intensive and adversarial (e.g. Cox & Townsend, 1998). Ng (2000) attributed many of the industry ills to the quantity and complexity of the shared communication. Faraj (1999) stressed a need for common standards for the exchange of data, suggesting that these would address the questions of information and communication technology (ICT) uptake and integration, leading to shared common business processes (e.g. Yamazaki, 1995). Alshawi and Underwood (1999) predicted project teams working in a shared electronic workspace, outlining multiple benefits possible from such a move. The New South Wales Government (1998) echoed its desirability, highlighting both the complexity of the problem and the potential rewards of solving it. Egan (1998) and Finch (2000) observed that these costly investments had yet to fulfill their potential (Bulmer & Brewer, 2000). Downward cost pressures, increasing specialisation and technical complexity of projects create a demand for an integrated approach to ICT in the industry (Brown et al, 1996). However 'islands of automation' first identified by Kartham (1994) are still common, leading to an unacceptably low level of ICT integration across the professions and throughout the constructed asset's life cycle.

A number of factors are identified that explain the disappointing results from the use of ICT within the CI. These include:

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

Implicit in most of these factors is the recognition that the best intra-organisational ICT deployment will fail to deliver optimal returns if the inter-organisational dimension is suboptimal. This in turn links 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 way in which firms relate to each other, curing many of the in-

dustry's ills as a result. Rivard (2000) sought evidence for it 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 is hard to find, with later commentators suggesting that revolutionary change is not possible in the current climate where business leaders remain sceptical about the full range of potential benefits touted by ICT promoters (Bulmer and Brewer, 2000). Key to this scepticism is the difficulty in ascertaining the nature and extent of the benefits gained from ICT investments, fuelled by the prevalent project-centric focus. The diversity of ICT systems and business processes within the industry, the amount of time, effort and resources that must be devoted to realigning an organisation's business processes with those of the rest of the temporary project organisation (TPO) are all seen as impediments to achieving full benefit.

2 TEMPORARY PROJECT ORGANISATIONS AS SUPPLY CHAINS.

McGeorge and Palmer (2002) identified key themes in Supply Chain Management (SCM) theory thus:

- Improved customer value and reduction of costs
- Strategic management of the chain of relationships
- Synchronisation of information, product and funds flow, and
- Competitiveness, market forces and innovation.

Improvements in these areas have been be linked to the effective use of ICT within a supply chain (SC), (DTI, 2001) making project information cheaper and more accessible in a timely manner. London and Kenley (2001) charted the development of the SC movement across the disciplines of distribution/logistics, production, strategic procurement management and industrial organisation management. They determined that the use of ICT in these areas would increase cost and time certainty (e.g. Latham, 1994, Flemming and Koppelman, 1996), increase value for facility owners and managers (e.g. Fischer, 2000), facilitate lean construction (e.g. Ballard & Howell, 1995, Cox and Townsend, 1998), and assist in the conduct business relationships (Ford, 1997).

The business process is traditionally a social activity conducted at an interpersonal level between human actors, but one that involves other non-human actants. Hakansson and Johanson (1992) postulated that SCs were industrial networks comprised of three elements, namely actors, activities and resources. They argued that each of these elements functioned as a network in its own right but that the outcome of their interaction was visible to an observer as more or less cohesive action. The network was scalable, and could equally be taken as a group of actors within a firm, an entire firm or an agglomeration of firms sharing a mutual interdependence such as a TPO. Lambert and Cooper (2000) presented a root and branch network for SCM that used three dimensions to describe the SC, namely horizontal structure - the number of tiers across the SC, vertical structure - the number of suppliers or customers within a tier, and horizontal position - the position of the focus company, relative to the poles of the SC. Their model also classified the nature of the Business Process Links between the various network actors.

