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Supply Chain Management Mapping for the Forest Products Industry: Three cases from western Canada

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ABSTRACT

In this paper, we review the development of supply chain management (SCM) and identify a number of considerations for applying these techniques to the forest products industry. A review of the literature found that SCM initiatives were primarily customer focused, where a significant amount of market pull exists. However, the forest products industry is characterized by sales of commodity products with push marketing. Successful implementation of SCM in these types of supply chains were found to focus on efficiencies through: 1) increasing throughput and 2) reducing inventories. Potential for efficiency improvements are larger when a holistic perspective is applied, integrating processes across companies in the supply chain.

Two supply chain mapping methods were identified from the literature as key techniques for use in the forest products industry, and these were applied to three case companies in the western Canadian province of British Columbia. In general, it was found to be especially challenging to apply these techniques (and SCM in general) to commodity-based supply chains because of uncertainty in raw material supply, the relatively long lead times in production, and production processes that generate a relatively high percentage of consequence products. However, the mapping processes yielded some promising results with respect to creating an overview of supply chain structures, time consumption, and inventories. One major benefit derived from applying these methods would be improved communications between actors, customers, and suppliers along the supply chain. The authors suggest that SCM mapping tools be modified to improve their performance in analyzing supply chains for the forest products industry.

Introduction

The term supply chain management (SCM) is fast becoming part of the everyday lexicon of business and business research. The number of research papers related to SCM in business and management journals has risen from five or less each year prior to 1991 to 266 in 2000[1]. Despite frequent use, the meaning and scope of SCM is often unclear, and the term itself is poorly defined. In the forest products industry, the potential for improving performance and profitability through SCM has yet to be realized.

(1) According to the database ABI/FORM, which covers approximately 1,000 business and management periodicals (Larson and Rogers 1998).

The application of SCM techniques has proven to dramatically improve efficiencies in a variety of industries. For example, the Dell Computer Corporation benefited from receiving payments for sales within 24 hours and reducing their total inventories to a value equivalent to 11 days of sales. This was accomplished by significantly reducing their supplier base, by incorporating a "just-in-time" (JIT) approach to manage the inbound logistics of components, and by reducing the delivery lead time required. In addition, their use of standard product modules makes it possible to tailor each computer to customer needs in real-time, enabling increased customization without increased inventories (Christopher 1998). Similar successes have been reported by Procter & Gamble (Lee et al. 1997a, 1997b) and Campbell Soup Company (Fisher 1997).

The target for SCM is improved overall profitability and competitiveness (Ellram 1991; Cooper et al. 1997; Persson 1997; Christopher 1998; Meredith and Shafer 1999; Chopra and Meindl 2001; Mentzer 2001). There are a variety of strategies proposed which are sometimes seemingly contradictory, such as reducing inventories while increasing service, or increasing customization while reducing lead times. Hence, the numerous reported failures of SCM initiatives (Porter 1996; Fisher 1997; Fine 1998; Stank et al. 1999) are not particularly surprising.

Matching supplies with consumer demand along the entire supply chain requires a commitment to coordination of material flows across companies through sharing of information, risks, costs, and gains between the actors involved (New 1996; Lambert et al. 1996; Lee et al. 1997a; Mason-Jones and Towill 1998; Stank et al. 1999; Lee 2000; Chopra and Meindl 2001). However, complex structures and relationships between actors can hinder progress in supply chains (Lee and Billington 1992). Fisher (1997), in particular, argues that despite access to state-of-the-art technology, the performance of many supply chains has never been worse. This is due to a lack of understanding on how to apply SCM techniques across different products and markets to better serve the consumer, while simultaneously improving performance and profits.

The potential gains from SCM and the recent introduction of the concept in forest industries by academics (e.g., Andersson et al. 1999; Carlsson and Rönnquist 1999; Lehtonen 1999; Högnäs 2000; Helstad et al. 2001; Juslin and Hansen 2002; Pulkki 2001; Smith 2001) and practitioners (e.g., Kenny 1999a, 1999b; McDougall 1999; Palevich 1999; Peterson et al. 1999) serve as the background for this study.

Study Objectives

This exploratory study has several objectives. First, we investigate and define the concept of SCM through a review of published literature. We then describe the characteristics of material flows common to the forest industries. Next, we present two complementary supply chain mapping methods intended to provide an overview of supply chains in general. Using these methods, the supply chains of three western Canadian companies from the solid wood sector are mapped. Based on the mapping results, we outline critical areas for future research concerning the development and application of SCM methods both for the three cases analyzed and in depicting the supply chains in the solid wood products sector more generally. Lastly, we make suggestions regarding modifications of the methods to better serve the needs of the forest industry.

It should be noted that, while qualitative data in the form of case study information was collected in this analysis, our intent was not to use this information to generalize onto the population of solid wood producers in western Canada. Rather, it was to highlight the potential that adopting supply chain management practices has to offer. Likewise, the mapping methods presented are not meant to provide definitive solutions, but are used to illustrate and elucidate possible strategic tools that can be used by forest products companies, both in Canada and internationally.

Defining Supply Chain Management

Intuitively, the words *supply* and *chain* imply a transfer of something between two or more linked parties. The frequent occurrence of the expression "supply chain" in recent publications, combined with an unawareness of what the term is actually describing, has led to some confusion (Cooper et al. 1997; Ganeshan et al. 1998). For example, supply chains can be viewed from the perspective of the product or the firm. The term is also used commonly as a synonym for purchasing, materials management, and distribution (New 1997).

As the variation of organizational structures and operations in different industries is large, developing a general definition of the supply chain concept is not a simple task. This is exemplified by the large number of recently proposed definitions (e.g., Lamming 1996; Cooper et al. 1997; Persson 1997; Mattsson 1999a; Otto and Kotzab 1999; Mentzer et al. 2001). In addition, new concepts with similar meanings have frequently been introduced (Persson 1997; New 1996, 1997; Croom et al. 2000; Tan 2001). The large variation in supply chain terminology may be the result of dissimilarities in business environments (Bowersox et al. 1992; Mattsson 2000), the continual evolution of new management concepts, a concurrent lack of critical inquiry (Persson 1997), and a general lack of collaboration between different research institutions studying SCM (Bechtel and Jayaram 1997; Croom et al. 2000; Tan 2001). At the very least, the variety of definitions indicates a definite lack of unified thought in this field of management studies (Otto and Kotzab 1999). The result is that the exact meaning of SCM is unclear to both academics and practitioners (Bechtel and Jayaram 1997; Mattsson 1999a).

The supply chain is most commonly defined as a network of actors(2) that produce and deliver products to customers (Lee and Billington 1992; Christopher 1998; Fine 1998; Larson and Rogers 1998; Mattsson 2000; Lee 2000; Chopra and Meindl 2001; Mentzer et al. 2001). Others suggest that the supply chain is the processes and activities that take place for the same purpose (Stevens 1989; La Londe 1994; Handfield and Nichols 1999; Bovel and Martha 2000). Perceiving the supply chain as a network of physical actors is preferred, as this makes the complex phenomenon become more tangible and easier to grasp. Mattsson (2000) required that a fundamental characteristic of supply chains is that there are several consecutive actors in receiver and vendor relationships, and proposed the following definition:

> *"A supply chain is a physical network of entities through which materials, (directly, or via inventory), information, and cash flow. The supply chain starts with a raw material supplier and ends with the customer that consumes the products produced by the chain."*

(2) In this context, the term "actors" is preferred over "firms" as the smallest unit of supply chains, since this draws attention to the processes that are performed irrespective of the ownership structure of the actors involved.

In an applied setting, an actor will often narrowly define its supply chain from its immediate upstream suppliers to its immediate downstream customers (Lehtonen 1999; Mattsson 1999a). It has, however, been argued that all of the organizations that contribute or add value to the product must be regarded as parts of the supply chain (Handfield and Nichols 1999; Mattsson 1999a; Chopra and Meindl 2001). Other researchers have gone one step further and included reverse flows (e.g., returns of defective goods, customer satisfaction policies, and environmental disposal) in the supply chain concept (Ballou 1999; Handfield and Nichols 1999; Lee 2000; Tan 2001). The difficulty in assessing the beginning and the end of supply chains is one of the inherent weaknesses of the concept (Lehtonen 1999). For this reason, research revolving around supply chain issues should always begin with a proper definition of the chain under study, including the researcher's interpretation of the supply chain concept, to allow for objective and comparable analyses to emerge across research projects.

To reduce complexity of real world problems, the supply chain may be viewed from the perspectives of a particular actor within the chain. Alternatively, complexity may be reduced, while maintaining a holistic perspective on all of the actors involved, by applying a product or a product group focus (Scott and Westbrook 1991; New 1997).

Failing to incorporate a holistic approach to supply chain problems may result in a loss of a great deal of relevant information. From a practical point of view, this can be a formidable task – obtaining perspectives spanning across all of the actors involved in the value adding processes is complicated due to the limited control that each actor has on the supply chain (Mattsson 1999a). In SCM research, an appropriate combination of actor and product focuses is often a trade-off between requirements for a very detailed analysis and the research team's ability to manage complexity.

That said, it must be acknowledged that the existence of all actors along the supply chain is entirely predicated upon consumers' willingness to pay for produced goods and services (La Londe 1994; Christopher 1998; Handfield and Nichols 1999; Mattsson 1999a). Thus, a consumer focus is a fundamental requirement for any supply chain (Persson 1997; Christopher 1998; Mattsson 1999a; Lee 2000).

A working definition of *supply chain management* emerges from the perception of the supply chain as a network of actors. SCM is closely related to logistics, both originating from similar schools of management thought (Bechtel and Jayaram 1997; New 1997; Mentzer et al. 2001). However, it is a broader and more holistic concept than logistics (Cooper et al. 1997; Larson and Rogers 1998; Mattsson 1999a; Lambert and Cooper 2000; Mentzer et al. 2001). In addition to management and control of material and information flows, SCM involves collaboration and integration between actors, new product development, and coordinated flows of materials, services, and information (Mattsson 1999a). Based on this, Mattsson (1999a) proposes the following definition of SCM:

> *"Supply chain management implies planning, development, coordination, organisation, steering, and control of intra and inter-organisational processes from a holistic perspective and accounting for exchanges of materials, information, cash, product development activities and marketing activities in supply chains."*

The twin objectives of SCM are to improve profitability and competitiveness for all actors in the chain (Persson 1997). Achievement of these goals requires a focus on the consumer, while simultaneously enhancing coordination and integration of the flow of materials and encouraging the exploitation of "win-win" relationships. An effective supply chain strategy can, for example, result in improved customer service and reduced or maintained delivery lead times, while simultaneously reducing inventories (Persson 1995; Fisher 1997; Lee et al. 1997a). One means of reaching this target is by improving the accessibility of sales and inventory information in the supply chain, thereby substituting inventory with information (Macbeth and Ferguson 1994; Persson 1995, 1997; Christopher 1998; Mattsson 2000; Mentzer 2001). This requirement for transparency across the chain means that relationships and communication skills among actors are critical for success (Macbeth and Ferguson 1994; Christopher 1998; Andersson 1999; Mattsson 1999a; Mentzer 2001).

