10 REENGINEERING THE SUPPLY CHAIN USING COLLABORATIVE TECHNOLOGY: OPPORTUNITIES AND BARRIERS TO CHANGE IN THE BUILDING AND CONSTRUCTION INDUSTRY

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Abstract

Inter-organizational collaborative technologies provide potential competitive benefits based on time and cost advantages and value addition, especially when combined with supply chain reengineering. The building and construction industry would appear to be an ideal candidate for such IT-enabled reengineering because operations and project delivery are primarily organized around networks of collaborating organizations. This qualitative study of the Australian building and construction industry, however, finds a very low level of IT adoption. In explaining this phenomenon, we identify industry-level conditions as important factors influencing the low level of IT-based collaboration and suggest industry-level interventions which could stimulate both IT adoption and associated supply chain reengineering.

Keywords: Collaborative technology, supply chain, construction industry, information technology, barriers to adoption, reengineering.

1. Introduction

Inter-organizational collaboration, enabled by information technology (IT), is considered to be a source of competitive advantage for firms which reengineer their supply chain to optimize the benefits from collaboration (Chatfield and Yetton 1998; Johnston and Vitale 1988; Konsynski and McFarlan 1990). Advances in IT now allow firms to exchange information and share databases and business processes, with associated cost, time and value gains. Mutual business advantages to collaborating partners have been demonstrated in arrangements such as that between Wal-Mart and their suppliers (Janah 1998; Stalk, Evans and Schulman 1992). Much current economic and strategic commentary promotes a focus on core capabilities with outsourcing of all other activities (Quinn, Doorley and Paquette 1990). IT enables firms to outsource a range of operations to closely collaborating suppliers without losing control, because the technology makes the partners' businesses transparent to each other (Bensaou 1997; Snow, Miles and Coleman 1992). Even where there are not mutual benefits, power asymmetries have resulted in powerful corporations imposing inter-organizational collaboration through IT (Hart and Saunders 1997). Some proponents of collaboration encourage managers to believe that there is both a technical and strategic imperative driving them to transform their organizations into virtual corporations (Davidow and Malone 1992).

However, both adoption of and gains from IT-enabled collaboration are dependent to some extent upon factors such as the underlying exchange relationship, levels of interdependence, bargaining power and trust between the partners (Bensaou 1997; Choudhury 1997; Hart and Saunders 1997; Kumar and van Dissel 1996). Damsgaard (1999), for example, shows how an electronic market in freight handling in Hong Kong is unlikely to be fully developed because of the unequal distribution of benefits it would entail. More generally, some commentators have noted that game theory explains when collaboration is and is not likely to occur on the basis of the balance of benefits and costs for each party (Loebbecke, van Fenema and Powell 1999).

Most studies of IT-enabled inter-organizational collaboration have focused on specific industries (car industry, aircraft parts), typically characterised by limited types of inter-organizational relationships (powerful buyer, weak pool of suppliers) and using particular technologies (EDI). This paper examines an industry characterized by high levels of inter-organizational contracting, alliances and joint ventures—the building and construction industry—in which one would expect significant synergies from various forms of IT-based collaboration. However, very low levels of adoption of inter-organizational systems are found. The paper seeks to explain why this low level of IT use occurs and what actions may lead the industry to reengineer its supply chain to capture the benefits of IT-based collaboration. The paper identifies industry-level reasons for rationalizing the supply chain through IT and industry and organization-level factors that have militated against more than superficial adoption of collaborative technologies.

The contribution of this paper, therefore, is to demonstrate the importance of industry conditions in influencing levels of collaboration. In particular, it shows, notwithstanding the prevailing political wisdom of nonintervention by governments, that even if there are strategic benefits from collaboration, industry-level interventions such as government industry policy initiatives may sometimes be required to enable a collaborative dynamic. These findings are of particular interest because the Australian building and construction industry, which is the focus of this study, has for years operated to deliver projects through virtual or network organizations without inter-organizational IT.