There are synergies between these two SCM models. Both identify roles for human participants, activities/processes and materiel/resources. Both have been developed from the purchasing/logistics and marketing/TQM perspectives. Most importantly both regard the network as the most appropriate structure for modeling the SC. However, neither is specifically tailored to the CI or the TPO as a supply chain in its own right. A third model has been constructed (see figure 1) that places the project, rather than any single actor, at the heart of the TPO SC. This position is justified because:

- Industrial network theory allows for the delineation of a network to occur at any point from the individual upwards. Whilst it is accepted that the entire construction industry can be thought of as one large SC (e.g. AEGIS, 1999), it is held that the performance of TPOs can best be investigated by the use of a model that is defined by a permeable boundary at the project level.
- Such a model utilises the network perspective of Hakansson and Johanson (1992), and accommodates the focal company perspective of Lambert and Cooper (2000). Further, it places the project at the heart of the network (Jennings and Kenley, 1996, cited in Chen, 2000), a position that the authors feel is justified when it is considered that it is the project's existence that triggers network formation.

This model accords with a fully ICT-mediated supply chain, where a project web site or an object model resides at the heart of all project communication and information flows.

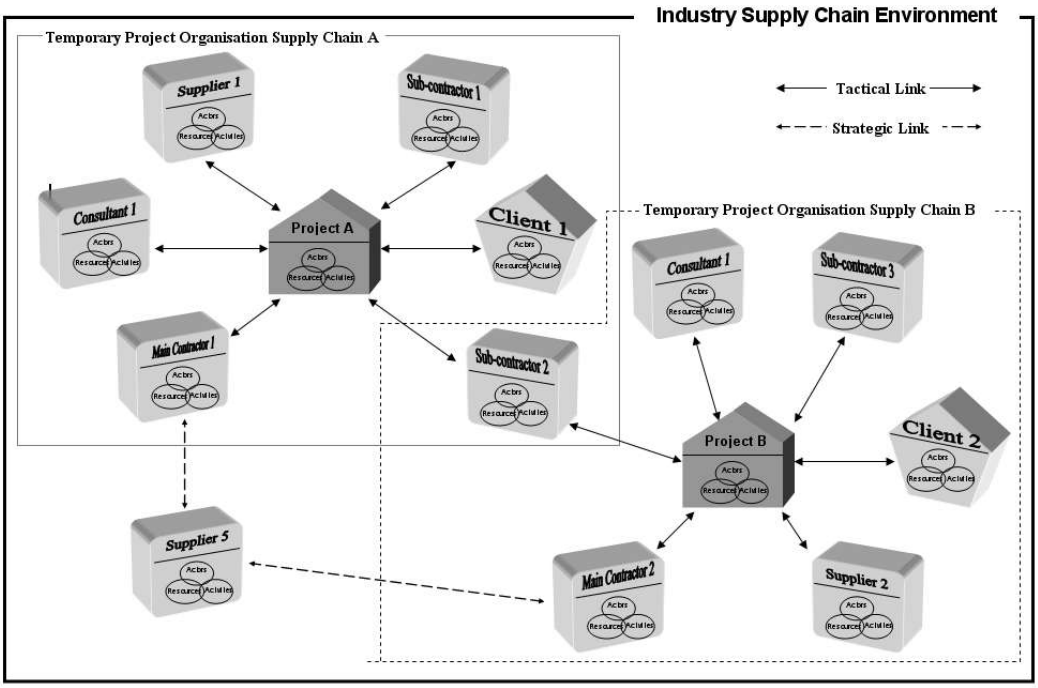

Figure 1. Project-centric supply network model

3 THE INFLUENCE OF ICT ON FIRMS IN A TPO SC

In order to explain why the CI persistently displays "islands of adoption" rather than the more homogeneous ICT integration found in other industries it is first necessary to identify the range of influences that have the potential to affect ICT uptake and integration by individual firms. To this end an exhaustive literature review was conducted during 2002, the results of which were subjected to meta-analysis. This identified influences that included:

- Management style of the ICT adopter;
- Technological considerations including ICT capability, causal conditions for implementation, shared protocols and perceived benefits;
- Resource management within the supply chain including, logistics, purchasing, implementation issues and attitude to strategic relationships;
- Supply chain performance including, customer satisfaction, supply time lags, productivity (perceived), ROI, relative technological competitiveness, innovation, and security monitoring and auditing;
- Power relationships including, ability to dictate SC protocols, ability to influence SC ICT, and threat to future business opportunities;
- Competitive position including, formation and maintenance of strategic relationships, and competitive advantage;
- Communication channels, both intra and inter organisational;
- Business attitude, be it proactive, reactive, or dictated by firm size;
- Monitoring benefits, the effectiveness of the various methods for ascertaining ROI;
- Training, both internal and across the SC; and
- Environmental factors including, experience, nature of suppliers and nature of customers.

