Project teams and ICT: surfacing the critical success factors.

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ABSTRACT: This paper reports on the second stage in a project, funded by the Co-operative Research Centre for Construction Innovation (CRC-CI) in Australia, investigating the critical success factors for ICT mediated supply chains. It argues that Information and Communication Technology (ICT) adoption in the construction industry has yet to deliver its full potential, and that a need exists to identify and understand the factors that should be addressed to reap this full potential. It describes a national questionnaire survey that was conducted to identify the critical success factors that underpin the integration of ICT in supply chains. It establishes that organisational commitment, organisational attitude to communication, rights and duties, investment drive, guarantee/protection/assurance were all identified as being critical issues to be addressed by firms wishing to successfully adopt and integrate ICT into their supply chain operations. The paper concludes with recommendations for further research.

1 INTRODUCTION

The construction industry is often criticised for the lack of initiatives to improve practices and productivity. One major criticism is the fragmented nature of the industry (Cox & Ireland, 2002; Latham, 1994; Egan, 1998), which leads to inefficient communication among project teams. Among the solutions intended to address this issue, the uptake of Information and Communication Technology (ICT) was widely anticipated to increase the effectiveness of project delivery. However, it has been established that although the uptake of ICT to automate business processes has given productivity gains at an automation level (Egan 1998, Finch 2000; Li et al., 2000; Love et al., 2000), the full potential of ICT to integrate operations along supply chains is not widespread (Bulmer & Brewer,2000).

It is accounted that the dissatisfactory performance of ICT investments are not to be blamed on the uptake of ICT, but rather on the poor integration of ICT into the structure of construction industry processes. The failure to consider the 'temporary project organisation' and 'network relationships' that characterise the construction industry business environment by the focus organisations during implementation of ICT is a likely cause for unsatisfactory performance (Brewer et al 2003).

The model in Figure 1 illustrates the 'integration gap' between the business processes at work in the construction industry and ICT used to facilitate them, which arises if ICT is not mindfully integrated into construction projects and participant organisations. In addition, it introduces the notion that the level of integration intensifies from simple 'office-wide automation' to 'pan-supply chain process integration'.

For effective integration, an industry-wide understanding of generic factors that influence integration should be identified. Since supply chain concepts can be used to address the issue of industry fragmentation and communication, they can therefore provide a frame work to study ICT integration. It follows that high integration between ICT and construction industry business processes, along an idealised supply chain will lead to major performance improvements across the sector.

Little is known of the attitudes at the level of the individual firm as to 'what must be done, what must be attended to' in order for their involvement in ICT mediated supply chains to yield higher business performance and be considered successful in their terms. This paper explores the views and experiences of participants in ICT enabled project supply chains to uncover the factors that are critical for "success" in this context. The objective of the study therefore was to identify those factors that were considered of critical importance to a firm's successful participation in an ICT mediated supply chain.

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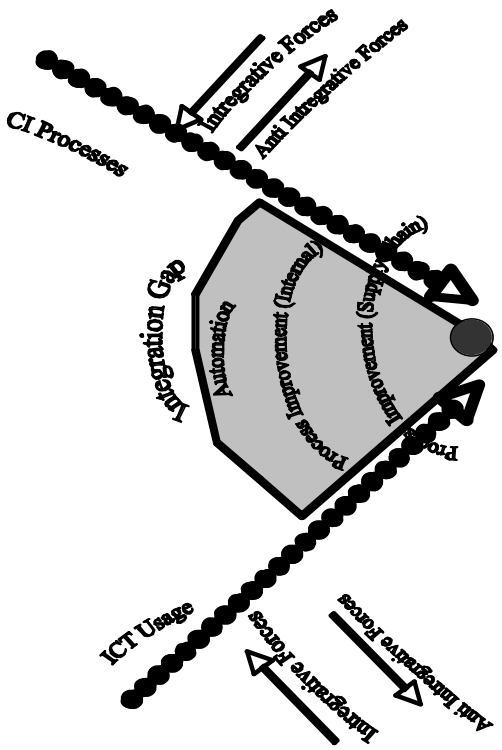

Figure 1 – Project focus to process improvement using ICT and SCM concepts (Modified from Gajendran et al 2003)

The findings revealed a range of five factors, which were identified as being important in achieving success and/or reducing the likelihood of failure in the operation of an ICT mediated supply chain.

