# The E-nable Supply Chain – Opportunities and challenges for forest business

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September 2004

Working Paper DT-2004-JMF-1

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## Abstract

Supply chains are composed of complex set of networks representing multiple organizations that often have conflicting objectives (Simchi-Levi *et al.* (2000)). Supply chain management has the goal to integrate these networks of suppliers, manufacturing centers, distribution capacity and customers into a system improving operational efficiency and customer service. The objective is simple: the best performing supply chains are ones that best match supply, manufacturing and distribution to demand. In such a context, *Information & Communication Technologies* (ICT) are necessary for both the development and execution of the forest supply chain. This paper proposes to describe the main components of the forest supply chain and to discuss some of the opportunities and challenges for business organizations and the research community with regard to the development and adoption of ICT to support its operations.

# I. Introduction

The current forest business environment is one of increased global competitiveness both within the forestry sector, with the rise of plantation forests in the southern hemisphere and the increased production from Russian forests, and from substitution by non-wood alternatives such as steel and masonry products. Companies must find methods to increase their operational efficiency while meeting increasing service expectations if they are to prosper in the future. Jones (1999) states that typical firms can improve multiple supply chain performance measures through improved planning and communications among organizations. These include a reduction in inventory levels between 15 to 60%, improved delivery to customers by 20 to 30% while still reducing their supply chain costs by 20 to 30%.

## a. The forest products industry supply chain

The FPI supply chain is unique among businesses due to a number of factors. First, the time frames used in the forest industry are much longer than most businesses with rotations lengths, i.e., the time for a tree to be grown, varying from a minimum of 5 years for tropical hardwoods to over 100 years for boreal conifer species. These timeframes exceed almost all other industries. They result in large uncertainties regarding the markets that these products will likely satisfy, but also the ability and the performance of the supply chain to satisfy these markets. In addition to this large uncertainty regarding the demand, forest companies have significant sources of uncertainty and variability in the supply portion of the supply chain. This variability includes the spatial variability regarding the distribution of trees within the forest. This results in poorly controlled product flows from harvesting to order fulfillment. Raw material properties such as density, modulus of elasticity, knot size and lignin content vary significantly between trees, stands and forests and can affect the type and quality of products that can be produced, as well as the efficiency of the transformation process. These many sources of variability, which are usually known but not necessarily modeled, should be included in planning and scheduling tools at all levels of the supply chain in order to reduce their impact on the business (Antanies (2002)). However, it is the uncertainty due to a lack of knowledge that requires a long-term commitment to data collection at all levels that will in turn be used to gain additional knowledge and control over supply chain operations. It seems consequently that one of the roles of ICT is to capture, store and communicate such information to supply chain partners, while another role of ICT is to use this information to offset these multiple sources of variability.

From the wood transformation perspective, the forest business is a divergent activity where trees are cut to produce a variety of logs and each log type is further converted into lumber of various sizes and grades. The result is a co-production of products that requires a combination of pull-push supply chain management practices in which customers' demand pulls a portion of the forest products while another portion that may exceed demand is pushed through the supply chain to be sold only after it is produced (or forecasted to be produced).

Given this inherent complexity of the forest supply chain, it seems clear that successful forest companies will be ones that adopt and use ICT to appropriately manage this complexity so as to gain the necessary operating edge to meet the new economic challenges.

## II. Acquisition, sharing and use of information in the forest products supply chain

The FPI supply chain is quite different from other sectors for which the use of ICT to acquire, share and use information to make decisions is well developed (though still far from being generally used). As many aspects regarding the use of ICT are specific to this industry, several issues must be addressed in order to face the new challenges of the global and digital economy.

Managing a supply chain can be seen as making decisions regarding many aspects of a company's activities, including what and when to buy/produce/distribute, from which supplier, to what market, how to manufacture products and design new products, how to distribute them, etc. All this in order to acquire raw materials, transform them into components and finished goods, and distribute them to consumers. From an ICT perspective, making these decisions requires the use of information that represents the states (past, present and future) of the system to control and its environment, and the nature of the decisions to be made. The latter aspect includes representations of what can be controlled and what is a given (which may include the output of other decisions), respectively referred to as the decision variables and the parameters. It also includes the relationships between the decision variables and on the one hand, a set of objectives to minimize or maximize, i.e., the objective function, and on the other hand, the limits of the system to control and its environment, i.e., the constraints.