From this a model was constructed (figure 2) that acknowledges the, often inter-related, nature of all these influences and noted that they could have either a positive or negative effect; in the parlance of this study they are viewed as either ‘success factors’ or ‘barriers’.

4 DELPHI STUDY: UNDERPINNING THEORY

Traditionally this process has been used for two purposes: exploration or confirmation of a concept(s). Delphi is particularly suited to exploring complex problems that require an element of subjective analysis (Kaynak et al., 1994; Mitchell and McGoldrick, 1994), especially in industries that are undergoing rapid change (Jillson, 1979). According to Linstone and Turoff (2002) specific applications include the following which appropriate to this study;

- Delineating the pros and cons associated with potential policy options
- Developing causal relationships in complex economic or social phenomenon
- Distinguishing and clarifying real and perceived human motivations
- Exposing priorities of personal values, social goals

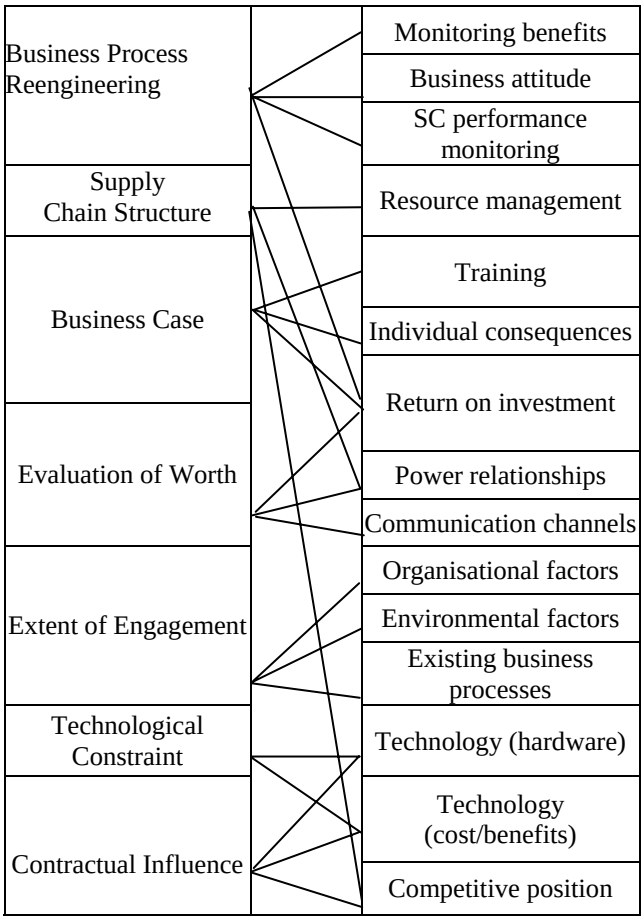

Figure 2. Emergent themes and sub-themes from literature.

The Delphi process is said to have two distinct forms, of which the most common is the conventional paper and pencil version, and the contemporary version referred to as the Delphi conference (Linstone and Turoff, 2002), which is a "real time" version of the conventional Delphi and can use computers to mediate the process (e.g. Bradley and Stewart, 2002).

Whichever method is employed, a Delphi survey is designed to obtain and distill the opinions of experts over a series of rounds, which move from the general to the specific, from diversity to consensus or polarity, requiring justification from those holding dissenting positions (Delbecq et al., 1986). Inter-round feedback should increase participant awareness of the issues and aid both convergence and/or polarity (Rowe et al., 1991). Irrespective of the details of design, there are three aspects to a Delphi study that separate it from any other methodology, namely participant anonymity, researcher-mediated feedback, and statistical group response, ensuring that all individual responses are reflected in the final outcome (Rowe et al, 1991).

