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An industrial organization economic supply chain approach for the construction industry: a review

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Understanding industries in terms of the concepts of chains, clusters and networks is becoming increasingly important in economies around the world. Supply chain management for an individual organization is an emerging field of research in the construction management discipline, but less attention has been devoted to investigating the nature of the construction supply chains and their industrial organizational economic environment. This selected review of construction and mainstream management supply chain literature is organized around four themes; distribution, production, strategic procurement management and industrial organization economics, and highlights the need to develop an industrial organization economic supply chain framework for construction. The merging of the supply chain concept with the industrial organization model as a methodology for understanding firm conduct and industry structure and performance is an important contribution to both construction supply chain and construction economic theory. Much of the industrial organization supply chain literature has tended to focus upon manufacturing industries, where typically firms are permanent organizations. This raises issues as to the differences between industries founded upon temporary compared with permanent organizations. There is potential for the development of an industrial organization methodology applicable to the project based industry. Ultimately industrial organization research seeks to have direct implications for industry performance and government policies.

Keywords: Supply chain theory, critical review, construction industry, industrial organization economics

Introduction

Traditionally, industry analysis has focused on sectors that include groups of firms with similar characteristics, engaged in similar production processes, producing similar goods or services and occupying similar positions (AEGIS, 1999). According to Marceau (AEGIS, 1999), recent attention has been on chains, clusters and complexes. This represents a shift from the purely mechanistic conceptions of the nature of industrial organization as a market consisting of a collection of establishments producing homogeneous outputs (Scott and Storper, 1986) to a more complex

interconnected and interdependent set of markets and firms.

There has been a lack of theoretical and empirical research within the construction community that considers the fundamental structural, economic and organizational nature of the industry's supply chains. There is also little detailed understanding of their different types, complexity and behaviour. An industrial organizational economics theory would provide a framework which would both challenge and complement the performance and benchmarking of current supply chain research.

This paper charts some of the major movements and models of the supply chain literature over the past two decades, according to four major themes and using

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both mainstream management and construction management literature. The purpose of this critical discussion is to argue the need for a construction supply chain model based upon the industrial organization model.

Background

The subject matter of industrial organization economics is the behaviour of firms in industries. An industrial organization economic framework accepts that there are relationships between the 'structure' of markets, the conduct of firms and the performance of firms. Construction supply chain theory can be strengthened by considerations of industrial organization economics.

The emergence of a wider perspective of industrial organization through such concepts as supply chains, industrial networks and clusters, inter-organizational relationships and strategic alliances is often associated with the aim to improve industry competitiveness and innovation. This is an indication of the growing importance of understanding the underlying nature of industries through the behaviour of firms, their relationships and interdependence between organizations (Grabher, 1993). The research has sought to establish causal relationships between improved efficiency and effectiveness and firm clusters and industrial networks.

The main research focus regarding interfirm relationships between parties in construction is, understandably, at the project level, particularly project management and organizational structures and best practice procurement systems (Walker, 1996; Rowlinson and McDermott, 1999). The underlying theme to much of this project research is that improved relationships and integration of key stakeholders are critical to addressing the perceived ills of an industry that is underperforming, inefficient, unproductive, fragmented and wasteful. Often this research places boundaries around the project environment and does not locate the project team or stakeholders within the economic and business environment and the firm's market or sector.

At the sector level, the input-output methodology has also emerged as a technique for understanding interdependence between whole sectors that supply to the production of a construction project. In this manner firms are aggregated in terms of their contribution to the output. It is possible to trace the effects of a change in demand or change in output of one good or service throughout its interlinked relationships. The most significant proponent of the input-output analysis technique has been Bon (2000). The level of analysis tends to be quite global in nature: for example,

the input and output between the whole agriculture, manufacturing, services and construction sectors.

Both approaches to the analysis of construction supply chains are quite useful. However, there appears to be a gap in our understanding between the highly aggregated and intersector analysis, which groups many disparate firms together, and the inter-organizational project analysis, which ignores the 'business of construction' i.e. each firm's market and competitors. This paper bridges the gap, through the merging of the supply chain metaphor and the industrial organization framework, and in reviewing the supply chain literature it charts some of the major movements.