The correct strategy to improve the competitiveness of supply chains depends on the characteristics of the chain under study. Fisher (1997) argues that strategies for SCM depend largely on the properties of the product. As any supply chain delivers a variety of products to consumers, it might be necessary to apply several strategies, even within one supply chain (Macbeth and Ferguson 1994; New 1997). Porter (1996) provides examples of how firms apply different strategies when offering similar products to different markets. The challenge in pursuing appropriate supply chain strategies is never ending as the product characteristics that win orders in the marketplace change over time (Hill 1994). While price is often the order winner for commodities, the order winner for recently released products may be the "ability to respond to volatile demand". For deliveries to JIT manufacturing, the order winner might be "on-time-delivery" (Hill 1994). To successfully implement SCM strategies, firms must identify the order winners before their competitors, while conforming to all of the basic requirements of the product (Hill 1994).

The overall performance of a supply chain is affected by the performance of all actors in the chain and by their ability to respond to changes in the product requirements required at different levels within the supply chain. Thus, a holistic approach and prudent analyses are paramount in the quest for superior supply chain performance and competitiveness. The evaluation of any supply chain should extend far beyond the operations of the individual firms involved.

Characteristics of Material Flows in the Forest Products Industry

Several critical considerations must be taken into account when describing material flows, including the structure and organization of actors, lead times, and the degree to which flows are "pushed" (initiated by delivering actor) or "pulled" (initiated by receiving actor) through the chain. A number of different material flow structures have been proposed (Burbidge 1994; Macbeth and

Ferguson 1994; Mattsson 1999b), five of which are presented in **Figure 1**. Supply chains are comprised of combinations of these types of flows from points of origin to points of consumption.

Figure 1. Types of material flows and their characteristics.

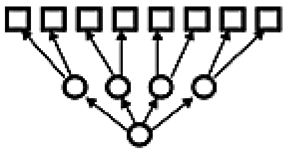
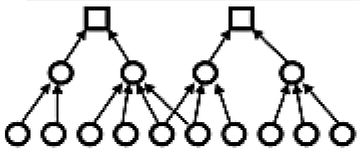
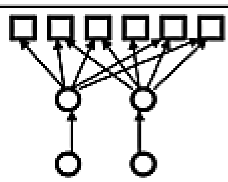
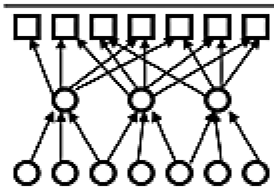
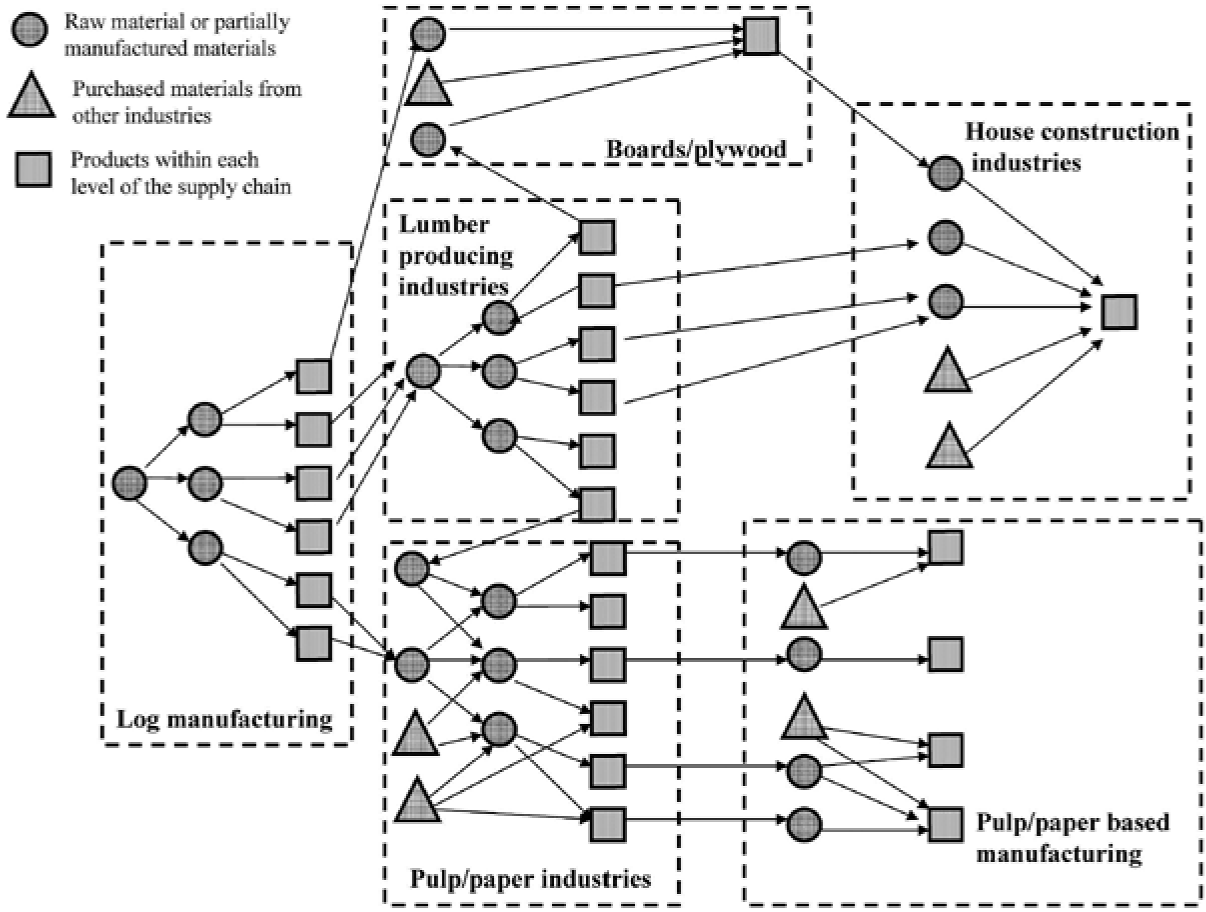
	V-type (Mattsson 1999a; Macbeth and Ferguson 1994) Implosive (Burbidge 1994)	Diverging flows involve partitioning or splitting the raw material into a number of products.	The breakdown operation in lumber production
	A-type (Mattsson 1999a; Macbeth and Ferguson 1994) Explosive (Burbidge 1994)	Converging flows refer to situations where several raw materials end up in significantly lesser amounts of end products.	Assembly operations in general: • assembly of computers • assembly of furniture
	T-type (Mattsson 1999a; Macbeth and Ferguson 1994)	The T-type is where a small number of raw materials end up as a larger number of end products. The number of converging points increases as focus is moved downstream in the supply chain.	The paper industry utilises only a few ingredients, but a large number of paper qualities and types can be produced.
	X-type (Mattsson 1999a)	The X-type is characterised by a large number of raw materials that converge into a lesser number of parts or modules that can be combined into a multitude of end products.	Use of modules makes it possible to create a multitude of products from a moderate number of parts: • automotive industry, • manufacture of kitchen cabinets
	I-type (Mattsson 1999a; Macbeth and Ferguson 1994) Process (Burbidge 1994)	The I-type has one raw material that ends up as one final product. Typically, this is true for separation processes, or processes where the raw material is shaped into a product.	Lumber remanufacturing.

Figure 2 provides a representation of the types of material flows that occur in the forest products industry and shows how they are divergent and interrelated. In essence, products from one processing stage serve as raw materials for other segments. In diverging environments, material planning of raw materials is rarely a complex problem due to stable consumption of a limited number of raw materials (Lehtonen et al. 1999). The forest products sector traditionally has been made up of long and complex supply chains with several intermediaries occurring between resource extraction, manufacturing, and end use (Sinclair 1992; Nerman 2000).

Figure 2. Generalized representation of material flows and relationships in forest industry supply chains (intermediaries are excluded to reduce complexity).



For diverging flows, such as in lumber manufacturing, the composition of the product mix results from trade-offs made in production planning and from uncertainties in the raw materials and production processes. This is because the production of one product results in concurrent production of additional lumber products of other dimensions, lengths, and qualities. These are referred to as "consequence products" (Markgren and Lycken 2001; Nerman 2000; Rask and Andersson 2001). This dependency between products (defined by dimension, grades, moisture content, and surfacing), combined with the uncertainty inherent in the raw material, makes it infeasible to have complete control over lumber manufacturing processes (Markgren and Lycken 2001; Nerman 2000; Rask and Andersson 2001). The situation is further complicated as by-products (e.g., chips for pulp and paper production) also constitute a considerable share of the total volume and value produced. In the final analysis, both by-products and consequence products are important determinants of profitability in lumber manufacturing.

During lumber manufacturing, there are several shifts that occur in the structure of material flows. For example, the breakdown process in the sawmill is a series of diverging flows. Lumber is sorted by dimension at the back end of the sawmill (diverging flow), and then is dried and surfaced in batches (I-type flows). After surfacing, the lumber is graded and sorted in another diverging flow. If managed independently, these shifts in flow-type can result in the build-up of work-in-progress (WIP) inventories, especially when producing large batches.

Initiation and control of flows in supply chains can be described by what are known as "order penetration points", the points at which a product is matched with a customer (Sharman 1984). Order penetration points exist for every customer/vendor relationship in the supply chain (Lehtonen 1999), and their location along a supply chain determines the extent to which the material flows are based on push or pull principles. Push-based flows are initiated by an upstream delivering actor with little or no input from downstream customers. An example is when production plans are made from forecasting market events (Mattsson 1999a; Chopra and Meindl 2001). Pull-based flows, on the other hand, are initiated entirely by downstream customers (Andries and Gelder 1995; Mattsson 1999a, 2000; Chopra and Meindl 2001). A recent trend in manufacturing and distribution has been to increase the degree of pull-based flows, most notably in the form of customized products (Mattsson 2000). When pull-control is implemented, an increasing number of operations must be performed after the order has been received, and delivery lead times for the customer tend to increase (Persson and Virum 1995). Nonetheless, the total throughput time for the producer is often reduced because of decreased inventories. However, requirements for excess manufacturing capacity increase when inventories are no longer used to buffer variations in demand (Harmon 1992). Hence, high capacity utilization is difficult to combine with pull-based flows, unless demand is relatively stable and manufacturing lead times are short (Kalsaas 1995; Lehtonen et al. 1999; Mattsson 1999b).