2 ICT AND SUPPLY CHAINS

Agreement is yet to be reached on a common definition for supply chain management, however the key theme of supply chains is a series of linked relationships and processes (members, resources, information etc) beyond the individual organisation's boundaries, which add value to the system (Kauffman 2002). Supply chain management is about managing these chain-wide relationships and information in an effective way to achieve greater business efficiency. Within the supply chain, there is a constant flow of information that is vital to the effective functioning of the chain, which strengthens the role of ICT in the supply chain. To achieve this at the level of the project, different parties to the supply chain need to understand the business and information requirements for engagement with it. This process should continue throughout the project life cycle (Hassan et al., 1999) so that the participants will achieve their economic goals. It is evident that the urge to construct ICT mediated supply chains will increase in the near future as a response for organisational survival; therefore it is timely to establish the CSFs and best practice guides for such initiatives. Review of the relevant literature, together with the results from a previously conducted Delphi study of experts generated the candidate success factors (see Table 1) identified as influencing the effectiveness of ICT in supply chain situations.

Table 1: Candidate Success Factors overview

Management style	Participating, supportive and committed Senior management
Technological issues	ICT capacity (hardware & software), ICT compatibility with trading partners, organisations comfort with participants, training of participants.
Attitude to relationships	Trading partner selection methods, adoption of data and, communication structure, communication attitude, education of personnel, information sharing
Business attitude	Proactive continuous improvement (TQM, JIT, VM), Reactive Innovation laggard
Investment performance	Customer satisfaction, Return on Investment (ROI), Relative technology competitiveness
Security	Security monitoring and auditing, Willingness to share information, Intellectual property relights
Power relationships	Dominant dictator of SC ICT, threat to future business opportunities
Competitive position	Formation of strategic partnerships, competitive advantage relative to competitors
Individual consequences	Different role, different job skills, new concerns
Training	Recruit people with appropriate experience. Commitment of the organisation to support training.

Based on Akintoye et al (2000), Vakola & Wilson (2004), Nagi et al (2004), Crook & Kumar (1998), Angeles et al (2001), Goulding & Alshwai (2002), Angeles & Nath, (2000)

3 'CRITICAL SUCCESS FACTORS'

3.1 *CSF as a Concept*

Rockart (1979a pp. 217) defines critical success factors as:

'The limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organisation.'

CSFs as a *concept* is about the few key areas where 'things must go right' for the business to be competitive. Therefore, the identified areas must be managed properly to avoid suboptimal outcomes and the application of the CSF concept should make explicit the areas crucial for organisational success. As success is an elusive concept, the definition of success used in this project was not simply defined in terms of 'bottom-line', return-on-investment, or similar. Nor was it defined purely from a single stakeholder's perspective. Rather it used a holistic perspective and inclusive approach that emphasised that success from one stakeholder's perspective might differ considerably from another's. This sug-

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gests that rigour can only be achieved by using a wider, inter-stakeholder perspective (Bullen and Rockart ,1986).

3.2 *CSF as a methodology*

CSF as a *methodology* originally involved interviews with mangers and senior executives to extract their views (Rockart, 1979b). This was criticised for being overly difficult in application, suffering from a lack of validity when considering the effect of analyst - manager biases and difficulty in identifying the true causality of factors. Moreover, perceived CSFs could differ between organisations, and between managers within individual organisations. Therefore the identification of CSFs for an organisation or industry masts be approached with objectivity when trying to establish "generic" or "collective" success factors (Bullen and Rockart, 1986). This requires a sound research philosophy and theoretical/analytical approach to be adopted when conceptualising, analysing and establishing CSFs. Research methodology should consider the problem in context and suggest a research process, based on logical reasoning.