Charting the supply chain movement

The supply chain concept is part of an eclectic and developing hybridized field. It became an explicit area of research in the mid 1980s and originated largely from the two separate management streams of distribution and production, which merged into the field of logistics (Coyle *et al.*, 1996).

There is much debate in the research community on the confusion regarding interpretations of the supply chain concept (New, 1997; Day, 1998; Hines, 1998). It is not the intention of this paper to favour one definition over another; rather, it is considered useful to chart some of the more significant streams that have influenced definitions and models.

Since it became an identifiable area of research, the supply chain concept has been widened through the influence of other research frameworks, and for this literature review these may be grouped broadly into four themes: 1, distribution; 2, production; 3, strategic procurement management; and 4, industrial organization economics

Also, construction research involving the supply chain concept is a relatively new field, having explicitly emerged in the mid 1990s. Similar to the mainstream management literature, it is evolving with corresponding influences from the theory of production, distribution and strategic procurement. Significantly, there has not been any construction industry research merging the supply chain and industrial organization fields, as found in other industry studies by Nishiguchi (1987), Ellram (1991), Hines (1994), Harland (1996) and Lambert *et al.* (1998).

Figure 1 charts some of the more significant supply chain events, models and definitions against these four influences for the two decades 1980–2000. It is important to understand some of the major pieces in the puzzle, since the streams are interwoven. The chart highlights key interpretations of the construction supply chain concept. The circled portion of the diagram

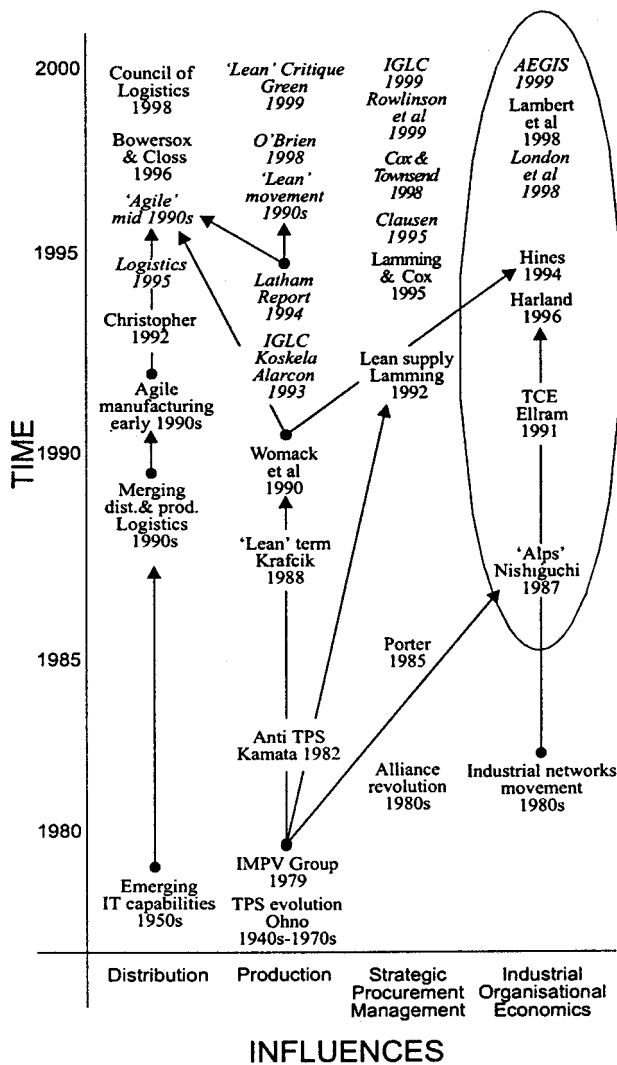


Figure 1 Chart of supply chain streams of research 1980–1999. Notes: italicized text refers to Construction Management research; arrows show research connections.

represents the theoretical origins of the approach to the supply chain concept advocated in this paper.

Distribution

Distribution: mainstream management

Supply chain management (SCM) has often been associated with the management of the physical distribution of products from raw material through manufacturing processes to 'point of sale' for the end product.

Christopher (1992) has been considered one of the pioneers of the logistics and supply chain movement. Borrowing from Porter's value chain concept (1985), he moved the perspective of materials management from a tactical low level task in the organization to a

strategic management concept that supports customer focus and creates competitive advantage.