In order to simplify the process of decision making, the information that is used is usually a simplified representation of the decision context that contains an appropriate level of details. In particular, because of the bounded rationality of human managers and the limited computational capacity of decision support systems, decision making only takes into account a limited amount of information. Hence, long- and mid-term decisions usually use information that is aggregated in terms of product family, time bucket, or geographical zone. Such representations are built from information that is either collected at the level of the system to control (e.g., forest inventory, and machine capacity), shared with business partners (e.g., demand forecast and transactions, and delivery plan), or jointly created with business partners (e.g., demand forecast, supply plan and promotion plan).

In companies, decision making can be IT-supported to various extents. Traditionally, in the FPI, decision making relies mainly on human managers who have their own understanding, i.e., representations of the decisions to make and their own rules to help them use the available information to make these decisions. Thus, a consequence of the introduction of a new *Information System* (IS) to support a company's operations and decisions is directly concerned with the acquisition, the transformation and the use of information. This paper proposes to discuss these issues with a particular emphasis on the challenges faced today by the FPI, and the challenges that are still in the domain of research.

### a. Transactional and analytical ICT in the FPI

Most IT-enabled companies have focused their attention on the adoption of IS in order to support their handling of raw information related to their customers and suppliers, including customer and supplier accounts and transactions, or related to the execution of their manufacturing operations, i.e., *Manufacturing Execution Systems* (MES). Shapiro (2001) explains that this type of IS is referred to as *transactional IT*, in reference to the transactional data it handles. The author explains that transactional ICT is concerned with acquiring, processing and communicating raw data and with compiling and disseminating reports that summarize these data. In companies, this type of ICT is generally introduced for financial purposes allowing top management to monitor the financial situation of their company. Such ICT includes *Enterprise Resource Planning* (ERP) systems, which facilitates the flow of raw data that is usually stored in one central repository (i.e., database), and at controlling data ownership throughout the company (i.e., rights to input, access, modify or delete information) in order to maintain the consistency of these data for all applications (i.e., data are entered only once). Even though ERP systems are sometime criticized for (1) their lack of flexibility to adapt to companies' processes and products representations, and (2) their limited compatibility with other IS, they are considered as a company's information backbone. In the FPI, most large companies have adopted ERP systems. However, few have pushed beyond the basic adoption of IT. Except for the paper industry where the level of adoption is usually more advanced, few companies have adopted IS to directly address decision making.

Because faster communication of transactional data cannot provide a competitive advantage to companies, Shapiro (2001) explains that companies must distinguish between transactional ICT and *analytical IT*. Analytical ICT aims at supporting supply chain planning problems using informational representations that describe, on the one hand, the state (either measured or assessed) of the system to control and its environment, which is referred to as the *descriptive models*, and, on the other hand, the nature of the decisions to be made, which is referred to as *normative models*. Figure 1 proposes an example of such decisions for the lumber industry. Descriptive models are the representations that are necessary to specify decision making contexts. In the FPI, they include among others channel demand forecasting models, managerial accounting models, forest inventory assessment models and input-output-process mix models. The structure of these representations are usually not identical to the raw data representations in ERP systems, which is often a source of numerous integration problems between transactional and analytical IT. Therefore, this requires the use of separate decision databases[1] as well as methods to aggregate raw data into representations that are usable for decision making. In addition to the descriptive models, normative models, sometime called *optimization models*, are used to describe relationships between decision variables and parameters. In brief, these models are used to describe, through mathematical relationships, the complete set of decision options

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[1] The reader is referred to Shapiro (2001) for a detailed description of decision databases.

available to managers and how these options affect the objective function, which may take into account many conflicting goals[2]. With such models, managers can evaluate the impact of various scenarios and various supply chain decisions in terms of goal achievement before making their final decision.

### b. General ICT challenges in the FPI

Many studies have shown the lower ICT adoption rate of the FPI compared to other industrial sectors (Vlosky (2002)), Karuranga *et al.* (submitted), Kozak (2002)). As mentioned previously, except for the paper industry which usually exhibits higher ICT adoption rate, applications of ICT in the FPI appear to be restricted to roles that do not involve supply chain planning and decision making support, which is most entirely left to human managers and their ability to develop spreadsheet applications. Whatever the reasons behind these lower adoption rates, this is certainly one of the most significant challenges in the FPI. Unfortunately, it is not the only one.

For instance, as discussed previously, the FPI faces numerous sources of variability which are directly related to the heterogeneous nature of the forest and the fiber. These sources of variability are currently far from being perfectly modeled, thus introducing many uncertainties in the process of decision making, which in turn force managers to compensate by larger inventories, longer response time, all the while missing business opportunities. In this context, it appears that having more information and more realistic representations of these sources of variability, or sharing interpretations of variability (e.g., demand forecast, forest inventory data) with business partners, can certainly improve decisions by reducing the uncertainties that generally flaw the performance of the forest products supply chain.