2. The Australian Building And Construction Industry

The Australian building and construction industry undertakes all forms of building and construction including residential building, commercial building and civil engineering comprising houses, high-rises, offices, shopping centers, industrial plant and infrastructure. It accounts for 6.7% of GDP. This level of economic activity is achieved by some 150,000 companies employing 597,000 people. Average company size is only four people, with the majority being one person firms. The industry consists of several quite distinct sectors. These include the consultants principally involved in design work, such as architects, consulting engineers and quantity surveyors, and the contractors, comprising principal contractors who undertake actual building and construction, and specialist contractors (formerly referred to as subcontractors), who offer specialist building services such as concrete pouring, air conditioning provision and tunnel boring.

The industry structure is often described as "fragmented." Projects are typically delivered through a supply chain consisting of the consultants and contractors, coordinated sometimes by the principal contractor, sometimes by the architect, sometimes by the client, and sometimes by a combination of these. Each new project typically assembles a different set of consultants and contractors, often reflecting the developer's preferences rather than those of the consultants and contractors. Relationships among the different players are punctuated; they last for the period of a contract and may not be renewed for several years. There is understanding of each others' strengths and weaknesses but little or no trust. There is currently a perception among industry leaders that the supply chain is inefficient and requires reengineering.

Not only is the industry fragmented in terms of its different sectors, it is also highly localized. This is largely because of the location-sensitive nature of planning approval processes, although other factors such as geography and labor issues may also be relevant. The general trend to globalization has been slow to assert itself in this industry: a few globally known civil engineers do business in Australia; one major principal contractor, Concrete Constructions, is German-owned; a small minority of larger Australian companies have operations in Asia.

The industry has in the past suffered from a reputation for poor performance in relation to project delivery but the performance of the larger companies has improved significantly over the last 15 to 20 years. One of the causes of earlier problems with performance was poor industrial relations, but this has changed dramatically. Today, the industry is experiencing an Olympics-fueled boom. Despite high demand, the industry continues to be highly competitive with many companies experiencing very low margins. It is agreed throughout the industry that business is cost-driven. The emphasis on cost comes from the customer, often property developers whose principal interest is their margin in on-selling a project. Issues such as building performance and maintenance profile over its lifetime are relatively unimportant to the immediate customer and so are often sacrificed to cost.

One outcome of the industry's fragmentation and low margins is a continuing power struggle between the different sectors. This is most visible between architects and principal contractors. Architects are keen to regain control of the building process while principal contractors increasingly seek to undertake "design and construct" work. More generally, each sector is aware that if it could break into other sectors, not only could it appropriate their profits, but it could also streamline coordination between their activities. This situation is complicated by coopetition (Loebbecke, van Fenema and Powell 1999), that is firms may compete for a contract and then cooperate as contractor-subcontractor on that contract, and they may also cooperate as business partners in subsequent tenders.

3. Study Method

The objective of this study was to understand how IT can provide long-term benefits to the building and construction industry through inter-organizational collaboration across the supply chain. As there have been relatively few studies of the strategic application of IT in building and construction (Ahmad, Russell and Abou-Zeid 1995; Brandon, Betts and Wamelink 1998), with the exception of technical research relating to computer-assisted architecture, we saw ourselves as undertaking exploratory research and therefore adopted a qualitative approach.

The fieldwork was undertaken by the authors between June and August 1998. In order to achieve broad coverage, we segmented the industry into sectors (architects, quantity surveyors, engineering consultants, contractors [principal and specialist] and building manufacturers and suppliers). We divided companies by size from large to small-to-medium-sized enterprises (SMEs). We selected firms to study on the basis of a matrix of sectors and sizes, and added some major clients. In total, we interviewed one or more senior managers from 30 organizations using a semi-structured interview format based on an initial protocol of common questions.

The interviews were conducted primarily in firms with a presence in the Sydney region, although many also operated in other Australian states. We visited companies located in outback Australia, and conducted telephone interviews with companies as far afield as Perth. In order to reduce the probability of bias, we interviewed senior managers of acknowledged technology leaders as well as less advanced technology users in all industry sectors. We sought to identify actual and potential business benefits from IT-enabled collaboration and barriers to, or inhibitors of, adoption. Most interviews were conducted by at least two members of the study team. All were recorded, written up within 24 hours, and copied to the other members of the team.