Such research has emphasized the development of integrated supply chain processes to support the planning and co-ordination of complex supply chain systems for efficient and timely movement and storage of products and/or materials (Bowersox and Closs, 1996). For example, modelling of these systems has involved mapping of time and cost resources and also such concepts as 'time-compression' and 'just-in-time' (Hall, 1983; Wantuck, 1989), relative location of stock and warehouse management (Gold, 1991), transportation analysis and optimization models to improve logistics performance.

Frequently, this approach has relied upon hard systems methodologies to model, forecast and predict the product, information and funds flow. Research methodologies have been characterized by both case studies and simulation models for fast moving consumables, in particular for the retail industry, where technological innovations such as electronic data interchange and vendor managed inventory have harnessed the capabilities of information technology to radically alter the flow of information and to create greater responsiveness to changing customer trends (Stock, 1990; Introna, 1991). This flexibility in the chain, in response to customer demand, has been the cornerstone of the 'agile manufacturing' concept.

Distribution: construction

Construction researchers have applied the SCM philosophy to materials flow, seeking to establish the relationship between site productivity and improved materials management (Akintoye, 1995; O'Brien, 1995; Agapiou *et al.*, 1998; Tommelein and En Yi Li, 1999).

'Agile' construction was taken up by some construction researchers, who argued that 'lean' practices and benchmarking would be an essential ingredient in achieving the target of a real cost reduction of 30% (Graves, 2000). The concepts of agile construction and lean construction are blurred, with some claiming that there is a difference (Barlow, 1998) and others using the concepts interchangeably (Graves, 2000). Lean construction has been taken up with more enthusiasm by the construction research community and is discussed in the next section on production.

Production literature related to the supply chain concept

Production theory: mainstream management

Production theory, particularly 'lean' production, has been another major influence on the supply chain

movement. One of the seminal texts is *The Machine that Changed the World* (Womack *et al.*, 1990), which resulted from an international benchmarking study associated with the International Motor Vehicle Program at MIT. Their study described and analysed the method of production termed lean production, best exemplified by the Toyota Production System, and pioneered by the Japanese executive Ohno. The term 'lean' was actually first coined to describe this system by Krafcik (1988). The epistemology of lean production is contrasted with craft and mass production. Craft production was based upon the notion that manufacturers of complex products required skilled labour within a collaborative environment, supported by a system of apprentice-journeyman-master plus craft guilds, etc. This gave way to mass production whereby unskilled labour could perform tasks designated and instructed by managers. Lean production is often considered as a reaction by the Japanese to mass production.

One of the most important lessons from the lean approach is that it attempts customization of high volume production, to provide customers with exactly what they want at the time they want it. To achieve this end the lean approach is characterized by improving flexibility, reducing waste and improving flow along the supply chain. The flow is improved through management and control of each actor along the supply chain. This relies largely upon some form of total integration from the raw material supplier to the various subcontractors who supply materials or components to the manufacturer.

Merging production and distribution

Prior to the 1960s, production and distribution were fragmented, eventually evolving into two identifiable streams in the early 1980s. In the last decade the research area of integrated logistics management has subsumed both fields (Coyle *et al.*, 1996). There has been much debate about distinguishing the fields of logistics and supply chain management. This distinction was clarified by the Council of Logistics Management, a peak international body of industry and academic representatives (Lambert *et al.*, 1998). It was accepted that supply chain management was more than simply logistics and operational issues and that strategic supply chain management subsumed logistics. The distinction between logistics and supply chain management was made only recently in the construction literature (London *et al.*, 1998). The majority of construction production researchers have tended to focus upon the production and logistics debate when discussing supply chains.

Production approach: construction

In recent years the construction research community has been reconceptualizing the construction industry as a 'manufacturing process', with implications for supply chain research. One approach, the 'generic design and construction process protocol', treats the industry as a production process (Aouad *et al.*, 1999). This research described the industry as a single process map for all phases by adopting the manufacturing model of 'new product development'.

An alternative view of construction production theory (O'Brien, 1995) was concerned with materials flow, and it raised important questions for workflow. O'Brien investigated the production and inventory decisions of multiple firms within the construction supply chain. He indicated that any managerial philosophy, such as 'just-in-time', applied to one site for one project in the construction environment, is problematic due to the temporary nature of project organizations. O'Brien (1998) presented a systems view of the construction production supply chain, identifying that supply chain management offers the potential to optimize supply chain cost performance. Borrowing and modifying production manufacturing capacity cost models, he investigated 18 firms to identify how capacity constraints of subcontractors and suppliers affect the costs associated with construction project schedule and scope changes. The work forms a foundation on which to build models for supply chain performance.