This research adopts the CSF concept and has taken a collective, multi stakeholder view along the supply chain to establish the CSFs. The research method described below utilised the foregoing to establish the conceptual and operational approaches required to surface the CSF for this project.

4 RESEARCH METHOD

Although this research is set in an Australian construction industry context, the identification of the candidate success factors took a broad perspective. A comprehensive review of the literature, combined with the results from a Delphi study with the international participants (researchers and practitioners) enabled identification of a full range of candidates success criteria for ICT enabled supply chains (Stage 1 of the CRC CI research project). However, establishing the 'generic' Australian context of CSF for ICT mediated supply chains involved obtaining views from a significant number of experienced practitioners to ascertain what they considered to be critical factors for success. Analysis should minimise the degree to which researcher subjectivity affects the findings, therefore quantitative research was considered to be most appropriate. The survey methodology and the statistical techniques deemed to be appropriate are discussed in detail below.

4.1 *Step 1- Establishing the broader critical success factors*

Step 1 was concerned with developing the constructs for the questionnaire. This was greatly influenced by the findings of the Delphi and literature. Each construct in the survey was assigned a logical measurement scale. A '0 to 100' Likert scale was used to capture the rating. This was used as it was felt to be convenient for the respondents to relate to a general 1- 100 scale.

4.2 *Step 2- Method of surveying and sampling*

The questionnaire survey was designed to target experienced industry practitioners. The target groups were the major stakeholders commonly found in project supply chains, namely clients, consultants (architects, quantity surveyors, engineers), head contractors and subcontractors. Establishing the population for the survey was extremely difficult as databases comprising Australia-wide lists of construction organisations were not available. Moreover, the population contained both participants with ICT mediated supply chain experience (who were considered suitable respondents) and participants who had little or no experience with them. However, the questionnaire accommodated both sets of firms by using a self-assessed ICT continuum that organised the ICT technology in a hierarchical manner based on complexity and usage. Only questionnaires from the middle and high end of the continuum were used to identify the CSFs.

The survey options of email, postal and online were evaluated for this research. Email was eliminated due to the ethics consideration - maintaining anonymity while the online survey disregarded due to sampling, bias and data validity concerns. Therefore, postal survey was chosen as the most appropriate method for collecting data. Once the data had been collected, the following tests were identified as being the most appropriate to perform in order to identify the CSFs.

The study utilised a stratified, random sampling concept, which took into account the Australia-wide populations of the sub groups, namely architects, consultants, main contractors and sub contractors. Out of a total of 2000 questionnaires posted 309 responses were received. Out of the 309 responses, 213 were considered relevant to meet the selection criteria for inclusion in the study.

4.3 *Step 3- Data screening*

The data collected was then screened to address issues arising as a result of missing values. Generally, for continuous data, it is frequently found that the procedure used to replace missing values is to add in the mean score of that variable based on all the rest of the valid responses. The rationale for using this approach is that the mean is the best single replacement value, although this method does nevertheless suffer from some disadvantages (Hair *et al*., 1997).

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4.4 *Step 4- One sample t-test*

A one sample t-test was performed on all 21 variables, with a test value of 50 (of a 0-100 scale) being indicative of respondents ambivalence. Values of less than 50 were indicative of non criticality.

4.5 *Step 5- Screening instrument validity*

The next step was to perform a reliability analysis on the survey instrument, that is, to determine that property of the measuring instrument that causes it to give similar results for similar inputs. By way of explanation, coefficient 'alpha' is an estimate of reliability and is not a sufficient measure for unidimensionality or validity. That is, alpha is designed as a measure of internal consistency. Alpha measures range between 0 to 1 and where the result is closer to 1 so the greater the internal consistency.