Both during the fieldwork and on its completion, we sought to identify variant forms of supply chain and the different ways companies could add value within them. We listed the barriers to IT-enabled collaboration, then separated them into those that could be addressed at the industry level and those that could not. This formed the basis for devising recommendations for policy and practical steps to encourage successful reengineering of the supply chain.

4. Findings

4.1 The Supply Chain Opportunity

All the leading industry thinkers whom we interviewed had identified the need for change. They identified four underlying reasons:

1. Threat of global competition. In an era of globalization, any firm anywhere in the world that can leverage IT to enable it to compete differently will be a threat to all others in the industry.
2. Underutilization of IT. Building and construction is an information intensive industry that has as yet used IT for little more than personal productivity benefits.
3. Supply-chain inefficiency. It is recognized that the current supply chain is characterized by concentration of specialist activity within a specific stage, but with almost no sharing across organizations across stages. There is little understanding of prior decisions and little preparedness to combine different knowledge. For example, architects often ignore the issue of how "buildable" their designs are for a contractor and, equally, contractors may compromise a design feature during building because they do not understand the design rationale.
4. Availability of enabling technology. Various software technologies are available to permit more intensive cross-sectoral collaboration.

We found that the source of the greatest potential for transforming the industry, beyond another round of driving down costs, lies in reengineering the supply chain to deliver increased value for the client. There are three levels of potential benefit from cross-sectoral collaboration:

Level 1 IT can be, and typically is, used to improve the efficiency, speed and quality of communication across sectors, thereby reducing cycle times and making a small gain in quality for the whole supply chain.

Level 2 IT can be, but typically is not as yet, used to facilitate the creation of a transformed supply chain. By taking a different approach to cross-sectoral relationships, for example by encouraging greater concurrence between tasks conducted by firms in different sectors through greater sharing of information, it may be possible to achieve substantial savings in time and money for the client.

Level 3 In a supply chain characterized by the sharing of information and knowledge, the potential exists to increase the total value to the ultimate client (the developer/operator of the building or plant) by improving performance on multiple dimensions. For example, if architects, engineers, contractors and clients use appropriately rich communication channels to share information when a design is first being conceived, it will be possible to design and build more efficiently, with less difficulty, and with far greater benefit to the customer. New kinds of solution developed collaboratively would potentially be safe, aesthetic, easy to build, provide better return on the asset, and perform better for the client. For example, the Canadian architect, Frank Gehry, when he built the Guggenheim Museum in Bilbao, was able to create a totally innovative, landmark building because his design process was tightly linked through IT to his suppliers. This meant that he was able to ensure the feasibility of his design as he developed it.

4.2 IT Use

We found widespread agreement throughout the industry that IT is necessary and valuable. This industry view is based on the gains firms have made through automation, and on the perception that "ours is an information intensive industry." Typically, firms in each industry sector have adopted IT systems and tools which directly assist in the performance of their specialist tasks. This has allowed them to automate a number of time-consuming and error-prone activities and gain Level 1 benefits in cycle-time, productivity and accuracy. For example, the use of CAD for drafting has resulted in firms in all sectors gaining these benefits when changes to drawings are required. This usage reflects the automation phase of IT adoption. Its benefits have been achieved with little organizational change.

So far, the inter-organizational application of IT in the building and construction industry has delivered only Level 1 benefits. It has been confined to the automation of communications. Larger contractors typically use PCs to relay progress information from sites to the head office, and occasionally for some intra-firm knowledge sharing. Inter-firm e-mail partially replaces ordinary mail, courier, telephone and fax, and it is common for CAD files to be e-mailed to and from consultants. One architecture firm gave some consultants read-only privileges to access its CAD files, but this is rare. Electronic Funds Transfer (EFT) automates payments among contractors. These innovations have helped reduce cycle time and are now regarded as a competitive necessity.

Some firms we interviewed had begun to "informate" (Zuboff 1988). Further, in a few of the firms studied, the use of IT had begun to transform the way they do business. For example, the architectural firm of Flower and Samios chose to integrate the architectural design and documentation processes, thereby eliminating the need for draftsmen (Yetton, Johnston and Craig 1994). That firm also discovered that it can add greater value for its clients by providing them with a wider range of services based on the new core competencies it has developed. Companies like this have succeeded in staying ahead of their competitors not merely by automating but by changing their organization as well. Their strategic advantage has been their preparedness and ability to continually innovate, and to manage the change necessary to gain substantial business benefits.