Lean construction

The lean construction movement has, from 1993, led much discussion on supply chains through the International Group for Lean Construction annual conferences. Lean construction evolved from lean production, a developing field that is centred primarily upon a production philosophy for construction. In so doing, key protagonists have explored workflow and conversion processes, (Koskela, 1993) waste reduction and efficient use of resources, through lean project management, lean supply, lean design, lean partnering and co-operative supply chain management (Alarcon, 1997). The central themes have been eliminating waste and improving workflow in the construction.

To date, much of the construction literature has applied the lean concept without contextualization: for example, without the detailed empirical exploration of market structures that underpin the construction environment. Such researchers in the lean production field have understood this important issue. The contextualization of lean production that supports lean thinking has been provided through organizational and indus-

trial organizational economic descriptions of the automotive and electrical industry supply chains (Lamming, 1993; Hines, 1994; Nishiguchi, 1994; Sugimoto, 1997). This understanding of the organization of the supply chain is an important part of the philosophy of lean thinking.

In recent times the value to the construction industry of the lean thinking dogma and rhetoric (Green, 1999) has been questioned. Green challenged the narrowly defined instrumental rationalist approach currently undertaken in the movement. He aimed at introducing literature that provided evidence of the human cost of lean methods in Japanese industry, including repression of independent trade unionism, societal costs (pollution and congestion) and regressive models of human resource management (Kamata, 1982; Sugimoto, 1997). Kamata (1982) provides a personal account of life as an assembly-line worker inside the walls of a Toyota plant, the physical exhaustion he experienced meeting impossible production targets, the army like treatment of employees, the need for conformity and tight surveillance, etc. Green (1999) argued that 'while the lean rhetoric of flexibility, quality and teamwork is persuasive, critical observers claim that it translates in practice to control, exploitation and surveillance'. Lean proponents respond, defending their movement with the argument that it is based upon a long history of production management thinking, particularly the physics of production (Ballard and Howell, 1999) and that lean thinking simply offers a new way to organize production.

Lean production implementation by large producers would not have been possible had it not been supported by highly organized governance structures in the supply chain. Supply chains were organized into hierarchical clusters of tightly tiered structures of subcontracting firms known as *keiretsu* (Hines, 1994; Nishiguchi, 1994). Lean construction researchers, in their quest for production efficiency, in many cases have forgotten that organizing and controlling the market on a very wide and deep scale was instrumental in lean implementation. Nishiguchi developed a historical description and analysis of the Japanese subcontracting system, and provided empirical evidence of the development and organization of industry from the 1920s through to the present day, highlighting the underlying structural characteristics of markets and the evolution of the subcontracting interorganizational relationships.

Japanese economists have debated the nature of Japan's subcontracting of small enterprises typically from two perspectives. The first position relies upon the dualist theory; this holds that 'big businesses accumulate their capital by exploiting and controlling small businesses which have little choice but to offer workers

low pay under inferior working conditions' (Sugimoto, 1997). The prosperity of Japanese industries, particularly in the automotive and electronics sectors, occurs with the sacrifice of many subcontractors. The core dualist theory suggests that economic agents, either workers or firms, located in different segments of the economy, are treated unequally, regardless of their objective worth.

The second position emphasizes the 'vitality, dynamism and innovativeness of small businesses that have responded flexibly to the needs of clients and markets' (Sugimoto, 1997). Nishiguchi (1994) along with Sugimoto (1997) attempted to reject the dualist theory, claiming that Japanese business is more complex. Nishiguchi presented empirical evidence of sustainable growth and high asset specificity of the small to medium size subcontractor firms within lean supply, and also showed that union membership in Japan has remained the same, and that interscale wage differentials between large and small firms were not as marked as some suggest.

Sugimoto (1997) concluded that both positions exist, and that the variation in value orientations and lifestyle of workers is dependent upon the extent of control of the small businesses by the larger companies at the top of the hierarchy. Those who tended to diversify their connections were less controlled and more innovative, participatory and openly entrepreneurial.