4.6 *Step 6- Factor Analysis*

Step 6 determines whether a factor categorisation can be derived for CSFs from the survey. Factor analysis is a technique that is often used to create new variables that summarise all the information that might be available in the original variables. Factor analysis might also be used to examine the relationships between the measured variables in a data set. Factor analysis provides an indication of the degree of relationship and the patterns of linkages between variables. The principal component extraction, along with Varimax rotation were employed to assess the factor structure in this study. Factors with high loading should have excellent face (construct) validity. The assessment of factor analysis outputs requires considerable understanding of the data and it is rare for the arithmetic of factor alone to produce entirely clear results (Gorge *et al*. 1997). The analysis was performed on the statements with varimax rotation. The factor loadings that were less than 0.3 were suppressed and factors were identified based on loadings that were greater than 0.4 (Nunnally, 1978).

5 RESULTS AND ANALYSIS

5.1 *Descriptive analysis*

Table 2 gives the profile of the 231 respondents, excluding the missing data. The majority of the organisations have been in business for 10-25 years, while the sample contains organisations that have been in business for up to 90 years. Employee numbers in the sample organisations range from 4 to 2000 and average organisational turnover ranges from $0.45m to $1bn. Table 3 gives the respondent group characteristics. Around 20 % of the respondents have overseas operations while majority of the firms operate in one or two Australian states. The sample profile indicates a good representation of the population in question.

Table 2: Summary of the sample organisation characteristics.

Profile	Frequency	Percentiles			
		25	50	75	99
Years in business	229	10	16	25	89.8
No. of employees	231	4	7	22	2072
Average turnover ($)	215	0.45m	1m	6m	1.0bn
Biggest project ($)	198	1m	3.1m	22.5m	4.01bn

Table 3: Summary of the sample respondent profile.

	Frequency	%
Participants groups		
Client	17	7.4
Principal Contractor	19	8.3
Sub-contractor	88	38.3
Architect	58	25.2
Engineer	19	8.3
Quantity Surveyor	29	12.6
Total	230	100%
Number of States Active in Australia		
1	142	63.1
2	40	17.8
3 or more	49	19.1
Total	225	100%
Overseas Operations		
No	205	88.7
Yes	26	11.3
Total	231	100%

5.2 *One Sample T test*

The one sample t-test performed on the variables with a test value of 50, identified that four of the candidate success factors were not considered critical for ICT mediated supply chains in the Australian context (refer to Table 4 for results). The non-critical factors are:

Q22. Customer demand is the driver for the adoption of new technology.

Q26. An open minded attitude to sharing project information is required.

Q31. The introduction of government regulations to stipulate minimum technology requirements is desirable.

Q32 Stipulation of one industry wide technology standard is desirable

Qs 22, 26, 32 produced ambivalent responses and Q 31 indicated a non-critical response. Therefore

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these four variables were disregarded in the further analysis.

Table 4- One sample t-test results

One-Sample Test Test Value = 50			
	t	Significance (2-tailed)	Mean Difference
(Q19)	35.332	0	27.8
(Q20)	6.29	0	8.84
(Q21)	9.716	0	11.61
(Q22)	1.196	0.233	1.72
(Q23)	5.014	0	6.56
(Q24)	9.767	0	13.55
(Q25)	21.725	0	23.63
(Q26)	0.159	0.874	0.23
(Q27)	6.117	0	8.41
(Q28)	42.256	0	30.38
(Q29)	36.229	0	27.9
(Q30)	10.779	0	12.55
(Q31)	-3.086	0.002	-5.13
(Q32)	0.748	0.455	1.14
(Q33)	24.307	0	22.77
(Q34)	5.839	0	8.32
(Q35)	16.319	0	15.85
(Q36)	16.664	0	16.98
(Q37)	25.967	0	24.23
(Q38)	5.509	0	7.38
(Q39)	15.353	0	17.34

5.3 *Reliability of the scale*

The reliability of the original scale with 21 items was 0.7325, and its reliability was not improved by deleting any further items. However, due to the elimination of 4 items (non CSFs) from the original scale, reliability analysis was performed again on the 17 remaining items with the result that reliability marginally improved to 0.7374 and again would not improve by deleting any more items.