5 DELPHI STUDY: IMPLEMENTATION AND ANALYSIS

A key determinant in the design of the study was the geographical dispersal of the invited panelists, who were located on three continents in both the northern and southern hemispheres. Familiarity with the Blackboard teaching platform provided an opportunity to facilitate asynchronous discussion in an online conference, using a threaded discussion forum. Access to a dedicated, password-protected area for participants was created, each of whom was issued with a personal account together with a pseudonym, thus guaranteeing their anonymity. Thirty invitations were issued and thirteen panelists recruited.

Participants were presented with seven statements (see Table 1) and asked to express their opinion and level of agreement/disagreement. The participants made their initial statements and then discussed differences of opinion until polarity or consensus was indicated. At this point a summary was generated to trigger further discussion, this being provided with a time limit. A further summary was generated, and returned for approval. This process concluded with a third round.

The survey data was collected in text form as anonymous postings to a series of themed, threaded discussions. These were collated into a database, with fields that also listed the various attributes of the author and the posting (who, when, thread title). Three research team members analysed the text passages for emerging attributes (keywords, developing sub-themes) in a coding process. The coding process utilised open coding for theme identification and axial coding for theme development. After each round of analysis the team would resolve coding conflicts at a meeting. The meeting outcomes would then form the basis for the summaries.

Three rounds of summary-generation occurred throughout the study. The initial round of summarisation used the seven themed threads, whilst the second consolidated these down to three 'super themes'. These were very general, representing, in the judgment of the researchers, the roots of the discussions. These were then developed using a 'branch and leaf' diagram (figure 2), which illustrated the sub-themes and their origins. This was intended to conclude the study and indeed, received qualified support from the respondents. However there was a common request for the 'leaves' to be given more substance. In response to this feedback the research team produced an augmented explanatory summary for each of the leaves.

Table 1. Round 1 Delphi study content domains and trigger statements

Topic	Statement
Business Case	The decision to engage with an ICT mediated supply chain will, in all likelihood be a tactical decision, driven by the desire to work on a specific construction project, rather than a strategic, organisational decision.
Evaluation of worth	When evaluating the correctness of the decision to engage with an ICT mediated supply chain the return on investment, formation of strategic relationships and the opportunity to obtain repeat work will be of equal importance.
ICT Integration-Business Process Re-engineering	New communication practices and technologies are the most important trigger for Business Process Re-engineering (BPR) within an organisation. On the other hand, the interface between the organisation's older staff and those same technologies are the biggest inhibitor of BPR.
Supply Chain Structure	Supply chains in the construction industry form as networks, where the management of process links between participants from different levels in the project team is often of equal importance to project success (in terms of time, cost and quality). As a consequence, the main supply chain participants must pay equal attention to the management of relationships at all levels within the project.
Contractual Influence	The development of contract law is the main determinant of the type and quality of relationships within a supply chain. ICT has, and will continue to have a marginal influence on the development of these relationships, and will have no appreciable effect upon the nature of future contracts.
Extent of Engagement	Maximum benefits will not be derived from the management of ICT mediated supply chains until all participants, including suppliers and sub-contractors engage electronically.
Technological Constraint	Much of the lack of enthusiasm to engage with ICT mediated supply chains hinges on the lack of standards and protocols for communication.

6 RESULTS

The following sections describe the findings for each "leaf" in figure 3. They were derived from the final round of Delphi contributions accepted by the panellists as a true representation of their final position, by consolidation of individual coding undertaken by the research team. A subsequent comparison was conducted by the research team to establish the extent of correlation with the literature review, thereby identifying the new issues and influences uncovered by the study. These are reported in section 7.

6.1 *HUMAN FACTORS*

The success of Information and Communication Technology (ICT) uptake and integration (both intra- and inter-organisational) depends upon the existence of a receptive and committed culture (be it internal or external). This culture displays the following characteristics:

6.1.1 *Relationships*

Increased willingness to form and maintain relationships with supply chain partners at the interpersonal level – even when they are mediated electronically. However, it is not clear that these relationships will all become stable and long-term, nor is it clear that this would be a desirable outcome.