Strategic procurement management

Strategic procurement management: mainstream management

A 'strategic' perspective of the supply chain concept emerged in the 1980s which subsequently evolved into strategic procurement (Porter, 1985; Christopher, 1992; Lamming, 1992; Lamming and Cox, 1995; Ross, 1998). Typically this involved positioning a firm competitively in the marketplace by developing appropriate sourcing and management strategies for suppliers. Porter (1985) developed the concept of the value chain as a tool for firms to improve competitive advantage in an industry. Further to this is the concept of strategic procurement management, which is the development of an external sourcing and supply strategy designed to maintain a sustainable position for that organization in the total value chain.

Lamming (1995) identified the importance of supplier development through allied business partners and strategic collaborative partnerships to enable lean production to take place. He termed this lean supply. In contrast to the accepted view of control in the lean supply chain, Lamming suggested that achieving lean supply is a complex matter because of the nature of

competition in markets, because the suppliers are involved simultaneously in several other chains. Jealous guarding of expertise cannot be maintained in the lean enterprise because trust between firms is required.

Strategic procurement is much wider than the lean movement. It is a concept applicable to all firms, and not simply those involved in production and manufacturing. A significant part of strategic procurement is concerned with business alliances. Co-operation among firms has grown rapidly since the early 1980s as alliances have proliferated in one industry after another (Gomes-Casseres, 1996).

Ross (1998) acknowledged two levels in conceptualizing supply chain management, namely the strategic and tactical, and his research concentrated on the emerging strategic capabilities of the supply chain management concept: 'Supply chain management is a continuously evolving management philosophy that seeks to unify the collective productive competencies and resources of the business functions found both within the enterprise and outside in the firm's allied business partners located along intersecting supply channels into a highly competitive, customer-enriching supply system focused on developing innovative solutions and synchronizing the flow of marketplace products, services and information to create unique, individualized sources of customer value'.

Strategic procurement management: construction

Strategic management was a relatively new field in construction in 1991, with little literature available (Langford and Male, 1991). The intervening decade has not seen a growth in this area, but rather a growth in the research related to management and procurement for the individual project. The strategic management of interorganizational relationships is still relatively new, with a growing focus on project alliances. Early research into such concepts as strategic alliances, serial contracting (Green and Lenard, 1999), multiple project delivery (Miller, 1999) organizational design (Murray *et al.*, 1999), vertical integration (Clausen, 1995) and supply chain procurement (Cox and Townsend, 1998) are indications of a growing awareness of strategic organizational management in construction supply chain research (published in Rowlinson and McDermott (1999).

Cox and Townsend (1998) proposed the 'critical asset and relational competence approach to construction supply chain management' model that relied upon clients controlling the supply chain. The authors advocated that clients should understand the underlying structural market characteristics of their own construction supply chains, and develop contingent approaches

to procurement based upon this understanding. They considered the UK construction research based upon lean and agile manufacturing inappropriate, because it lacked contextual understanding of the construction industry. They even suggested that: 'It is our view that if the Latham Report, and the somewhat naive research industry into automotive partnerships and lean and agile manufacturing processes that it has spawned, had devoted more time to analysing and understanding the properties of the unique supply chains which make up the complex reality of the UK construction industry a greater service might have been done to value improvement in construction'.

Other researchers have conducted similar case study research on strategic procurement and supply chain management. Olsson (2000), through a qualitative case study on supply chain management of a Swedish housing project driven by Skanska and IKEA, highlighted that a conventional construction approach was found to be too expensive to meet particular client demands. With a similar business approach, Cardoso (1999) developed a model for comparing entrepreneurial business strategies of contractors based upon two competitive strategies, cost leadership and differentiation. A small study was conducted comparing these variables between six companies in Brazil and France. A methodology developed by Hong-Minh *et al.* (1999), 'terrain scan mapping', aimed to identify the key problems and relevant good practices for each industrial partner. The origins of her research are found in such disciplines as lean thinking, agility, business process re-engineering and business systems engineering.