5.4 *Factor Analysis*

In this study factor analysis was first applied to determine the underlying structure of the factors, and to create a meaningful factor framework to provide structure for the 17 critical variables.

The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) was performed to check for the sampling validity, and Bartlett's Test of Sphericity was used for testing the presence of correlation. The KMO was 0.739 (>0.05 minimum acceptance value) and the Bartlett's test of sphericity for was found to be 633.174 with significance beyond the 0.000 level. These results satisfied the criteria for performing factor analysis on the identified statements.

The factor rotation solution identified 5 factors with eigenvalues of above 1, and the proportion of the variance explained 53.37. Table 5 summarises the results of the factor analysis. Refer to Table 7 for detailed candidate success factor statements.

Table 5: Factor analysis results

Rotated Component Matrix					
	Component				
	1	2	3	4	5
(Q28)	**0.732**				
(Q29)	**0.69**				
(Q33)	**0.635**				
(Q19)	**0.606**			-0.319	
(Q30)		**0.708**			
Q27)		**0.576**		0.318	
(Q24)		**0.573**		0.39	
(Q38)		**0.477**	0.332		
(Q36)			**0.708**		
(Q39)			**0.669**		
(Q37)			**0.611**		
(Q34)				**0.719**	
(Q23)				**0.649**	
(Q35)			0.318	**0.402**	
(Q21)					**0.805**
(Q20)		0.471			**0.537**
(Q25)	0.372	0.405			**-0.488**
Extraction Method: Principal Component Analysis.					
Rotation Method: Varimax with Kaiser Normalization.					

Following factors were named from the rotated matrix factor.

Table 6. Critical success factors framework

Factor 1	Organisational commitment
Factor 2	Organisational attitude to communication
Factor 3	Rights and duties
Factor 4	Investment drive
Factor 5	Guarantee/protection/ assurance

6 DISCUSSION

This study has identified the critical success factors for ICT mediated supply chains (table 6) and their sub-dimensions are described in the following sections:

6.1 *Organisational Commitment*

Commitment of the organisation is a crucial prerequisite for its successful uptake of ICT and its subsequent integration with the project supply chains that

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it does business with. In particular the commitment of senior management is important for successful management of both its relationships with trading partners and human resource development through training. Also the commitment of the organisation's employees is essential for the success of new technology initiatives. Finally, ICT driven project communications require a culture of transparency/trust during information transactions with trading partners.

Table 7. CSF statements for ICT mediated supply chains

Statements
19. Senior management commitment is necessary for strategic relationships.
20. ICT adoption across a project team is usually imposed by a powerful organisation within the team.
21. Supply chain adoption of ICT must be supported by a 'champion' within the project team
22. Customer demand is the driver for the adoption of new technology.
23. Competitors trigger an organisation's adoption of new technology.
24. The fragmented nature of construction projects hinders the effective operation of ICT.
25. The guarantee of information security is crucial
26. An open minded attitude to sharing project information is required.
27. ICT works best for firms that engage in long-term collaborative relationships (e.g. partnering)
28. The commitment of the organisation's employees is essential for the success of ICT.
29. Successful deployment of ICT requires continuous investment in human resource development and training.
30. Currently there is inadequate provision for usage of ICT in the standard conditions of contracts
31. The introduction of government regulations to stipulate minimum technology requirements is desirable.
32. Stipulation of one industry wide technology standard is desirable.
33. Transparency/trust in information transactions is essential for the optimal use of ICT.
34. Organisations commit to new technology investment as a project-based, tactical decision.
35. Organisations commit to investment in ICT as a long-term, strategic decision.
36. Organisations should acknowledge the sensitivity of other team member's information.
37. It is important to identify and respect the intellectual property of project information.
38. It is desirable to avoid multiple online systems led by different participants.
39. The powerful ICT promoter should support technologically weak or small organisations in the project team.