6.1.2 *Comfort with Technology*

Familiarity with, and acceptance of ICT communication channels at all levels and within all functions of the business, which is enabled by training.

6.1.3 *Training*

Responsive, needs driven and easily accessed; available to all, in a way that is appropriate to user needs.

6.1.4 *Competing Demands/Personal ROI*

Organisational culture should be sensitive to the way in which staff operating in a dynamic, high-pressure project environment might regard the time commitment required to come up to speed with new innovations. It is desirable therefore that there is a demonstrable benefit to engagement at the individual level.

6.2 *BUSINESS PROCESS*

Within an organisation, the commitment to Business Process Re-engineering (BPR) has to predate the introduction of ICT, but for the effect of BPR to be maximal alignment of BP is required across the supply chain of which the firm is a member. They will initially be driven by self-interest. This may manifest itself in decision-making driven variously by Return On Investment (ROI), project goals or strategic objectives. However, in all cases, a top-down willingness to try something new, with a clear out-

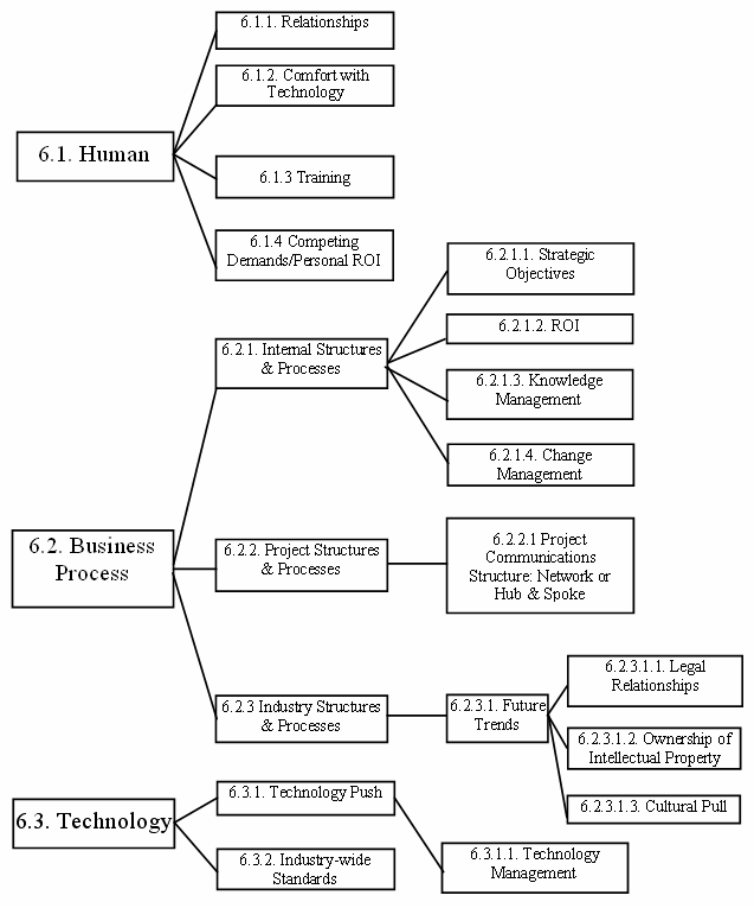

Figure 2. Branch and Leaf diagram

come in mind, is required. These principles may be experienced at three levels:

6.2.1 *Internal Structures & Processes*

These relate to the firm's internal structure and the way in which its formal processes are designed to operate and interact with its trading partners.

Strategic Objectives

These must be formulated at the highest level and be adequately resourced - these might require ICT enablement, or view ICT as a strategic objective. Typically they will involve a degree of strategic alignment of the supply chain

ROI

The concept may need to be re-conceptualised as something more akin to a key performance indicator than an accounting process – though some ICT champions may have difficulty in overcoming the project profit focus of their organisations.

Knowledge Management

Capture of "lessons learned" may be facilitated by the use of ICT, leading to accelerated organisational change.

Change Management

This must be planned and cannot be abandoned to ad-hoc, reactive processes.