Consistently, researchers have concentrated upon a small group of firms and the supply chain management concept. Clausen's Danish study (1995) also focused upon the key firms in the main construction contract as they evaluated a government programme, where the 'government', acting as a large client, intended on improving productivity and international competitiveness in the construction industry. The central argument to the programme was the 'need for vertical integration of the different actors and their functions in the construction process' (Clausen, 1995), with the premise that key actors in the process should be involved in strategic decisions at the outset. Clausen (1995) determined that the programme was much less successful than anticipated, because there was discontinuity in the supply of projects to the consortia, and firms were concerned about the financial risk of committing their resources to a single client. The conclusions suggest that the degree of uncertainty in the supply of projects and the inherent risk for firms involved are very important factors in supply chain management.

The interplay between supply and demand, the balance of power or control and incentive has been considered by others in the form of serial contracting (Green and Lenard, 1999) and multiple project delivery (Miller, 1999). Although many authors suggest the importance of understanding the entire scope of the supply chain (Taylor and Björnsson, 1999; Vrijihaef and Koskela, 1999) the supply chain is often still perceived as the contractor's supply chain. London and colleagues (London *et al.*, 1998; London and Kenley, 1999) suggested that the client is the more likely proponent and beneficiary for the management of the supply chain.

In all these models, construction supply chains are viewed from the perspective of the single organization and its ability to control other firms. However, there is still a dearth of empirical research addressing the supply chain across the breadth of the industry and advancing the debate towards understanding, describing and analysing the structure and behaviour of supply chains.

Many authors in strategic procurement have moved the debate regarding supply chains with respect to: the need for the development of appropriate relationships; the problems of unreliable supply; the different degrees of control between firms, and the difficulties due to the temporary nature of a project based industry. However, these are all characteristics of the real world construction industry. The approach advocated in the present review is to accept the characteristics of the real world in the first instance and the inherent structural characteristics of a project based industry, as opposed to a process based industry, rather than attempting unachievable, inappropriate and unrealistic changes to an idealistic model of a supply chain (Cox and Townsend, 1998).

Merging industrial organization economics and supply chain concepts

Industrial organization methodology deals with the performance of business enterprises and the effects of market structures on market conduct (pricing policy, restrictive practices, and innovation), and how firms are organized, owned and managed (Bancock *et al.*, 1998). The most important elements of market structure in these models refer to: the nature of the demand (buyer concentration, number and size of buyers); existing distribution of power among rival firms (seller concentration, number and size of sellers); entry/exit barriers; government intervention; and physical structuring of relationships (horizontal and vertical integration) (Litman, 1998). The role of the industrial organization model is to give substance to the tradi-

tional neoclassical abstract concepts of market types (Litman, 1998).

Ellram (1991) took an industrial organizational perspective, although from a single organization's ability to manage the supply chain. She suggested types of competitive relationship that firms undertake from transaction, short term contract, long term contract, joint venture, equity interest to acquisition. These involve increasing commitment on the part of the firms. She described the key conditions under which supply chain management relationships are attractive according to an industrial organization perspective. The main thrust was that supply chain management is 'simply a different way of competing in the market' that falls between transactional-type relationships and acquisition, and assumes a variety of economic organizational forms (Ellram, 1991). This was one of the first discussions to explore the implications of Williamson's transaction cost economic theory and industrial organization economics related to supply chain management. Situations conducive to supply chain management included: (i) recurrent transactions requiring moderately specialized assets; (ii) recurrent transactions requiring highly specialized assets; and (iii) operations under moderately high to high uncertainty. Such prescriptions should be considered with caution: 'arguments designed to prove the inevitability of this or that particular form of organization are hard to reconcile, not only with the differences between the capital and socialist worlds, but also with the differences that exist within each of these' (Richardson, 1996).

Transaction cost economics theory has just as many critics as supporters. One of the main criticisms is that it has tended to assume a market and hierarchy dichotomy (Richardson, 1996). Theorists have found it difficult to explain contractual relationships between firms where clearly the transaction costs were high and yet firms did not vertically integrate. There are a variety of institutional arrangements between the two extremes of market versus hierarchy, which do not fall neatly into the transaction cost model and clearly demonstrate that markets are not the only way prices are coordinated (Alter and Hage, 1993). However, there is potential for future research relating transaction cost economics to the supply chain movement for the construction industry. Transaction cost economics tends to focus upon individual contractual relationships, whereas supply chain theory aims to understand many interdependent relationships as the unit of analysis.