Products in the solid wood industries are, to a large extent, what Fisher (1997) describes as functional products (commodities). Supply chains delivering commodities should strive for physical efficiencies in the supply chain which maximize performance and minimize costs, such as increasing capacity utilization, reducing inventories or shortening lead times (Fisher 1997). Short delivery lead times can be combined with high capacity utilization, but this increases both inventory holding costs and the associated risk of obsolescence.

The recently increased attention to customer needs suggests that products are becoming increasingly customized (Mattsson 2000). Customization tends to occur in lumber remanufacturing rather than in the sawmill. However, increasing customization results in smaller batch sizes and correspondingly more frequent machine set-ups, meaning that delivery lead times tend to increase and capacity utilization is often reduced. Complex planning and scheduling can help to alleviate these problems (McDougall 1999), and there are potentials for reducing both obsolescence and inventory holding costs.

In the last few decades, cost reduction has been one of the major objectives for forest products companies. To a large extent, decisions in the industry are based solely on the optimal solution of sub-problems, such as minimum roadside or mill-site costs. This approach will rarely lead to the global optimum for a supply chain (Pulkki 2001). Recently, the focus in the forest products industry has shifted from the supply of raw materials to the customer (Sinclair 1992; Carlsson and Rönnqvist 1999, Högnäs 2000), and there has been a trend toward reducing roundwood inventories (Carlsson and Rönnqvist 1999, Högnäs 2000). The individual actors within the supply chain are now approaching a point where investments in cost reduction and improved efficiencies provide better returns when apportioned between firms rather than within firms (Carlsson and Rönnqvist 1999). However, a closer integration of actors increases the complexity of planning problems in the supply chain. In addition, decisions made in forest operations (e.g., log bucking) will impact the possible outcomes in later manufacturing stages. Clearly, interdependent operations should be planned, managed, and coordinated jointly.

Forest industry supply chains are characterized and complicated by divergent flows, uncertainties in production, and the occurrence of by-products. It is likely that potential improvements through integration and customer orientation are considerable. However, it is also likely that this will require the development of relationships along the supply chain based on trust and loyalty.

Methods

Study Approach

The roles of individual firms in supply chains vary and are highly dependent on the characteristics and structure of each specific supply chain being studied. Almost without exception, each firm participates in numerous supply chains delivering products to various markets. Wilding (1998) shows examples of how seemingly independent actors in supply chains can affect each other through what is referred to as “parallel interactions”. For example, an order to a vendor requiring immediate delivery may be the result of the manufacturer being forced to re-schedule because a second vendor was unable to deliver parts for the originally planned production. Hence, it becomes difficult, if not impossible, to separate the unit of analysis, whether it is the individual firm or a sequence of actors in a supply chain, from the context within which it operates. Such situations make case studies a highly appropriate research strategy (Miles and Huberman 1994; Yin 1993, 1994). In addition, when the problem being studied is a current, real-life one, the investigator has little control over events and the appeal of case study methods further increases (Yin 1993, 1994). The purposes of this research conform well to the common aims of exploratory case studies, such as defining research questions and hypotheses, as well as determining the feasibility of desired research procedures (Yin 1993).

Selection of Cases

Three cases (supply chains) of lumber producers from the western Canadian province of British Columbia were selected for this analysis. The scope of the case studies was limited to the part of the supply chain operating in the North American market for lumber products to reduce the complexity of the problem. Time and budgetary constraints did not permit a larger number of cases. Our aim was to generally explore the state of SCM in the solid wood industries, so it became important, as well as challenging, to ensure that the three cases selected represented as much of the considerable variation in the western Canadian solid wood products sector as possible.

Lumber manufacturers in British Columbia are commonly divided into coastal and interior-based companies (Lee et al. 1999). They also vary according to ownership structure, from highly integrated (vertically as well as horizontally) corporations to smaller companies with fewer production facilities. Finally, the solid wood sector in British Columbia also differs with respect to markets for final products, types of raw materials used, and whether lumber manufacturing is the core business or merely one of several important competencies. Numerous cases would be required to completely capture this variation. However, for this exploratory assessment, we are confident that the three cases provide the best trade-off between representing industry variation and ensuring the availability of relevant information in a timely and cost-effective manner.

The final determinant in the selection of the three cases was each company’s willingness to participate in this research and provide access to personnel and information. Each selected company was first contacted by telephone to verify that they were willing to supply information through interviews with management personnel from several functional units. As a result of this pre-screening process, very few problems were later encountered in accessing and retrieving the relevant information for the completion of this study. Customers, suppliers, public authorities, and third-party logistics providers were also helpful in providing information for this research.

Case Profiles

The unit of analysis in each case is the supply chain from the extraction of logs (in the forest) to the sale of lumber (through wholesalers and retailers). In the interest of anonymity, the companies will be referred to as companies A, B, and C. Profiles of each of the case companies are presented in **Table 1**.

Table 1. Case profiles at time of analysis.

	Company A	Company B	Company C
General			
Total annual sales[a]	100	39	474
Net earnings[a]	100	5	64
Business segments	logs sales 75% lumber sales 23% real estate 2%	lumber sales 91% reman lumber sales 9%	retail 35% lumber sales 31% panel sales 9% pulp/paper sales 25%
Forest operations			
Main region	BC coast	BC coast	BC interior
Harvesting public land	2,400,000 m^3	0 m3	3,491,000 m^3
Harvesting private land	1,200,000 m^3	0 m^3	0 m^3
Open market log supply (by volume)	11%	73%	30%
Degree of mechanization	motor-manual felling and cable logging systems are common	na	harvesting and forwarding mainly mechanized
Log transportation modes	trucking from forest to water, then towing of log booms	towing of log booms from sales location to sawmills	trucking to mill or combined with towing operations across large lakes
Markets for logs (by volume)	Canada 29% Canada (contracts) 23% Japan 11% USA 10% pulpmills 10% own sawmill 16%	na	mills process most logs, while sorts that do not fit well with production are sold or traded for better logs with other lumber manufacturers
Lumber Production			
Number of sawmills	1	2	15
Lumber production[a]	100	145	979
Lumber sales[a]	100	167	699
Markets for lumber (by value)	Japan 65% Canada 35%	Japan 72% USA 15% Europe/other 7% Canada 6%	USA 50% Canada 32% Asia/other 18%
Number of customers	50	200	500
Number of key accounts	4	100	200

Largest customer (by total sales)	na	10%	<15%
Sales department	centralized	centralized	centralized
Production planning	decentralized	centralized	decentralized
Forecasting	na	based on historical production	based on historical production
Inventory management	one system for sawmill	no specific software	software keeps track of production and inventory at each mill
Lumber transportation modes	ship to Japan, truck within Canada	ship to Japan	railway within North America, truck to retail, ship to Europe/Asia

[a] In the interest of maintaining the anonymity of case companies, some categories are shown using values relative to a reference of 100 for company A.

The companies analyzed are not independent as company A is an important supplier of logs for company B (25% of supplies). Company A is a large forest owner in the coastal region of British Columbia, emphasizing low cost production of logs and lumber. About one-third of the log volume is delivered through long-term delivery agreements[(3)] and, of this, 30 percent is sold as pulpwood to a BC -based paper producer. The raw material supply of company B is based on open market purchases, where the raw material inventory exists in water close to the production facilities. Company B owns three remanufacturing plants[(4)], and although low cost production is emphasized, this is not as apparent as in the other two cases, mainly because consistently high quality is a requirement for deliveries to Japan. Company C is a large, integrated forest products company. Notably, company C's lumber production has tripled since 1990, mainly through acquisitions of other mills. The United States is their most important market, accounting for approximately 50 percent of sales.

(3) The vendor has committed to offer an annual volume of logs of a certain quality to a specific customer. If, however, the parties do not agree on price, the vendor is free to sell the logs to other accounts. The customer is free to decide whether or not to buy the offered logs.

(4) Two of the remanufacturing plants are operated as joint ventures. During the period of this study, company B was acquired by a major manufacturer of logs and lumber operating in the coastal region of British Columbia. The acquisition included the sawmills and two of the remanufacturing plants, which are now fully owned by the buyer.

Data Collection

As case studies are often criticized for being less rigorous than experiments and surveys (Yin 1994), we emphasized the use of multiple sources of evidence (Yin 1994). The main source of data came from personal and telephone interviews with key management staff (from each company's head office); however, staff from other companies or other functional units along the supply chain (customers, suppliers, and third-party logistics providers) were also interviewed. As the companies differed in size, varying numbers of employees were interviewed in each case, from four persons in company B to seven persons in the supply chain of company C. In addition, printed information from annual reports and the companies' official websites were also utilized. The printed information was primarily used to verify how each company presented its management structure and operations in interviews.

Based on the review of SCM literature, a set of questions were developed jointly by the authors. The questions were created to collect information about the companies' perceptions of SCM and possible applications of the main elements of SCM within their supply chains (focusing on the value chain, partnerships, time compression, and inventory reduction). Due to the differences between the companies analyzed, the set of questions differed somewhat in each of the three cases. However, the basic framework for the questioning was similar across all three supply chains, falling under six general themes relevant to SCM:

1. providing an overview of the supply chain that the company is a part of, as well as the main markets for the company's products;

2. exploring whether SCM and logistics are emphasized within the corporate culture through company vision/mission statements or strategies;

3. providing an overview of their procurement strategies – the companies involved, their roles, fluctuations throughout the year, lead times, the decisions that initiate replenishment of raw materials, and alternative sources of supply;

4. explaining how production is planned and executed including factors considered in production planning, location of order penetration points, production lead times and inventories, presence of by-products produced, and reasons for variations in lead times and inventories;

5. explaining how sales and distribution functions within the company are organized with respect to lead times and inventories in distribution, transfer of ownership, information flows related to production and sales between customers and suppliers, and sales and distribution of by-products; and

6. explaining the present state of development with respect to SCM principles including collaborations between organizations, the degree to which effects of investments on other actors in the chain are considered, interactions between customers and suppliers through internet technologies, the degree of emphasis on total cost reduction, and how total costs for the supply chain can be reduced.

The questions were sent to the interviewee a few days in advance of the actual interview. During the personal interview, the interviewee was given the opportunity to speak freely and the interviewer's task was largely to make sure that all the questions were satisfactorily answered. The interviews were recorded and transcribed and a subsequent structured summary was created based on the transcript. As a means of assuring the quality of the collected information, whenever uncertainties arose, a second interview was carried out over telephone for clarification. These shorter interviews were not recorded.

In cases where key management personnel were situated in a location away from their head office, a second type of interview was conducted. Here, the questions were not sent to the interviewee in advance, and the interviews were carried out over the telephone and not recorded. Due to the wide perspectives of SCM issues, suppliers, third-party logistics providers, and even customers' customers and suppliers' suppliers were also interviewed whenever there was a need for additional information. In these cases, the questions were not sent out in advance, and the interview was conducted over telephone.