We encountered a very few examples of initiatives toward achieving Level 2 benefits. One major principal contractor, Civil and Civic, had established a project-specific Web site on which all specialist contractors would record progress and other relevant information. The industry's largest client, the New South Wales Department of Public Works and Services (DPWS), had started to require that their contractors employ project-centered databases on contracts over a certain size.

4.3 Barriers to IT Use

By comparison with other industries such as retail and financial services, building and construction has been slow to adopt IT and slow to exploit it to its maximum. Reasons for non-adoption of IT include:

- Firms are very cautious in relation to technology risk and the risks associated with organizational change.

- Industry profit margins are generally so tight that firms, especially smaller ones, do not feel able to invest in change.

Reasons for slow or limited adoption include:

- The industry's emphasis on cost reduction means that it has little interest in benefits beyond automation.
- The benefits of automation for individual firms have been substantial, and for many may have seemed sufficient.
- Many firms believe that IT is a one-off investment.
- Fear of over-investment was widespread with several interviewees telling the researchers stories of companies actually or nearly going bankrupt as a result of spending too much on IT.

Unfortunately, reluctance to adopt new technology has resulted in some non-adopters, particularly architects, to go out of business. Those firms that have led in automation have gained business benefits such as greater volume of business and undiminished profit margins for a short period while their competitors have caught up. However, in the case of automation, it is so easy to imitate competitors' successes that over time costs have been reduced across the board and IT-based automation has become a competitive necessity but not a sustainable advantage.

In addition to those more general inhibitors of IT use, this study identified a number of inhibitors specific to IT-enabled collaboration. These included:

- Lack of vision. Few companies or senior executives have an overarching vision for the industry. Few are aware of the opportunities afforded by IT-enabled collaboration. The current Olympics-based boom encourages a view that the industry is doing well enough not to need to explore new, risky opportunities.
- Level of risk. Technology leaders saw themselves as potentially disadvantaged by having to bear costs associated with collaborating with less mature users of IT.
- Lack of a business model. Unlike auto manufacturing or retail-supplier relationships, there is no known example of how such a collaboration can be conducted satisfactorily in this industry. The industry does not have a basis for successful collaboration. Its culture is adversarial with a consequent lack of trust among firms. Given the struggle of industry players to enter business in other parts of the supply chain, it is not easy for potential collaborative partners across sectors to see how they might share the benefits of collaboration without risking their competitive advantage by exposing their operations to one or more partners. Many were concerned that collaboration would result in reduced margins as transparency would permit clients to more easily validate costings against actual work, and likewise contractors could better scrutinize subcontractors. Others were concerned that if the benefits do not accrue to competitors, they will ultimately all flow through to the customer. The risk-takers will not harvest the reward.
- Lack of capability. Automation through personal productivity technologies can be achieved without sophisticated IT management competencies. Inter-firm IT-enabled collaboration requires not only the ability to secure technology agreements with other firms, it also requires a level of managerial sophistication that is rare to find in this industry if knowledge sharing is to be achieved where previously there has been mistrust.
- Resistance to change. Resistance to the reengineering/organizational change necessary to gain a pay-off from the technology was commonly cited. Some

mentioned client resistance, clients being seen as highly conservative and uninterested in what IT might offer them. Technologists mentioned that senior partner and senior manager resistance was often based on lack of understanding of potential opportunities.

- Lack of a technology standard. While there are software technologies available to enable knowledge sharing and collaboration, none is currently regarded as standard.

In summary, up until now the industry has taken the easy gains from automation but these have typically not resulted in sustained advantage, merely survival. A few firms have gained more enduring competitive advantage through continual technological and organizational innovation. Even they have rarely innovated outside the boundaries of their own organization. Consequently, the industry's biggest opportunity, the reengineering of the supply chain, is currently a largely unexplored challenge.