One of the significant contributions by those using concepts derived from the industrial organization economics literature is the attempt to describe and analyse the structuring and interdependence of relationships in the system of supply chains. New (1997)

noted that the development of the idea of the supply chain owes much to the emergence from the 1950s of systems theory and the associated notion of holistic systems. There are many variations to systems theory, but at the core is the observation that a complex system cannot be understood completely by the segregated analysis of its constituent parts (Boulding, 1985).

Selected supply chain research published in mainstream management literature, has reported on the complex system of supply chains through inter-organizational structure. These are important models that merge the field of industrial organization and supply chain theory (Harland, 1994; Hines, 1994; Nishiguchi, 1994; Hobbs, 1996; Lambert *et al.*, 1998). There are two main epistemological differences between this stream of research and the others discussed thus far. First, industrial organization supply chain research tends to be primarily descriptive in the first instance, rather than prescriptive, and is more about supply chain than supply chain management. New (1997) explained the dichotomy between research on supply chains versus supply chain management. Second, the unit of analysis is not the individual firm or the individual relationship, but rather an aggregation of firms and relationships.

Although clearly Hines (1994) and Nishiguchi (1994) are advocates of the lean system of supply, some of the more significant contributions of their research were the descriptions of the historical, organizational and economical structure of the Japanese system of supply across the automotive and electronics industries. In many ways this has provided a 'richer' picture of lean production and supply chains than other writings of the apocalyptic posturing of the field's success.

Typically, suppliers are categorized and organized into either specialized subcontractors or standardized suppliers, based upon the degree of complexity of the supply item. It is within the specialized subcontractors that the pyramidal Japanese subcontracting system or the concept of clustered control lies. This system has traditionally been described as a pyramid with an individual assembler corporation at the top and successive tiers of highly specialized subcontractors, along the chain, increasing in number and decreasing in organizational size at each progressive stage. This represents a single company network encompassing all the relevant tiers necessary to produce the end product. Although this suggests a closed system, in reality first tier suppliers supply to many assemblers across the industry (Nishiguchi, 1994). This led to the alps structure of supply chains, a series of overlapping pyramids resembling mountain alps across an industry. Hines (1994) enlarged the industry specific view to look at the wider economy, and suggested that, rather than this closed rigid system, the Japanese subcontracting

system is moving more towards a structure of interlocking supplier networks. In that system, many firms supply more than one industry sector, and potentially operate in different tiers: for example, the electronics suppliers operate in a number of sectors.

Associated with each tier are 'supplier associations', which are a 'mutually benefiting group of a company's most important subcontractors, brought together on a regular basis for the purpose of co-ordination and co-operation as well as to assist all the members' (Hines, 1998). Typically, major materials supply corporations are sourced directly by the large assembler corporation, through strategic procurement; sourcing alliances are dealt with separately from the pyramid system. The supply of the material is provided to appropriate subcontractor tiers for the manufacture of components.

Hines (1998) developed a further technique for understanding a particular supply chain appearance at an overview or industry level, and termed it 'physical structure mapping'. Within this technique, the number of firms involved at various stages in the production process in the supply chain is related to tiers of suppliers. Subsequently, a secondary industry map is developed where the tiers are mapped against the value-adding process, or more strictly to the cost-adding process.

Lambert *et al.* (1998) also provided insights for mapping supply chain structure. They claimed, quite simply, that there are three primary structural aspects of an organization's supply chain structure: (1) members of the supply chain; (2) structural dimensions; and (3) types of process link. With regard to structural dimensions there are three critical dimensions. (a) Horizontal structure refers to the number of tiers across the supply chain, which in effect is the number of different functions that occur along the supply chain, and indicates the degree of specialization. (b) Vertical structure refers to the number of suppliers and customers represented within each tier. This reflects the degree of competition amongst suppliers. (c) Horizontal position is the relative position of the focal company within the end points of the supply chain.

Lambert *et al.* (1998) developed for the supply chain structure of an organization a generic map a complex network of suppliers and customers arranged in successive tiers from the focal organization. In many ways this model suggests methods of strategic procurement. However, the importance of this model for the industrial organization debate is the inclusion of a number of empirical case studies indicating the structure of different supply chains and the interconnection between a number of focal organizations' supply chains and the resultant networks of supply.