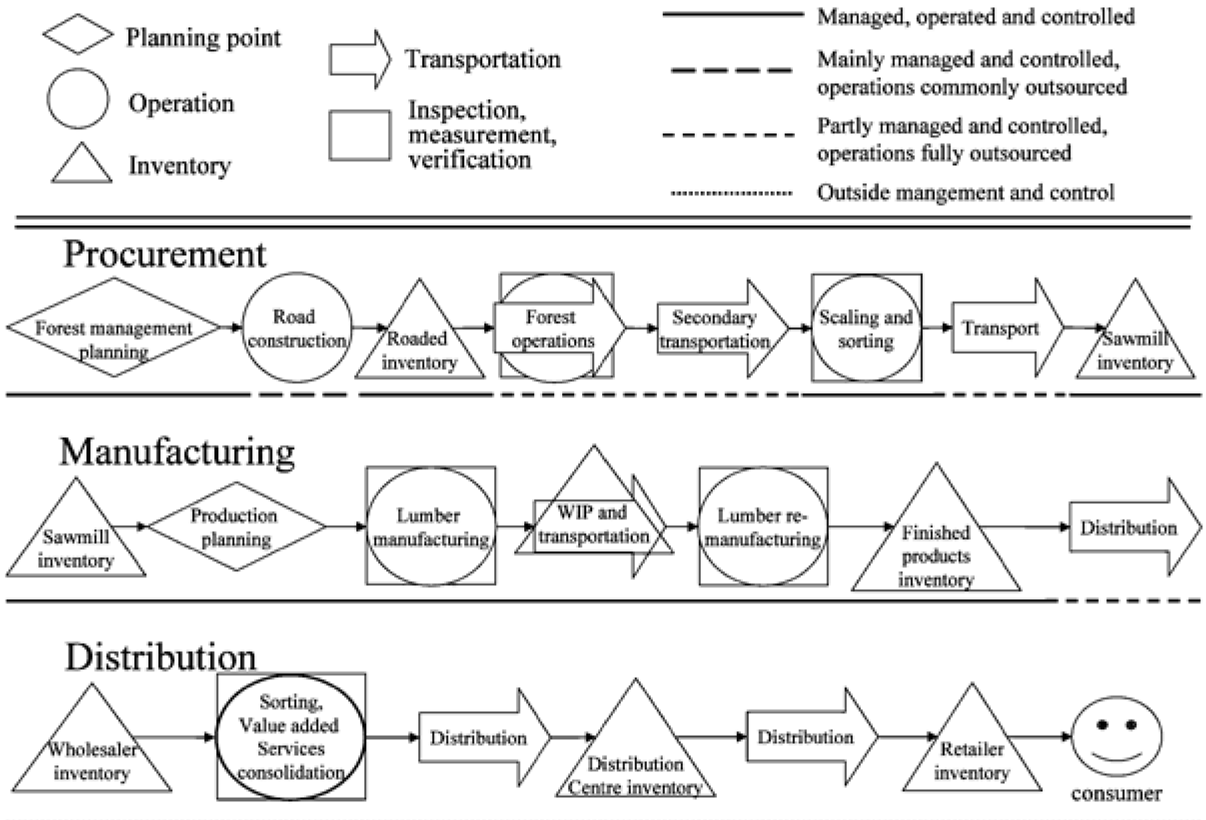
All of the individuals that were contacted were very willing to provide information both for the purposes of our research and to provide further clarification after the interviews had been conducted. In many cases, the interviewee was contacted several times, either to provide additional information or to explain seemingly conflicting information.

Supply Chain Mapping Methods

Two methods are presented for mapping supply chains: one focused on the supply chain structure and relationships between actors viewed from each of the focal companies and the other focused on time. Mapping the structure and relationships between actors within any given supply chain provides an overview of the environment for initiatives aimed at a closer integration of that supply chain, especially when combined with information pertaining to the relative importance of customers and suppliers. Lead time mapping provides an overview of the time spent in inventories relative to the time spent in operation for the main products in a supply chain, hence, showing what can be achieved through reductions in the amount of material tied up in the supply chain. By applying these two mapping methods concurrently, it is possible to create a broad, yet comprehensive overview of any given supply chain.

The first method, presented in **Figure 3**, maps the structure and organization of the supply chain viewed from a typical lumber producing forest products company (the focal company). This methodology is derived from Lambert and Cooper (2000), who developed an approach with a wide scope that maps all of the actors in a supply chain and identifies the business links between each actor based on the degree to which it is managed or monitored by the focal company. This study more narrowly focuses on a sequence of companies that deliver a major fraction of the production to the marketplace, as recommended by Scott and Westbrook (1991), and concentrates on actors that execute primary activities that directly affect the flow of materials (Lambert and Cooper 2000).

Figure 3. An example of how the structural mapping method can be applied.



The map in **Figure 3** is adapted to a hypothetical lumber producer in western Canada. Procurement, manufacturing, and distribution functions are each divided into smaller stages, and the types of activities performed at each stage are displayed (planning, operations, inventory, transportation, inspection/measurements/verification). The line beneath each stage indicates the degree of management and control over each activity, defined by the following four classes:

1. operations managed, operated, and controlled by the firm;
2. operations mainly managed and controlled by the firm, with limited outsourcing;
3. operations partly managed and controlled by the firm, with all operations outsourced; and
4. all operations residing outside of the management and control of the firm.

For clarity, the differences between operations that are *partly managed* versus *mainly managed* need to be elucidated. An operation that is partly managed outsources various standardized services. Commonly, there are several possible providers of the service in question, and the contract often goes to the lowest bidder (e.g., transportation services). An operation that is mainly managed may also include services subject to outsourcing, but the operations in question are typically more closely aligned to the company's economic returns (e.g., kiln-drying, where both the price of the service and how the process is performed are monitored). Operations that are mainly managed typically have fewer alternative service providers, and relationships between the focal company and the provider of the service tend to be more established and long term.

The second method applied in this study is known as lead time mapping[5] (Scott and Westbrook 1991). This method divides the accumulated lead time, defined as the total time spent in the supply chain from the start of the first activity until the final product is delivered to the customer, into the following components:

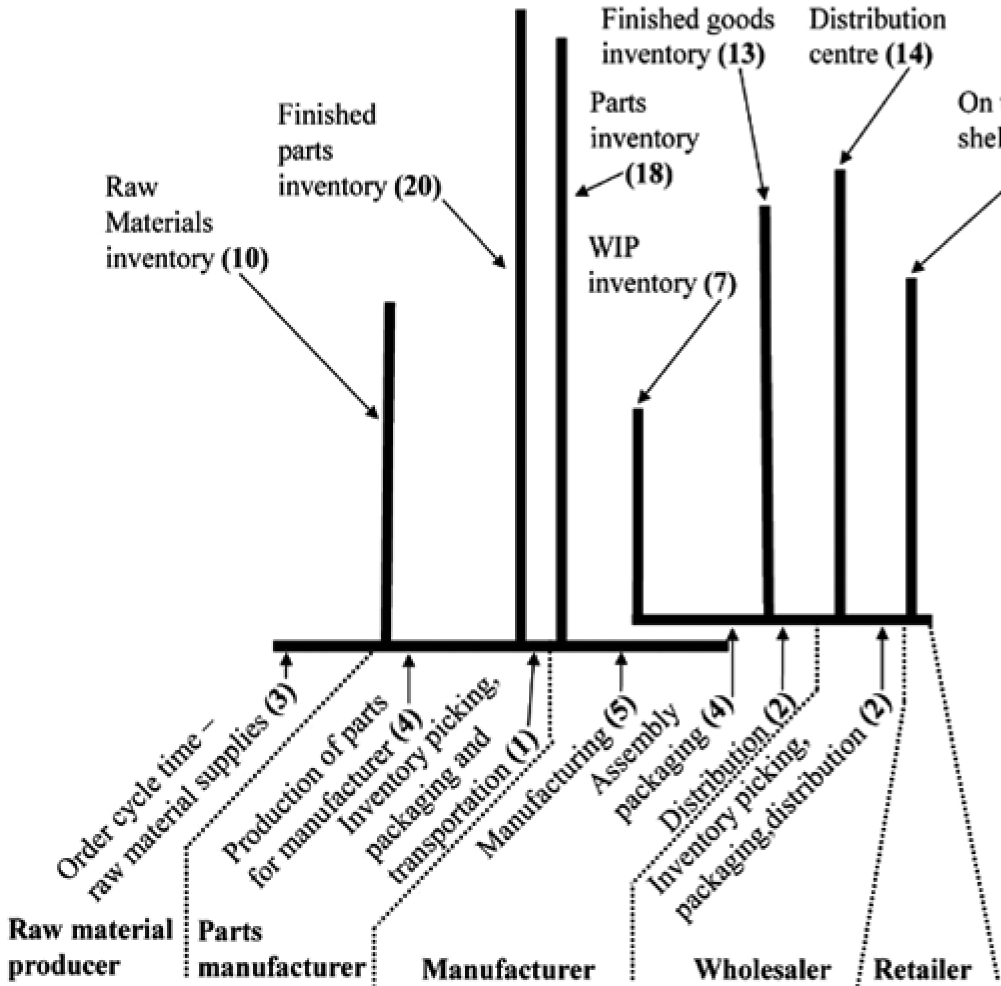
1. time spent in processes, such as transportation, assembly, packaging, and manufacturing; and

2. time spent in storage at the major stockholding points.

(5) Similar methods are described by Hines and Rich (1997) under the name “supply chain response matrix” and Barthezaghi et al. (1994) under the name “aggregate time models”.

The purpose of distinguishing between these two components is to display major stockholding points (which tend to account for most of the accumulated lead time) and to get a comparative overview of time requirements for different operations. The overall aim is to identify opportunities for reductions in the accumulated lead time, thereby also reducing the amount of material tied up in the supply chain (Scott and Westbrook 1991). Lead times can be easily measured by any organization, and represented graphically, as in **Figure 4**. The horizontal sections in **Figure 4** represent time devoted to operations (value added time), while the vertical lines represent time spent in storage (non-value added time) between operations.

Figure 4. A generic representation of a lead time map. Horizontal and vertical lines are drawn to the same scale, and represent time spent in processing (e.g., manufacturing, transporation) and in inventory, respectively.



This method is attractive, especially for sequential processes where activities are separated by stock -holding points and the next activity cannot start before the previous one has ended. Scott and Westbrook (1991) recommend that each map be simplified to include only one focal product delivered by the supply chain.