5. Discussion

The current competitive dynamic in the industry is that firms adopt IT as a necessity to drive down costs. Those who lag experience reduced margins or go out of business. The gap between the potential of the technology and its current use, even by industry leaders, indicates that these competitive dynamics will continue for the foreseeable future. However, unless the market grows significantly, the long run effect will be a decline in the number of firms in the industry and in the number of people employed, with the risk that (1) the industry will have limited opportunity to internationalize because current firm-specific cost reduction does not confer sufficient advantage for expansion into overseas markets and (2) overseas firms might successfully enter the Australian market.

The industry has the opportunity to mitigate some of these effects if it can be successful in learning how to reconfigure the supply chain and transform its organizations so as to deliver new, improved and qualitatively different service. In the remainder of this section, we discuss the two most likely organizational forms by which a new supply chain might be realised. We then make some recommendations for governmental or industry-level initiatives to help remove some of the barriers and kick-start the search for a reengineered supply chain.

5.1 Organizational Implications

Under the existing industry structure, the most obvious model for achieving a reengineered supply chain is a strategic alliance among several firms, each in a different sector, who would collaborate to develop integrated IT-enabled inter-organizational processes for their mutual benefit. The benefit would derive from their being able to better conduct business among themselves and by being able to compete more successfully for a larger range of projects.

The advantage of the strategic alliance model is that the benefits of specialization are fully retained. All parties retain economic incentives to innovate. There is flexibility to partner with firms other than those in the strategic alliance. The disadvantage is that the industry lacks a business model. This lack is particularly important because of the scarcity of trust in the industry, and the perceived levels of risk. In view of the power struggle among the consultants and contractors, it is even difficult to see just two players agreeing to share information and knowledge at sufficient depth to gain substantial benefits. Client preferences for varied mixes of consultants and contractors will militate against the creation of stable alliances. Moreover, because of the punctuated nature of industry relationships, there would be no guarantee that two collaborative partners could immediately build on an initial, experimental collaboration. The lack of a common technology platform or inter-operability standard will militate against experimenting with alliances.

A more likely scenario involves the creation of a vertically integrated "design and construct" business. The firm that vertically integrates will be able to explore different configurations of the supply chain because it has managerial control of multiple specialisms. It will, therefore, be able to explore and develop ways of integrating knowledge from different sectors. For example, it will be easier to ensure that construction knowledge is integrated into designs. While IT provides the communication technology to achieve such coordination, the firm will still need to evolve processes by which multiple sets of expertise are effectively pooled.

The advantage of the vertically integrated organization is that multiple industry specialisms are brought under the control of a single business vision. There is less reason for the specialists to compete and more reason to collaborate. It is flexible in its scope in that it is not necessary to attempt to integrate all parts of the supply chain. It is flexible to establish in that it is possible to integrate parts of the supply chain incrementally. Once established, it is likely to be stable and durable, permitting the organization to exploit the potential of cross-sectoral IT. The disadvantage of this form of organization is that it risks individual specialisms losing their focus, and hence their leadership in a particular area of expertise, particularly if the dominant form of management becomes process-based rather than functionally-based. This form of organization requires active management to oversee the introduction of new business processes and new management processes. It needs management to break down deeply ingrained prejudices and rivalries among staff from the different parts of the industry. It may encounter resistance from clients who are accustomed to being able to specify which architects, which consultants and which contractors are employed.

5.2 Recommendations for Government Supported Industry-level Action

A new industry supply chain will emerge from the commercial decisions of one or more firms. The task for government and industry bodies is to dismantle some of the barriers to IT use and to help enable technology-based collaboration.

The most basic requirement for action is the need to build awareness of the value of IT and to enhance and diffuse IT skills throughout the industry. Awareness can be built through a campaign to communicate the benefits of IT. For the purposes of preparing the ground for collaborative technology, it is important to emphasise this link between the competitive benefits of IT and organizational change.

This could be partly achieved by the government and industry sponsoring research to develop a body of case studies. In view of the hierarchy of subcontracting in the industry, in order to reengineer the supply chain it will be necessary to build the IT skill base of SMEs which currently make little or no use of the technology.