Harland (1996) widened the industrial organization of supply chains debate, suggesting the term 'supply

network' as a means of capturing the full complexity of the firms involved through a more holistic view of the process. A supply network may be defined as 'a number of entities, interconnected for the primary purpose of supply of goods and services required by end customers'. These entities may be engaged in long term relationships, but ultimately the boundary of the network is ambiguous. In reality, a spectrum of supply relationships exists, ranging from tight long term to loose short term relationships. The term 'supply network' seems to be gaining increased acceptance in the literature (Slack *et al.*, 1991).

One of the pioneers of the supply chain management concept, Christopher (1992) understood that in reality, supply chains and the supplier markets are quite complex and network-like. He offered the following definition of the supply chain: 'The supply chain is the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer'.

Callaghan (1998) discussed a number of concepts related to supply networks, including environment, strategy, structure, process, network evolution, and product/service dimensions. He concluded that little existing research has examined these in detail. The majority of research on supply networks examines the structural and strategic issue of vertical integration, but this has been on a general level, non-specific to particular circumstances. There are few empirical cross-comparisons of supply networks between industries.

Much of the supply and industrial network literature builds upon the industrial networks movement of the 1980s (Piore and Sabel, 1984). This body of research has tended to suggest that close-knit inter-organizational networks produce superior economic performance and quality, and that there should be a move away from the large, vertically integrated firms (Alter and Hage, 1993).

Future research on construction supply chain industrial organization

The role of the supply chain concept in construction will soon move beyond the rhetoric that it is a management tool to improve the performance of the industry. Future research may include optimization of supply chains, and enable more credible discussions of advantages of different types of network, cluster or chain.

Some studies have widened the perspective and have introduced industrial organizational concepts, for example, vertical integration (Clausen, 1995; Tommelein and En Yi Li, 1999), design specialization

and fragmentation (Tombesi, 1997), subcontractor/contractor dependence and the 'quasifirm' (Eccles, 1981) and buyer concentration or pooled procurement (Taylor and Bjornsson, 1999). There is no shortage of construction supply chain research that is action, applied or case study in orientation. Much of this empirical work is oriented to the project as the unit of analysis. There is a lack of work that approaches the research problem from a wider industrial context. A deeper and more detailed understanding of industrial organization theory and supply chains would further this debate, and this has been initiated (London and Kenley, 1998, 2000a,b).

The AEGIS model for the Building and Construction Industry Cluster also has contributed to the development of the wider industrial organization perspective. It discussed the industry as 'chain of production' and conceptualized the industry through five main sectors: onsite services; client services; building and construction supplies and products and fasteners; tools; and machinery and equipment. Existing statistics were used to describe the sectors in terms of industry income. However the authors noted that this is contrived, as sufficiently detailed data were not available. The major firms are organized and listed according to groups: suppliers, project firms and project clients. The discussion focuses upon general information about size and turnover, and addresses a market view of some key markets and the major players in the key markets, but does not seem to address the firm or project level of supply chains.

There is a need to develop this further, and explore the explicit interfirm supply chain relationships on projects within the context of the firm and market. The firm and market levels of analysis lie within the field of industrial organization economic theory.

Government public policy, particularly competition policy, should be informed by observing the current state of the supply chain and distilling certain properties about industrial organization. Until we are able to describe the vertical and horizontal relationships between firms and understand interdependences at a firm level in relation to the market level, it is difficult to compare the long term impact upon changes to the relational position between firms. In a global economy this may also have implications for competitiveness, sourcing, monitoring and traceability of products and materials. Specifically it will assist in understanding new players in the chain as e-commerce becomes more and more significant, for example dedicated supply procurement managers or transaction organizing companies.

Development of an industrial organization model specifically for construction supply chains also has implications for designing co-operative associations

across markets for purchasing. It will assist in locating innovative supply clusters and make transparent the roles of co-ordinators and controllers in the chain. Important questions will follow. What is the overall nature of the organizational relationships along the supply chain? What is the nature of the competitive environments within which organizations operate, and how will this affect the performance of firms in that market? How do firms source their suppliers? How does a supply chain form? Who actually supplies to whom? How is sourcing organized? What are the power relationships between firms and their suppliers along the chain? How do we analyse such fundamental structural and behavioural properties in the supply chain? In many cases the collection of these data will not be easy, as the construction industry frequently is secretive about methods of industrial sourcing, but it will be rewarding for the academic community and industry alike and should be pursued with vigour.

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