In **Figure 4**, the sum of the horizontal (value added operations) sections (21 days) represents the total time spent in process. For sequential operations, this is equivalent to the shortest possible time required to respond to increases in demand, assuming current operational efficiencies and maintained stock levels. The sum of the vertical (non-value added time) lines (92 days) is a measure of the total amount of inventories accumulated in the chain. The sum of the vertical (non-value added time) lines and the horizontal (113 days) sections represents an estimate of the amount of material tied up in the supply chain and an estimate of the time required to drain the channel given current levels of demand.

We modified this mapping method so that it would conform to the supply chains in the three cases, specifically where activities tend to be performed concurrently. For example, log hauling may start before harvesting has ended. For operations running concurrently, the original method (Scott and Westbrook 1991) overestimates throughput times, as well as the amount of material tied up in the supply chain. Referring to **Figure 4**, assembly begins after 2 days of manufacturing. When operations are performed concurrently, the map is shifted vertically. In this way, the time consumption of both operations are shown (5+4 days), as well as the gains from concurrent execution (3 days) and the response times from concurrent operations (2+4 days). In this case, concurrent production leads to a reduction in the shortest possible response time from 21 to 18 days and a reduction in the material tied up in the chain from 113 to 110 days.

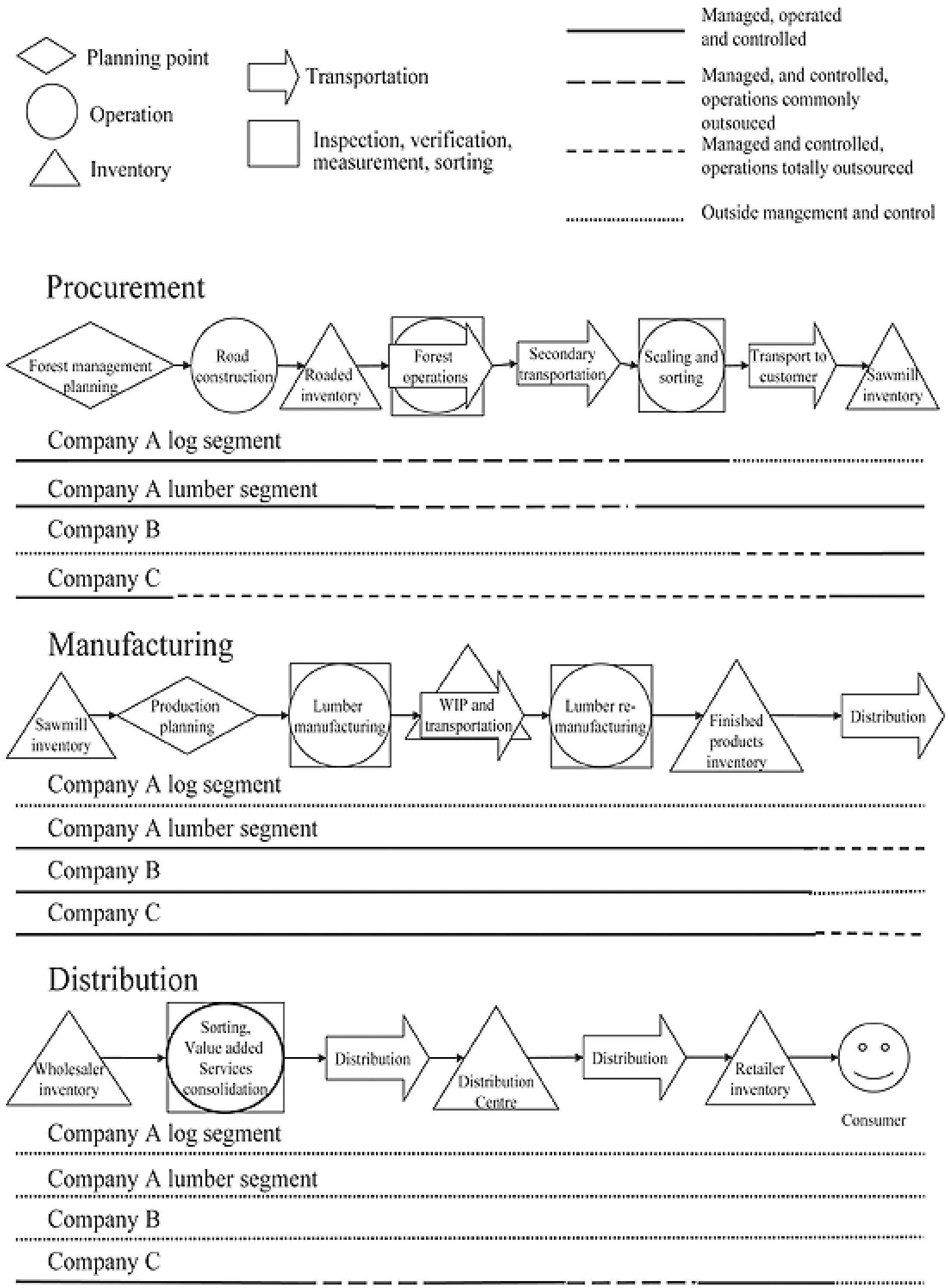
Results

Using the case study approach, three supply chains delivering solid wood products from western Canada are presented and mapped according to the methods described above. The analyses and mapping are conducted from the perspectives of the three focal companies, all of which operate in the solid wood products sector of British Columbia.

Mapping of Supply Chain Structures and Relationships

In order to describe the supply chain structures and relationships viewed from the perspectives of each of the three focal companies, results are presented for the main market of each supply chain. The map comparing the supply chain structures from each company's perspective is presented in **Figure 5**.

Figure 5. Map showing the main activities performed at each stage in the supply chain for the three focal companies. The map also shows the degree to which each focal company manages and controls the activities. For company A, two different market segments are included.



The part of the chain where company A fully manages and controls operations is longest in the lumber production segment, which accounts for only about 25 percent of net sales. The lumber manufacturing facility is aimed at turning lower quality logs from log production into lumber, mainly for the Japanese market. For this part of the chain, company A maintains control through ownership. Road construction, particularly on private land, is performed by the company's own road construction crews. Forest operations are outsourced to some degree, in particular the logging operations on public lands which must meet certain provincial government requirements. Dryland sorts are operated and controlled by company A, while transportation is mainly outsourced. Log purchases on the open log market provide a benchmark to control the costs of its own forest operations. Company A focuses on cost minimization, while maintaining high volume/value recoveries in forest operations and lumber manufacturing. In situations where there is a mismatch between supply and demand, company A accepts moderate price reductions for lumber as a control mechanism rather than using downtime.

Company A is able to track their logs from the sortyard to delivery at the mill site. In the case of waterborne distribution of logs, tugboat companies are engaged to transport and track log booms to customers. Company A also manages log inventories and delivers wood to a nearby pulp mill. This arrangement is facilitated by a common computer system between the two companies, which is a remnant from the past when the two companies were vertically integrated. For company A, this is the only computer system that is (unintentionally) integrated across firms. Company A considers its cost structure to be highly confidential, sharing information only on individual log and lumber transactions.

Company B manages and controls only a small part of its supply chain prior to the manufacturing step, and is therefore affected by actions taken by other chain members and competitors (**Figure 5**). Company B holds no harvesting rights; approximately 25 percent of its supplies are purchased according to 5 year, renewable logs/chips trade agreements with suppliers. Apart from these agreements, company B has no long-term commitments with other actors in the supply chain. The longest extension of the supply chain, where company B closely manages and controls operations, occurs in its speciality products and remanufactured lumber segments. Here, control is attained through ownership or joint ownership. The numerous major customers remain fairly consistent over time. As a means of fostering this customer loyalty, the emphasis in production is on manufacturing consistent and high-quality goods at the lowest possible costs. This implies a focus on volume/value recoveries, as well as high capacity utilization in lumber manufacturing. However, as sales always occur prior to the actual manufacturing date, downtime is used to prevent the production of unsold products.

In an attempt to reduce uncertainty of demand and price fluctuations for by-products, company C has invested in the production of panels and pulp/paper. The three production segments are, to a large degree, managed independently, with lumber manufacturing being the dominant segment in manufacturing (48% of net sales, excluding retail). With the exception of manufacturing at the mill site, most of the operations, such as harvesting, road construction, inbound transportation and distribution, are outsourced. Company C emphasizes a high degree of control over its forest operations, and forest management planning is the responsibility of its own planning department (**Figure 5**). Low costs are the target for all business operations. For example, logging contractors are benchmarked against the cost of logs from other suppliers and against an annual survey concerning the price of wood delivered to the mill site for forest companies in the BC interior. Sawmill production is rarely impacted by signals from the marketplace, and the primary goals of each mill are maintaining a high yield and high capacity utilization. The production from the different mills provides a stable product mix, with approximately 10 percent of their product lines (in total, there are more than 300 dimensional combinations) accounting for 80 to 90 percent of their manufacturing capacity. The target for company C is cost leadership in the market and, thus, its cost structures are considered highly proprietary information.

Using a centralized computer system, company C tracks its products until they are shipped. The centralized sales department attempts to sell its forecasted production prior to manufacturing. However, when faced with sluggish sales, company C uses downtime to prevent the over-production of lumber. The computerized planning systems are not integrated with transportation providers. Customers inquiring about the status of an order must redirect their inquiry to the transportation provider after the product is shipped. The only integration initiative across functional units was found in the retail segment. Here, company C operated a consignment stock at the company-owned distributor's location. Company C and the distributor jointly determined inventory levels, and the distributor was invoiced when products were shipped to retail outlets. Point of sales information from the retail outlets was not, however, shared with upstream actors in the supply chain.

Lead Time Mapping

To construct the lead time maps, it was, for comparative purposes, assumed that the initial volume of the wood flows for each company was 10,000 m^3, representing 3 to 6 days of production at the sawmills. Although not included in the supply chain maps for this analysis, it should be noted that forest management planning is a complex and constrained task. On public land, where forest companies must comply with provincial government codes, re-planning can become an arduous and time-consuming task. The desired flexibility in planning forest operations is best illustrated by company A, which produced 64 different harvest plans on private lands as customer demand varied throughout one particular year.

Figure 6 shows the lead time map for the supply chain of company A. Road access to mature forests is ensured prior to forest operations. The target for company A is to have accessible forest resources corresponding to 9 months of harvesting. A large proportion of the non-value adding time is in the form of inventories in forest operations. Starting at forest operations, the accumulated lead time for lumber deliveries is approximately 317 days (road construction excluded). Of this, 159 days can be attributed to wood procurement and 158 days to lumber production and delivery (**Figure 6**, summary of the three chains in **Table 2**). Delivery dates are generally flexible for North American and Japanese customers of logs and lumber. Commonly, there is a 1-month interval within which deliveries can be made. According to **Table 2**, approximately 60 percent of the time spent in forest operations is non-value adding, compared to roughly 80 percent for lumber manufacturing and distribution. The horizontal lines shifting upward in **Figure 6** demonstrate operations that are performed concurrently, which reduce the accumulated lead time. For primary transportation, the first 9 days are included, as they are needed to fill the roadside inventory. The last part of the primary transportation is performed concurrently with secondary transportation. Hence, the lead time from the felled and bucked inventory to the water inventory (29 days) is the result of adding times for primary transportation (9 days), roadside inventory (9 days), road hauling (2 days), inventory at sortyard (2 days), and sorting/water transportation (7 days).