6.2 *Organisational attitude to communication*

It is recognised that the culture of the construction industry negatively impacts on organisations attitude to communicating with trading partners. The fragmented nature of some construction projects is recognised as inhibiting the free flow of information and therefore more collaborative procurement approaches, which foster the development of more open communication channels, need to be encouraged. Therefore, a move from the purely competitive towards the collaborative and long term (e.g. partnering) is desirable. However, this engagement must be supported with proper agreements, tailored to an ICT enabled environment. Moreover, communications need to be based on a single, compatible structure rather than on multiple online systems led by different participants which tend to work negatively in the project environment.

6.3 *Rights and duties of organisations*

Organisations in the supply chain should be aware of their rights and duties, both formal and informal. Organisation in the supply chain should acknowledge that not all information (especially the commercially sensitive information of a trading partner) will be available to project team participants. Clear identification of ownership of the intellectual property of project information is important. Furthermore, for sustainable relationships, champions of ICT adoption across the supply chain (e.g. main contractor) must be prepared to support the weaker and less technologically able organisations (e.g. subcontractor) in order to maximise their own benefit from the technology.

6.4 *Investment drive*

Before embarking on ICT investment any organisation should make a clear investment decision, understanding the real motives and consequences of its decision. It may result in a short-term, project based, tactical decision, such as to invest in a particular type of new technology, the use of which is anticipated to be limited to a single project, in order to win a large contract that calls for its use. The return on investment would need to be recovered at the end of the project in order for it to be considered successful. This contrasts with an organisation taking a strategic decision to integrate ICT into its business processes across the firm, and even into adjacent trading partners. In such, although benefits might be apparent over a short period, the true ROI (which could include non-cost benefits such as effectiveness and performance gains) would require a longer-term perspective, possibly extending over several projects and strategic engagement with multiple project team partners.

6.5 *Guarantee/Protection/Assurance related ICT usage*

When new technology and protocols are introduced into project supply chains, their deployment is best supported by a 'champion' from within that chain,

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whose position and contractual power is such that they can moderate its use. Of particular concern to the rest of the project team, the guarantee of information security is crucial for the success of ICT in a project supply chain situation – this is only likely to be successfully moderated by a powerful team participant. Implicit in the foregoing is the recognition that the most appropriate organisation in the supply chain must exert leadership in terms of ICT protocols for project communication/management.

6.6 *Best practice guides*

This CRC CI project generated four sets of Best Practice Guides, currently in press, which utilise the factors described in sections 6.1 – 6.5. These are targeted at the needs of clients, main contractors, consultants and subcontractors, and include an interactive CD tool used to self-assess the readiness of these organisations to engage in ICT mediated supply chains.

7 CONCLUSIONS

In order to remain competitive in the construction industry, supply chain participants should be ready to face the challenges, be willing to innovate and change. It is believed that this will prove to be the sustainable path for the future. This paper identified the issues that need to be addressed to allow an organisation to venture onto the path successfully, nothing that the critical success factors that underpin the integration ICT in supply chains are, Organisational commitment, Organisational attitude to communication, Rights and duties, Investment drive, Guarantee/protection/assurance. It is noted that the critical success factors framework surfaced by this study will prove all the more persuasive as and when its findings are validated by some method of triangulation

It is highly significant that both implicit and explicit in each of the CSFs identified is the issue of an organisation's relationships with its trading partners, an area that is both complex and multi-dimensional. Whist the survey has identified its importance, it is recognised that it is not the appropriate tool with which to explore such a complex issue, nor illuminate the sub-dimensions that contribute to this complexity.

It is thus held that a series of detailed case studies of ICT mediated project supply chains will allow both the validation of the CSF framework and facilitate exploration of the relationships, both strategic and non-strategic, which exist within them.

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