6.2.2 *Project Communications Structure*

The relationship between the organisation type (leader or follower) and the way it equips itself (technically and culturally) is clearly linked. Whilst Network-like structures may be conceptually desirable, Hub & Spoke structures are a natural consequence of power-based relationships – successful organisations will adapt to either.

6.2.3 *Industry Structures & Processes*

These relate to the aggregated effects that all of the individual firms' experiences in various TPOs across the construction industry have upon the development of the legal, technological and social networks that regulate industry activities and define industry culture.

Future Trends

The industry is at a time of change, initiated in part, by the advent of ICT technologies. This will result in structural alterations to the industry, which will likely be felt first at the higher end, particularly in relation to:

- *Legal Relationships*
  Should be closer, longer-term, enshrined in contracts that emphasise assertive rather than adversarial relationships; triggered by the need for business process alignment enduring beyond the current project.
- *Ownership of Intellectual Property*
  New business models based upon the equitable creation and distribution of wealth created by ICT use and integration.
- *Cultural Pull*
  The desire to maximise benefit to ICT-enabled industry participants across the industry, resulting in an industry-wide restructure.

6.3 *TECHNOLOGY*

Interoperability between diverse systems is a vital key to widespread ICT adoption. The current 'hub & spoke' supply chain (SC) model, with the hub bearing the majority risk/cost of implementation, will be replaced by a situation where all SC participants carry a portion of the costs as the price that they pay for their increased profitability. Two competing forces are at work in this regard:

6.3.1 *Technology Push*

The pace of technological change is partly driven by ICT developers who wish to gain competitive advantage in their industry.

- *Technology Management*
  Construction industry ICT users must plan and monitor implementation and critically evaluate developments, introducing change to their organisation as a measured response to environmental change/strategic fit rather than as a "knee-jerk" to the latest fad or scare.

6.3.2 *Industry-wide Standards*

This is again driven by the ICT industry, but also by construction users hampered by poor levels of interoperability. Whilst it is the industry 'Holy Grail', innovators and/or early adopters will not wait for its development.

7 DISCUSSION AND CONCLUSIONS

Comparison of the literature and Delphi result models (e.g. figures 1 and 2) shows an overarching commonality of issues. However, the emphasis placed on the various issues indicated by the 'leaves' populating the result-driven model are significant in that they indicate where most effort should be directed for firms considering engagement with an ICT mediated supply chain. Detailed analysis of the panelists' responses also revealed strength of feeling when supporting or refuting the more contentious trigger statements. Most striking amongst these were the defence of older employees as being just as capable of adapting to new technology, and the polar positions adopted by the panelists when considering whether ICT was a strategic, long-term investment, or whether an ICT investment must be capable of recovering full investment costs over a single project in order to be considered a 'success'.

Legal and technological standards tailored to the needs of the ICT mediated project were given broad support, although in both cases there was support for the notion that those at the leading edge of the innovation wave would not wait for their development, preferring to adapt existing mechanisms until the arrival of better alternatives. This did not alter the likelihood that such ICT deployments might engender greater risks for participants and result in suboptimal outcomes.

The most striking finding was the presence of relationship issues across all three major areas defined by the study. At the human level, ICT was recognised both as an enabler (geographically dispersed project teams) and a possible inhibiter (loss of face-to-face contact). From a business process perspective the nature of ICT was seen as a possible trigger to/enabler of strategic business relationship formation and maintenance, but that this was not an inevitable consequence of its use. However, structural/cultural changes within the industry were possible, initiating at the top of the industry and permeating downwards over time. The introduction of technology into a firm was expected to trigger similar changes, especially when phased in as part of a managed process.

This paper has identified the problems associated with participation in ICT mediated SCs in a construction context, describing a model of TPO SC structure that is appropriate for investigating and analysing real cases of ICT uptake and integration across a CI project team. It has identified a range of issues, both positive and negative, that influence the success of uptake and integration in that context, confirming and extending it by reference to an international panel of experts, constructing a complete and contemporary model of influences that be further investigated in order to validate it using surveys or case studies. As an investigation of current thinking on the subject it is believed to be of value to practitioners, ICT developers and policymakers wishing to understand the concerns and attitudes of their trading partners, markets and customers.

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