Figure 6. Lead time map for the supply chain of company A. Times represented by vertical (inventories) and horizontal (operations) lines reflect reported averages. Vertical shifts in the figure show that operations are performed concurrently.

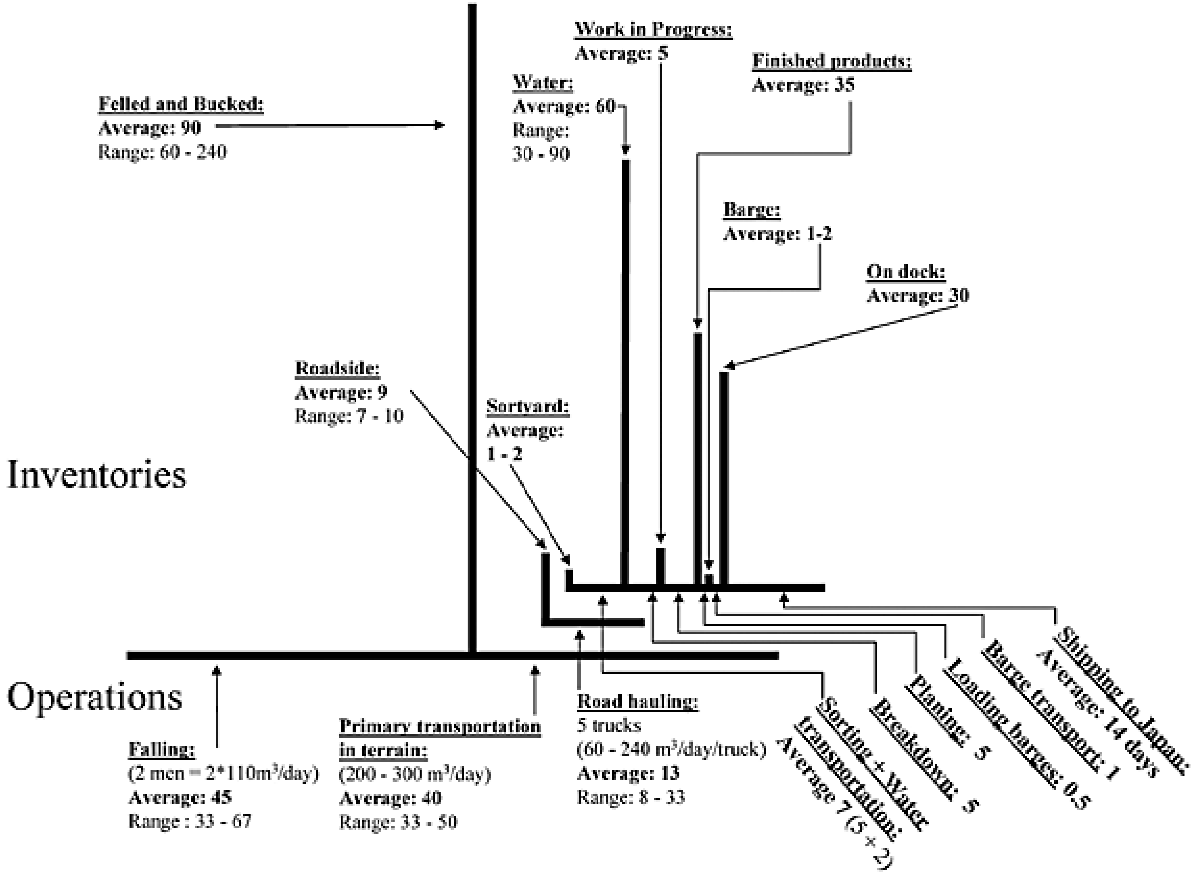


Table 2. Summary of the lead time maps (**Figures 6 through 8**). All values are given in days of production.[a]

Chain	Total material tied in chain	Minimum response time	Accumulated inventory		Time consumption					
			Wood procurement	Manufacturing and distribution	Procurement			Manufacturing and distribution		
					min.	avg.	max.	min.	avg.	max.
A	317	84	101	132	111	159	333	--	158	--
B	390	88	151	151	183	209	415	--	181	--
C	174	42	15	117	26	36	51	103	138	173

[a] As work in process (WIP) inventories and capacities for kiln-drying and surfacing are not known for company B, the information from company C was used (for sawing capacity and WIP inventories/kiln-drying capacity/surfacing capacity).

In the manufacturing operations of company B, the majority of non-value added time can be attributed to inventories of raw materials and finished products. That said, most of the finished products inventory is already destined for specific customers. The proportion of non-value added time in manufacturing is between 75 percent and 85 percent, depending on the size of the WIP inventories, and the capacities for kiln-drying and surfacing. Interestingly, company B and its vendor both kept considerable inventories of logs prior to and after the change of ownership (**Figure 6** and **Figure 7**). When the supply chains of companies A and B are considered together, finished products inventories (for company A) and raw materials inventories (for company B) account for roughly 50 percent of the non-value added time in the chain (more than 140 days). Water transportation times vary considerably from 2 days to several weeks, depending on where the wood is purchased and weather conditions.

Production planning and allocation of production to mills are centralized decisions, based on short-term considerations of the available log supplies and market demand forecasts provided by daily contact with key customers. Lumber sales are based on planned production. The delivery lead-times for finished products can become several weeks, depending largely on the sizes and the number of orders in the order file. That said, company B has flexible export contracts with regards to delivery times and shipped volumes.

Figure 7. Lead time map of the supply chain of company B. Times represented by vertical (inventories) and horizontal (operations) lines reflect reported averages. Vertical shifts in the figure show that operations are performed concurrently. Figures for log procurement are based on information from company A, company B's largest supplier. Lumber inventories are based on values obtained during its peak production period. As WIP inventories and capacities for kiln-drying and surfacing are not known for company B, the information from company C was used (for sawing capacity and WIP inventories/kiln-drying capacity/surfacing capacity).

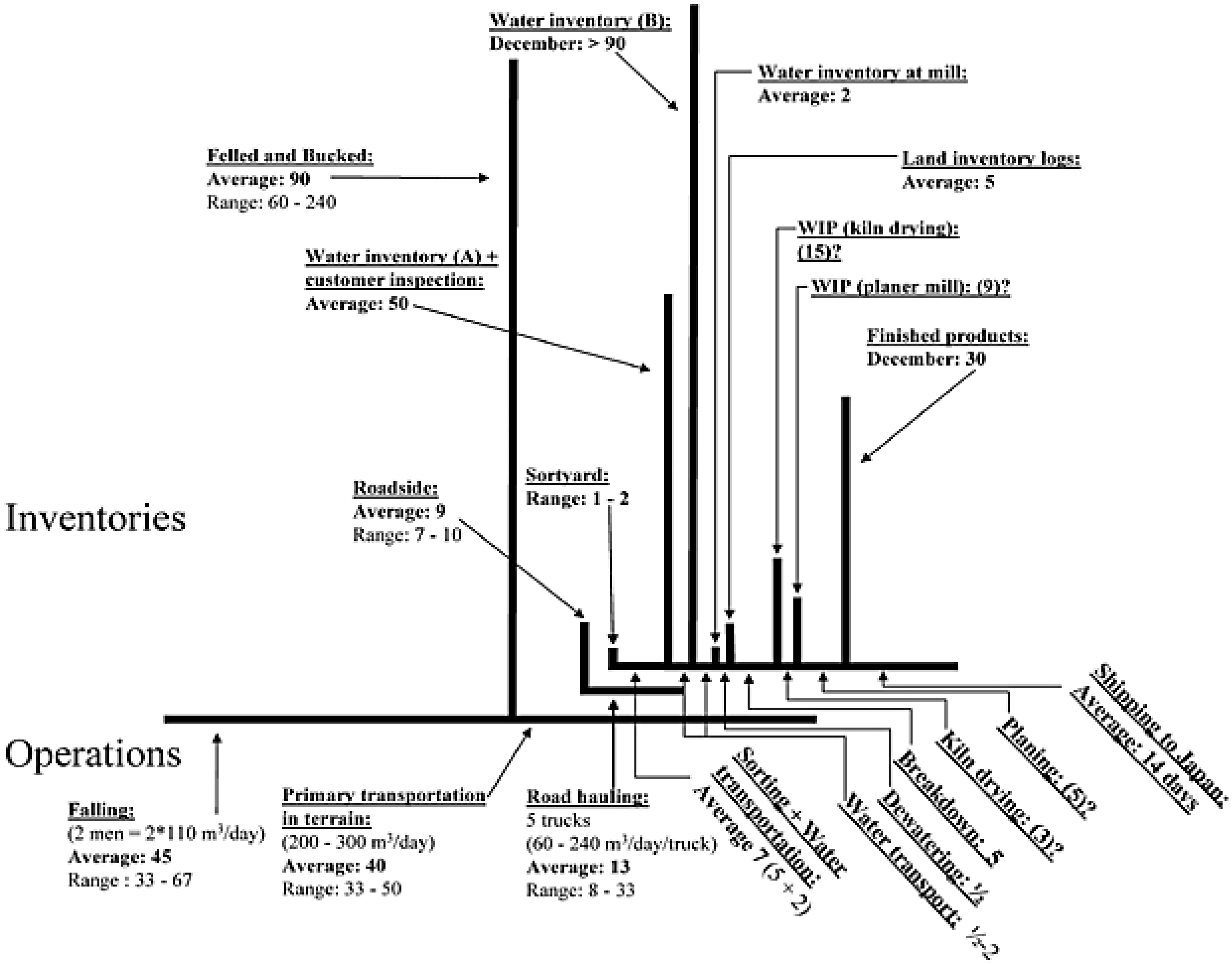
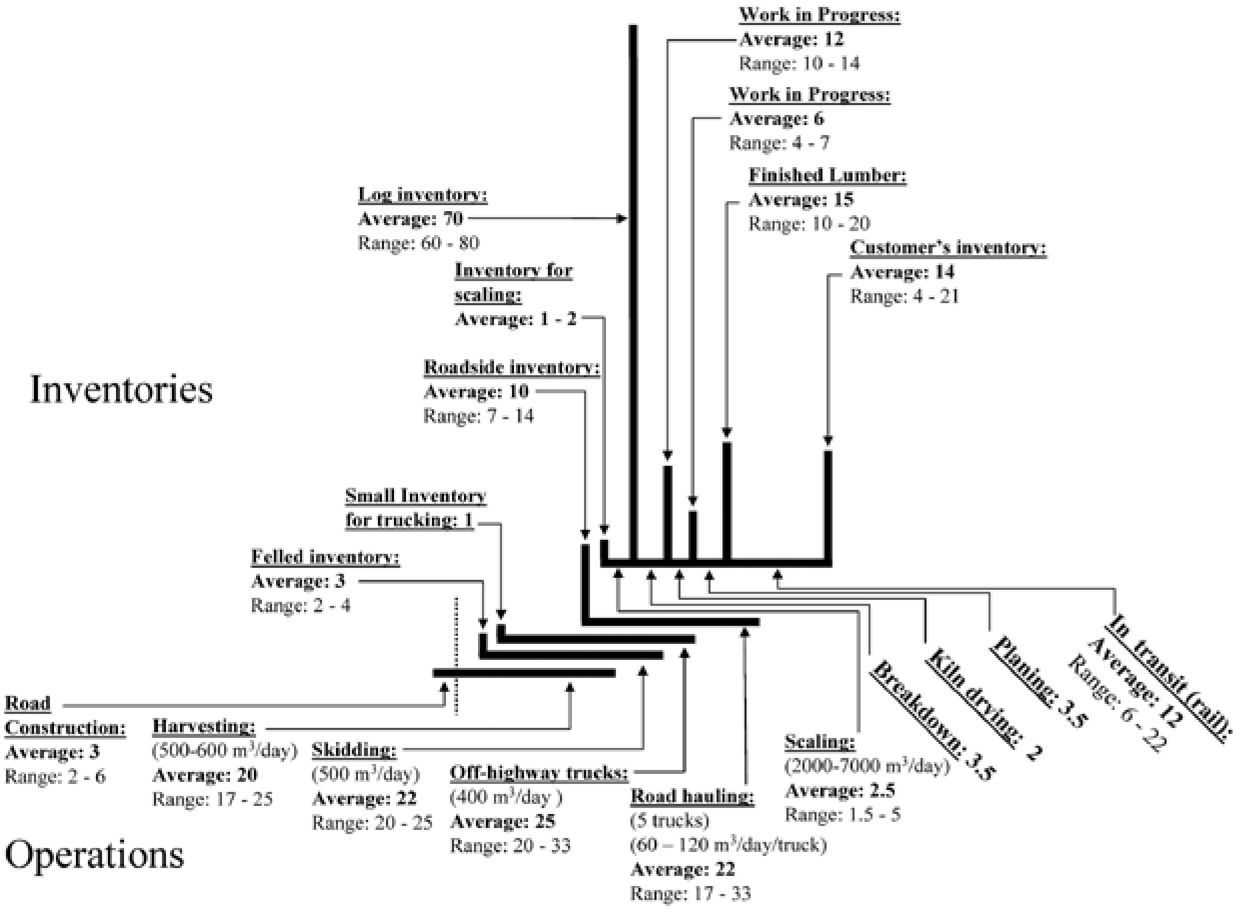