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[2] This may be done through an approach known as goal programming.

Another challenge faced by the FPI is related to the adaptation of its business processes in order to cope with the new economic reality. This is particularly true for the lumber industry in North America, which is still entrenched in old organizational paradigms which led it to invest in advanced production technology to optimize production cost and transformation efficiency, at the stake of organizational agility. This challenge notably includes the definition of logistic and decision models that can optimize (i.e., streamline, coordinate) supply chain operations through the use of *operations research* (OR) techniques. Such normative decision models are usually driven by the goal of finding the least cost scenario of customer orders fulfillment subject to constrained capacity and service levels. Unfortunately, there is a lack of such tools commercially available that can provide the FPI with specific planning support (Van Horne *et al.* (2004)). This may exacerbate the already low ICT adoption rate of the industry.

Another ICT challenge faced by the FPI concerns the growing trends of certification. Indeed, certification requires a range of information monitoring activities and new management practices in order to keep track of the origin of the harvested, transported and transformed resources from the forest to consumers, so as to guaranty the nature of the forest management practices from which products originate. Because the forest products supply chain often involves many companies, this raises another challenge related to the adoption of standards and open interfaces to facilitate information exchange across companies.

Finally, another challenge concerns the way companies do business together and the tools they use to support them to do so. E-business is usually defined as the "e-commerce functions (i.e., action of buying and selling over digital media) and includes both front- and back-office applications that form the engine for modern business media" (Kalakota and Robinson (1999)). In other words, it not only encompasses the way business partners are identified and transactions are negotiated and concluded, but also the way orders are planned, fulfilled and tracked across the supply chain and payments are made. It also includes the way longer-term contracts involving information sharing are technologically supported. A large range of applications, including services to find business partners and sell and buy products hosted by third party services providers, are commercially available to support these processes. However, as mentioned previously, the general low ICT adoption rate of the FPI makes it difficult to push further the adoption of such specific applications for which additional barriers may discourage companies (e.g., security issue and mistrust related to real-time data sharing). Furthermore, the adoption of e-business technologies is somewhat limited by the lack of available technology dedicated to the industry, known as the back-office, and in particular analytical IT. In other industries, e-business indeed builds on back-office technologies that enable partners to seamlessly access production plans, inventory data and even product location during transportation so as to support the organizations to coordinate their activities. E-business is about coordinating the supply chain.

## III. Role of ICT to support supply chain operations

This section proposes a description of the role of ICT regarding many aspects of supply chain operations in the FPI. However, this description does not follow the traditional path from the forest to consumers, but rather the opposite in order to emphasize the need to adapt the ability of forest products companies to quickly react to market changes and new customer expectations.

### a. Demand Management

*Demand Management* (DM) is a crucial supply chain operation which consists in many activities and decisions to be made (see Figure 1, demand planning and demand fulfillment/order promising). The aim of DM concerns the process of managing the fulfillment of customer orders in order to achieve the product-market strategic objectives of a company, subject to its generally geographically distributed capacity to satisfy the demand. At the tactical level, as depicted in Figure 1, this includes the management of the different customer segments and the allocation of capacity to these segments in order to coordinate the many facilities required to achieve the strategic objectives. At the operational level, this also includes the process of *order promising*[3] which aims at promising fair prices and reliable delivery dates to customers. DM may also include *revenue management* considerations by selecting within the overall company's strategy the customer orders that are the most profitable to fulfill[4].

In order to be efficient, DM first requires knowing the various markets to be served. Many forest products companies serve markets that are heterogeneous and dynamic. For instance, research in forest products marketing shows that lumber, even though it is often considered as a commodity product, is sold to various market segments that behave differently (e.g., long-term contract, spot market) and have different profitability and demand pattern/seasonality. DM includes the forecasting of each market segment's demand and profitability in order to manage the revenue of a company so as to decide how to allocate production capacity to market segments. Finally, DM is also concerned by the process of allocating orders to mills. Supply chain operation planning is

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[3] *Order promising* aims at determining in real time reliable order delivery dates, generally through the use of two methods. The first method is known as *Available-to-promise* (ATP). When a customer requests an item, ATP allows companies to quickly scan all locations within the company to determine current stock position, which includes both on-hand inventories and non-allocated inventories to be produced (from the production plan). Basically, ATP allows answering the questions: when do I have the inventory necessary to fill the order, and if I do not have the inventory for the required date, do I have the inventory to fill the order with other substitution items? Some ATP systems take into account that ATP can be allocated (referred to as AATP) to particular market segments defined either geographically or not. The second method is known as *Capable-to-promise* (CTP). If the company does not have the inventory (i.e., no ATP available to be promised), CTP allows evaluating a company's finite capacity and material constraints in order to determine whether or not the order can be produced and delivered. Finally, advanced order promising systems also include another tool known as *Profitable-to-promise* (PTP), which aims at evaluating the best way to meet the customer's needs while maintaining expected margins. Such tools are usually rule-based. They exploit cost and profit information to support companies to make informed decisions regarding possible order fulfillment options.