Therefore, government support for a program of short courses which provides both the business motivation for SMEs to invest in IT and the skills to use it is recommended. These courses could be run through a range of government sector technical and educational institutions with strong involvement from respected industry figures. A third initiative government and industry could take would be to develop and support a bank of information on industry best practice in relation to construction industry use of IT.

In terms of developing the opportunity for cross-sectoral collaboration, the industry needs to know about whatever business models have been adopted internationally and what impact they have had on industry structure and supply chain processes. Research leading to a published report would help build awareness of the opportunity across the industry as a whole.

Governments can also help develop the cross-sectoral opportunity through their role as major customers. By developing appropriate tender guidelines and contract management procedures, federal and state governments can specify varying degrees of collaboration as a contract requirement. The New South Wales Department of Public Works and Services (NSW DPWS) introduced such a requirement in 1998.

A third area for industry-level intervention is in developing a more value-added focus with attention to enhancing performance throughout the lifetime a building or facility. If a reengineered supply chain is going to deliver a sustainable advantage to firms, they will have to extend their thinking beyond cost and cycle-time reduction. The opportunity afforded by collaborative technology is for consultants and contractors to help add value for developers, occupants, operators and property managers by making buildings more usable, more appropriate to the needs of occupants, more flexible among uses, more manageable and more maintainable. While the top contractors have already started to adopt such a perspective, industry and government can accelerate its diffusion and acceptance by establishing industry awards for IT-based innovation and by supporting industry forums to explore collaborative value-adding strategies.

Finally, while collaborative technologies are already available and in use in isolated cases, government and industry should support efforts to establish an acceptable standard for collaborative IT in building and construction. Two initiatives stand out as worth supporting. First is the establishment of project-centered shared databases through which all participants in the supply chain can provide and access information about project progress. This is what NSW DPWS is promoting for projects where it is the client. Second is support for initiatives to achieve inter-operability among IT platforms. Industry technology leaders are currently involved in international standards bodies and they should be financially supported and encouraged to expedite their work.

6. Conclusions

The Australian building and construction industry has an opportunity to increase its competitiveness through reengineering the supply chain to increase information and knowledge sharing and collaboration. This has the potential to cut costs, reduce cycle time and add new value. However, the adoption of appropriate IT is a prerequisite and, as this study shows, a number of factors inhibit such adoption. This finding is made all the more pertinent by the fact that this particular industry has a long history of bringing a number of firms together into a virtual organization for the duration of a project. So, despite concerns about the potential threat of an international firm devising a business model for collaboration down the supply chain and entering the Australian market, and despite awareness that for the Australian industry to be the first mover would give it the opportunity to achieve a powerful position in overseas markets, it is doubtful that market forces alone will result in rapid redesign of the supply chain.

In order to reduce the risk of the industry being overtaken by foreign competition, initiatives are required at both the industry and governmental levels, although these can only help remove barriers: they cannot mandate new inter-organizational processes except insofar as government in its role as a powerful client can impose specific requirements in its contracts. Even then, while such requirements may impose some information sharing and require the adoption of some common technology, strategic alliances will not be established and significant knowledge will not be shared until individual consultants and contractors have a business model that offers mutual benefit and some protection from risk.

Creating the conditions for an IT-enabled supply chain is an appropriate part of government's general role in industry development. Nevertheless, it creates a dilemma. A reengineered supply chain will involve a degree of industry restructuring including rationalisation and probably consolidation. Some firms will be put out of business. So government will be faced with bearing the political cost of business failures in the interests of maintaining the industry's global competitiveness. In an industry consisting of so many small and vulnerable firms, the political fallout could be serious, so government may need to consider how to soften the landing for the losers in the industry restructure.

More generally, this study has shown that IT-enabled knowledge sharing will not be readily achieved by an industry just because inter-organizational technology is available and there are potential business benefits. The barriers can be substantial and may need to be addressed at the industry level. It is therefore necessary to understand more than the balance of benefits and costs for individual firms; it is necessary to understand how existing industry factors affect the likelihood of adoption. In particular, in an industry structure where no group of players is so powerful that it can impose knowledge sharing and collect the bulk of the benefits itself, market forces alone are unlikely to be sufficiently compelling for industry players to choose collaboration.

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