Figure 8. Lead time map for the supply chain of company C. Times represented by vertical (inventories) and horizontal (operations) lines reflect reported averages. Vertical shifts in the figure show that operations are performed concurrently.



Both **Figure 8** and **Table 2** show that the accumulated lead time for the supply chain of company C is approximately 170 days, which is the shortest of the three cases. Of this, 36 days are associated with wood procurement and 138 are associated with lumber manufacturing and distribution. Processes in wood procurement are, to a large extent, performed concurrently. Sawlog inventories at company C's sawmills are generally sufficient for 60 to 80 days of production. The faster throughput is enabled by the concurrent flows in wood procurement, the smaller number of products manufactured, and the subsequent need to maintain smaller inventories. Sales for company C are based on planned production schedules. As a result, delivery lead times for finished products can be several weeks, depending on the size of the order file at the time of sale. Sales contracts are mainly finalized prior to production, which makes the shortest possible delivery lead time almost 20 days, assuming processing of 10,000 m^3 of logs, a daily manufacturing capacity of 2,850 m^3 logs, and delivery to the nearest customers. Using the observed levels of WIP inventories and the range of distribution times from **Figure 8**, the delivery lead time falls between 39 and 72 days. Within its lumber segment, company C maintains accurate inventory information on forecasted production (based on available log supplies and manufacturing capacity), rough production, WIP inventories, and finished products from all of its mills in one common computer system. This system also provides opportunities for the integration of production and distribution through the selection of carriers based on transportation costs for each transaction.

The forecasting period for consumer demand obviously increases upstream in the supply chain and, consequently, the potential gains from a transparency of information decrease. For example, the required forecasting periods for different points along the supply chain of company C[(6)] increase as follows: 3 to 5 days for direct delivery from wholesaler inventory; 13 to 48 days from finished lumber inventory; 46 to 98 days from log inventory; 129 to 224 days from standing forest. Notably, the 3 to 5 day delivery lead time from the wholesaler's inventory is at odds with the 24 hour delivery lead time (across major parts of United States) guaranteed by one of company C's customers.

(6) The average time in stock at the retail outlet is not known.

Discussion

Based on the results of the case studies, the following discussion considers the degree to which the three companies studied align with some of the main principles of SCM presented in the introduction. First, we start with the cases' reported strategies/goals in manufacturing and consider requirements and challenges faced with increasingly emphasizing the customer in the supply chain. The main issues considered here are inventory management and time compression as these are the key elements in supply chain mapping. The subsequent effects on material and information flows are also discussed, with a consideration of how to foster relationships between actors within supply chains. Lastly, the discussion ends with an evaluation of the applied mapping methods.

The consistently reported emphasis on volume/value recoveries, capacity utilization and low-cost production by the three companies is surprising given their structural diversity (documented by the structural mapping in **Figure 5**). Optimizing productivity and costs for a limited part of the chain leads to sub-optimal results for the entire chain (Holmberg 2000; Pulkki 2001). In addition, this sort of strategic focus assumes infinite demand for all products, representing a low degree of customer focus and, ultimately, increasing the probability of obsolescence and price markdowns (Markgren and Lycken 2001). For companies B and C, a consequence of this production focus is that they commonly use downtime to avoid flooding the marketplace with their products. Although preferable to large and unsold inventories, the use of downtime for inventory control indicates an imperfect fit between customer demand and manufacturing and should be regarded as a last resort. Company A, on the other hand, has long lead times in production and a diversified market and prefers a price reduction tactic over the use of downtime. To serve their markets, such companies need to either maintain large inventories of numerous products, or have flexible production systems that enable changes in product mixes on short notice.

A second indication of a low degree of customer orientation in these cases relates to the loose requirements for on-time delivery and delivery speed (seen in **Figure 8**, for example, as variation in finished product inventory and time spent in transit). One issue may be that customers accept uncertainties in deliveries by keeping safety stocks, which may serve to discourage suppliers from improving their delivery performance. For example, house construction firms in Scandinavia have shown poor logistical performance and little concern for the final consumer with respect to on-time delivery (Olsson 2000). This sort of attitude to customer relations can easily be transferred upstream in the supply chain, resulting in a narrow production focus aimed at optimizing autonomous units along the chain. To successfully adopt SCM methods across the supply chain, improved communication of customer needs between actors is required (Chopra and Meindl 2001). Designing effective communication systems and procedures often requires a re-thinking of how material flows are organized with respect to initiation and control.

Mason-Jones and Towill (1997) have shown that access to point-of-sales information during the production planning process provides benefits to decision makers in operations planning, even for actors further upstream in the supply chain. The value of point of sales information increases as lead times are reduced, mainly through improved forecasting accuracies. In each of the three case studies, production plans were pushed through the system, while seeking to maximize recovery (value/volume) and minimize costs. A key objective in the sales and marketing departments of companies B and C is on selling the forecasted output prior to actual manufacturing. An alternative strategy could be that flows are increasingly controlled by pull-principles, wherein the needs and requirements of customers are the primary concern. This, however, puts a strong emphasis on lead time reduction, as customers generally require short delivery times.

A frequently proposed means of reducing lead times and inventories in supply chains is with the removal of intermediaries (van Ackere et al. 1993; Towill 1996). The delivery lead times from the case mills' lumber inventories were often 2 weeks or more (**Figures 6 through 8**), in contrast to the 24 hour delivery across the United States guaranteed by one of company C's customers. Even though company C has a company-wide system for inventory control in place, direct deliveries would likely result in a significant increase in delivery lead times, unless they were able to coordinate their efforts with their customers and transportation providers. Hence, pull-based manufacturing with direct deliveries is difficult when there are strict requirements concerning delivery speed. An additional obstacle to pull-based flows is that suppliers delivering products on a JIT basis commonly experience increases in inventories unless they are implementing pull-principles within their own operations (Waters-Fuller 1996).

The divergent flows in wood manufacturing make hybrid solutions relevant for production planning. Products with predictable outcomes and stable demand can be managed according to pull-principles, while consequence products and products with unpredictable outcomes and volatile demand can be managed using push-principles (Nerman 2000). For this hybrid strategy to be successful, updated information on markets and prices (e.g., point of sales (POS) information) must continually be made available to decision makers. Maness (1994) showed that an increase in the frequency of price updates in optimization software for lumber manufacturing could improve profitability. When the target for production is based on incoming orders and inventory costs are included in multiple period models (e.g., Maness and Norton 2002), it becomes possible to model how the net revenues are affected by changes in factors such as production strategy, market shifts, inventory costs, and log supply (Maness 1994). However, even with access to POS information, there is a need to forecast the market development 50 to 100 days into the future due to the long lead times from the log inventories to finished lumber inventories (**Figure 6 through 8**). Hence, significant lead time reduction, through speeding up material and information flows, becomes crucial. As lead times in production and distribution will vary for different products, it is essential to identify those product/customer combinations for which quick responses are required to increase the level of customer satisfaction. This strategy may be applied, even for large integrated companies, such as Company C. It then becomes possible to differentiate the company in the market based on reliable and flexible deliveries and customer satisfaction, rather than short delivery lead times and low prices.

To achieve this, actors in the supply chain should be encouraged to share information (e.g., POS-statistics, planned production, inventories) across companies. Although rare, some forest products companies currently share information on supply and demand, typified by “vendor managed inventories” (VMI). Here, the vendor owns and manages inventory at the customer’s location and can access demand data for planning and inventory control. That said, the solid wood products industry has been slow to adopt methods for the electronic transfer of information (Dupuy and Vlosky 2000), which is a prerequisite for the effective application of VMI. Rapid and effective transfer of information can be readily achieved through SCM software (Kenny 1999a; McLean 1999). The success of such software in the forest products industry is, however, not well documented, with most information available only from software developers.