[4] Revenue management is used for instance in the service industry when the customer segments that may be served by companies have different profitability and potential sale volume.

then concerned by coordinating the order-driven part of the company's supply chain with the part of the supply chain that is not geared up to *produce-to-order*.

### *Demand management opportunities for the FPI*

Many of the DM-related opportunities for the FPI are similar to those of others sectors, which include the improvement of (1) their ability to provide customers with reliable promises and a greater visibility of their order status; (2) their ability to provide accurate and reliable business intelligence and forecasts, and (3) their ability to sense market changes in order to improve their reactivity and their ability to take advantage of business opportunities. Even though DM is one of the most fundamental processes of a company, few companies in the FPI are equipped with proper ICT tools to face these challenges. If most large companies use transactional ICT to support the management of their customer accounts and transactions, few are indeed geared up with tools to meet these challenges so as to make clever DM decisions.

Another opportunity concerns the adoption of order management technologies which encompasses a set of DM tools that aims at managing customer orders throughout their entire lifecycle within and across organizational boundaries. Order management includes the capture of orders, their administration throughout the various functions of organizations, as well as the management of financial settlements and invoicing. Because it enhances the visibility of the customer order cycle across the supply chain and the ability to provide more reliable promises to customers, order management technology can support forest products companies to improve their control over all customer satisfaction.

Similarly, business intelligence encompasses various analytical tools which aim at enhancing the ability of a company to identify relevant information that can improve its response to its customer demand, and consequently, its ability to meet its strategic business objectives. Among these information systems, traditional forecasting tools such as Forecast Pro™ propose solutions that apply well known forecasting methods to demand data in order to build accurate demand forecasts. Forecasting is especially crucial in the FPI because of the forest's heterogeneous nature. Companies must indeed be able to accurately predict demand in order to specify in advance where to locate harvesting operations and the required equipment in order to best meet the demand (see section about logging and forest assessment). Forecasting is challenging because forest product companies must be able to handle both short-term business requirements and long-term forest growth and sustainable development. Finally, forecasting performance needs to be continuously monitored in order to constantly improve forecast accuracy and consequently decrease the need for large safety stocks across the supply chain. Along the same line, data mining[5] tools are also applied to demand management in order to extract information from large amounts of transactional data in order to predict future demand trends and help companies improve the way they allocate their offer to customer demand and consequently increase their profit. Data mining tools are also applied to analyze the impacts of marketing strategies on the demand such as promotion, or to identify customers whose demand patterns may indicate that they may leave, in order to give these customers particular attention.

### *Demand management challenges for business and research*

The DM-related challenges for business and research include other aspects as well. The most challenging of these aspects concerns the development of new customer-centered business models that exploit the Internet in order to (1) interact in a personalized manner with customers, which is usually addressed by technologies known as *Customer Relationship Management* (CRM); CRM allows companies to retain individual information about each customer in order to

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[5] Data mining applied to demand management consists in the use of ICT tools in order to automatically extract hidden information that can be used in order to predict future trends of customer behavior or demand patterns from data warehouses (i.e., large databases) containing customer transaction data.

better identify their needs and behavior; and (2) coordinate supply chain operations across organizations (see sections related to logistics and manufacturing). Leading edge companies in other sectors, such as DELL in the computer industry, already propose a single face to customers in order to advertise product availability, promise delivery dates, sell products, and track order status through the Internet. Many business models can be developed and implemented to support on-line transactions[6]. In particular, an important challenge concerns the development of on-line order promising capability (e.g., through the implementation of web services available to selected customers), which may be considered as an advanced form of e-business (i.e., customers could have an on-line access to what is really available to them whether it is on-hand or in the production plan). This challenge also includes a company's ability to sense demand and react to events and opportunities.

Finally, in order to be more competitive, forest product companies will need to develop and implement IS to support and manage their profit more efficiently. For instance, companies may develop analytical (either rule-based or optimization) models to assess order profitability in real-time in order to optimize the allocation of their offer to the demand with respect to their business objectives and logistics constraints. Such tools push the concept of Order Promising further to include the concept of profitable-to-promise. These tools are also critical for the development of a company's ability to evaluate the profitability of order changes and respond adequately to these changes.