For information to be shared among actors in a supply chain, relationships between customers and vendors must be based on trust (Mattsson 2000). Unfortunately, the degree of trust has been observed to be low in supply chains within the forest industry and customer-vendor relationships are often adversarial (Vlosky et al. 1998; Andersson et al. 1999). Tan (2001) claims that a shortage of raw materials in an industry (which was the situation in British Columbia during the course of this study) makes supply chain integration a difficult proposition. This is further complicated by the fact that lumber manufacturers in this study prefer having numerous small customers (less than 15% of sales each) to reduce the impacts of demand fluctuations and to avoid overly influential customers, thereby making their customer bases large and potentially volatile.

Supply chain integration is easier to implement with a small number of large customers. For example, Kozak and Cohen (1997) found that trust between a supplier (lumber manufacturer) and a customer (wood products distributor) was encouraged with a single sourcing strategy. A sawmill owned by Boise Cascade Corp. reduced the number of main customers that they had from 30 to 4, while tailoring the characteristics of their product offerings based on customer needs. The sharing of risks and returns resulted in stabilized sales and a relationship with mutual stakes and benefits (Peterson et al. 1999). In this case analysis, the reluctance to share information and cost structures with customers and suppliers is an indication of an excessive focus on product price across supply chains. This reluctance may also prevent improved coordination through the development of relationships based on trust. A general trend in industry development, also evident in this study, is consolidation (Mattsson 2000). Company C has grown through acquisitions, and company B was acquired by a larger lumber manufacturer prior to completion of this study. As customers and suppliers become larger, the potential benefits from partnering increase (Lambert et al. 1996).

Other factors which inhibit supply chain integration include long lead times, limited and inaccurate inventory information, and potential language barriers. For example, in company A, very little information about the quantities of different log types produced is available prior to the sortyard (**Figure 6**). Presently, a hybrid strategy is applied through a combination of long-term delivery agreements and sales at local log markets. Lower quality logs are manufactured into lumber by company A’s sawmill, thereby offsetting some of the consequence products from forest operations.

Company B has a short planning horizon and can potentially reduce uncertainties in supply and demand by closer coordination with its customers and suppliers. A further problem for both companies A and B in that respect is that most of their lumber exports are shipped to Japan, where cultural and language barriers make increasing the level of trust between organizations an even more challenging proposition.

Company C can initiate efficiency improvements within their own company because it controls a large fraction of the supply chain through ownership. This requires effective communication and acceptance of the overall strategic goals across all of the company divisions. In such a complex organizational environment, it is often difficult for each actor to see how they impact the overall goals of the company. This can negatively affect overall efficiencies and performance. In fact, different sub-units within a large company may have conflicting goals, and costs may be shifted between departments without improving the overall performance of the company (Lambert and Cooper 2000).

Clearly, increasing the focus on improving the fit between production and consumer demand requires rigid attention to the reduction of lead times and inventories. This is most effectively achieved by a holistic approach and requires close cooperation and trust across company borders. In order to move the SCM concept forward in the forest products industry, a shift in the mindsets of customers and suppliers will need to take place, from conducting business in an opportunistic and sub-optimal manner to focusing on how to improve the overall efficiency of supply chain processes.

Appropriateness of Methods

The methods presented here for mapping supply chains with respect to ownership structure and lead times are intended as a first step toward a better understanding of supply chain integration for forest products companies. While these methods previously have been applied primarily to industries with converging flows (unlike most of the forest products industry), they should be of interest to the forest industry, where the priorities have been on optimizing operations with little regard to customers and suppliers within the supply chain. That said, other methods for mapping supply chains exist[(7)] and warrant further investigation with respect to their appropriateness within the forest products sector. However, many of these other methods were not suitable for this study due to their scope being too wide (e.g., Lamming et al. 2000) or their requirements for detailed information (Bartezzaghi et al. 1994; Hines and Rich 1997). A recommendation for further research in this area would be to apply mapping methods with increased levels of detail (e.g., Bartezzaghi et al. 1993; Hines and Rich 1997; Lindroth 2001) in order to better identify potentials for improvement along supply chains and to develop appropriate performance measurements applicable to processes involving more than one company.

(7) These methods include *quality filter mapping* – for identifying causes of defects; *demand amplification mapping* – for identifying where demand is distorted; *process activity mapping* – detailed mapping of characteristics and lead times for processes; *physical structure* – for identifying the number of actors along the supply chain and how costs accumulate toward the final consumer; and *the product variety funnel* – for describing the degree of divergence or convergence along a supply chain expressed as the number of products observed at each stage in the supply chain.

The methods presented in this paper allow companies to learn more about their respective supply chains: their relationships and roles, the activities performed at each stage, and the inventories and time consumption required to meet demand. One major benefit derived from applying supply chain mapping methods is that communication improves between actors, customers, and suppliers. Constructing the maps and improving supply chain integration generally requires a joint effort from all actors along the supply chain. However, collaboration and information sharing can be troublesome for some companies due to the fact that forest products supply chains typically consist of complex networks of actors that may have adversarial relationships (Vlosky et al. 1998).

Learning about the time consumption required for each stage in the supply chain also serves to create a common understanding of how each actor can contribute to improvements in flows. Specifically, firms should identify the information that is required at each step, how operations can be simplified, how products can be manufactured to better fit the next link in the supply chain, and what the ideal properties of the final products are. Creating a common understanding of the processes in the supply chain and developing new procedures for management and control of material flows will become paramount in the years to come – the nature of competition is evolving from between companies to between supply chains (Christopher 1998; Mattsson 2000; Scott and Westbrook 1991).

Without a doubt, there are difficulties in applying these mapping methods to the forest industry, particularly in the case of lead time mapping. Problems to be overcome include adequately depicting the divergent flows of materials and the occurrence of large amounts of consequence products. Mapping methods must also be able to deal with the uncertainty of production characteristic to the forest products industry. For example, there is large variability in the costs of forest operations and transportation due to the spatial distribution of and variation in raw materials. Also, product recovery is highly dependent on the quality of logs which, in turn, is affected by the quality of the forest of origin and by the selected bucking patterns. Consequently, supply chain mapping may be better suited to the supply chains of individual mills, rather than a network of horizontally integrated plants. That said, when detailed information is available, lead time maps can and should be constructed individually for each tree species, or alternatively, each product.

Conclusion

In the forest products industry, many actors are involved in the supply chain for a particular product between the forest and the final consumer. Supply chain management seeks to integrate actors and eliminate inefficiencies by adopting a customer focus. The goal of SCM is to improve the profitability and competitiveness of all actors in the chain. In essence, it seeks to view the supply chain as if all actors were vertically integrated into one large company. The supply chain should preferably be managed holistically, even if the goals of some of the actors may be at odds.

In this paper, two methods for mapping supply chains in the forest products industry were presented. The mapping methods were applied to three cases from western Canada in order to evaluate their ability to describe supply chains within the forest sector. This was taken as a first step toward supply chain integration. Despite some shortcomings, these mapping approaches make it possible to analyse forest industry supply chains and identify possibilities and constraints for aligning market demand with timber supply from alternative forest types. The mapping processes yielded promising results with respect to creating an overview of supply chain structure, time consumption, and inventories. However, in order to better fit within the context of the forest products sector, the mapping methods must be improved to include diverging flows, changing product identities, and consequence products.

This paper shows that material flows in the forest products industry are primarily focused on push marketing of price sensitive commodity products. The primary methods for improving efficiencies along a commodity-based chain involve increasing throughput and capacity utilization and reducing work in process inventories. However, the long lead times characteristic to the forest products industry make it exceedingly difficult to control inventory. Consequently, SCM principles have not been widely adopted in the forest products industry to date. That said, the successful implementation of SCM methods will prove extremely challenging unless the actors within supply chains can shift their mindsets toward an efficient fulfilment of customer needs rather than solely optimizing of their own operations.

This paper has also identified some of the key challenges to applying existing SCM mapping tools to the forest products industry. These are primarily related to the distinguishing characteristics of the solid wood sector itself: uncertain raw material supplies, variation in raw material quality, the production of large amounts of consequence products, and a commodity approach to production and sales. For these reasons, the authors recommend that existing tools be modified to better serve the forest products industry. This would form the basis of an excellent future research project.

Literature Cited

Andersson, J. 1999. On activity based costing in supply chains. *In:* Building New Bridges in Logistics. Proceedings from the 11th Annual Conference for Nordic Researchers in Logistics, E. Larsson and U. Paulsson, eds. pp. 141-156.

Andersson, P., J. Bendz, L.O. Rask, and V. Svensson. 1999. Den logistiska flödesprocessen från skog till bygge – Struktur, funktioner, problem och potentialer. (The logistical flow process from forest to construction – Structure, functions, problems, and potentials.) Rapport från projekt Skogsresurs Logistik. Växjö Universitet. [In Swedish]. 76 pp.

Andries, B. and L. Gelder. 1995. Time-based manufacturing logistics. Logistics Information Management. 8 (3): 30-36.

Ballou, R.H. 1999. Business Logistics Management – Planning, organizing, and controlling the supply chain. 4th Ed. Prentice-Hall International, New Jersey, USA. 681 pp.

Bartezzaghi, E., G. Spina, and R. Verganti. 1994. Lead-time models of business processes. International Journal of Operations & Production Management. 14(5): 5-20.

Bechtel, C. and J. Jayaram. 1997. Supply chain management – A strategic perspective. International Journal of Logistics Management. 8(1): 15-34.

Bovel, D. and J. Martha. 2000. From supply chain to value net. Journal of Business Strategy. 23(4): 23-28.

Bowersox, D.J., P.J. Daugherty, C.L. Dröge, R.N. Germain, and D.S. Rogers. 1992. Logistical Excellence – It's Not Business as Usual. Digital Press, Burlington, Vermont, USA. 246 pp.

Burbidge, J.L. 1994. The use of periodic batch control (PBC) in the implosive industries. Production Planning & Control. 5(1): 97-102.

Carlsson, D. and M. Rönnquist. 1999. Wood Flow Problems in Swedish Forestry. Skogforsk Report No. 1, 1999. Uppsala, Sweden. 48 pp.

Chopra, S. and P. Meindl. 2001. Supply chain management: Strategy, planning, and operations. Prentice Hall, New Jersey, USA. 457 pp.

Christopher, M. 1998. Logistics and Supply Chain Management – Strategies for reducing cost and improving service. Prentice Hall, London, England. 294 pp.

Cooper, M.C., D.M. Lambert, and J.D. Pagh. 1997. Supply chain management: More than a new name for Logistics. The International Journal of Logistics Management. 8.(1): 1-14.

Croom, S., P. Romano, and M. Giannakis. 2000. Supply chain management: An analytical framework for critical literature review. European Journal of Purchasing & Supply Management. 6(1): 67-83.

Dupuy, C.A. and R.P. Vlosky. 2000. Status of electronic data interchange in the forest products industry. Forest Products Journal. 50(6):32-38.

Ellram, L.M. 1991.