### b. Distribution and logistics

Distribution and logistics encompass two main types of activities. On the one hand, distribution concerns all activities required to move finished products from the facilities where they are

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[6] For some successful examples, the interested reader is referred to ForestExpress (http://www.forestexpress.com/), Fordaq (http://www.fordaq.com/) and TimberWeb (http://www.timberweb.com/).

manufactured to the markets. As described in Figure 1, at a strategic level, this includes decisions related to warehouse location and capacity, transportation mode selection and capacity, inventory management policies, and product-warehouse-market allocations (i.e., what product is supplied to what warehouse, and what warehouse serves which market). Because companies tend to grow into larger global business networks of interdependent organizations, the management of distribution channels becomes crucial to their business profitability. On the other hand, logistics is usually concerned with transportation and inventory management of all raw materials, work-in-process, components and finished products from the forest to customers. In Figure 1, logistics decisions are multiple as they involve all transportation and inventory activities from log transportation and inventory management to the logistic support of distribution activities. Because distribution and logistics activities are common to most industrial sectors, planning and control are generally adequately IT-supported. This includes operational IS for the real-time geographical control of a fleet of trucks, i.e., *Transportation Management Systems* (TMS), up to analytical IS for network strategic planning (Figure 1). With such tools, some companies are already optimizing their distribution and logistics activities and network.

### *Distribution and logistics opportunities for the FPI*

As mentioned previously, one of the most important opportunities faced by the FPI concerns its ability to adapt to new customer-centered business models and the adoption of new ICT tools to support these new models. E-business is at the heart of such models. For years, forest products distribution was indeed (and still is in many countries) conducted through many layers of intermediaries and brokers. Due to many contributing factors, this situation has changed dramatically during the last ten years. Among other factors, the emergence of larger customers (e.g., large retailers and value-added industries) and their rising needs for secured and high quality procurement seem to have contributed to the development of new disintermediated business practices. For instance, in the lumber industry, world class forest products companies are forced by large retailer companies, such as The Home Depot, to extend their business offer to include the management of their customers' inventories and shelves by adopting best practices well established in other sectors, such as *Vendor Managed Inventory* (VMI), *Collaborative Planning Forecasting and Replenishment* (CPFR) and *Efficient Consumer Response* (ECR). Because they do not leave much room for errors, these practices require the use of appropriate IS to efficiently control distribution and logistics activities and communicate timely information to the right organizations. This includes notably the ability to (1) exchange information with customers to receive the right demand signals; (2) make appropriate replenishment decisions so as to know what inventory to replenish, when and how; and (3) plan transportation operations in order to economically fulfill customer needs.

Another opportunity in the fields of distribution and logistics concerns a company's ability to react quickly to unplanned changes and seize business opportunities. The ability is often referred to as agility. As mentioned in the previous section, the ability to sense demand changes is a fundamental aspect of supply chain management that must be complemented with the ability to quickly react to these changes. Distribution and logistics management appear to be at the heart of this ability. Tracking and real-time control technologies such as bar coding, *Radio Frequency Identification* (RFID), *Global Positioning Systems* (GPS), along with *Supply Chain Event Management*[7] technologies (SCEM), contribute to increase the control over distribution and

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[7] *Supply Chain Event Management* technologies aim at improving the control throughout the supply chain of unplanned events that may have consequences on companies' ability to fulfill customer needs. SCEM usually involves the monitoring of supply chain activities for exceptions and bottlenecks in order to provide alerts and notify any companies in the supply chain that might be affected by the event, even though it occurs in a different company. Notifying these events throughout a supply chain enables companies to proactively manage them in real time before they impair the supply chain performance. SCEM also improves visibility across all departments, business units, and companies.

logistics operations in order to provide managers with real-time information and support them to make decisions to react to events (either from the demand, production or supply side).

Furthermore, by enabling companies to monitor the movement of their material throughout their production and distribution networks, companies can also develop the ability to capture backhauling opportunities. However, as discussed in the next section, doing so requires competencies in routing and inventory management and the use of specific analytical ICT tools (Eriksson and Rönnqvist (2003)) and new business models (see next section).

Yet another opportunity, which can bring radical improvements of the distribution of final products to markets, concerns the strategic organization of the distribution network. This includes the selection of the location, capacity and technology of distribution centers and warehouses, the selection of transportation modes, as well as the allocation of products and customers to warehouses. Because of their prominent impact on a company's agility and profitability (indeed they determine both distribution efficiency and response time), these decisions require particular attention from top managers. The use of dedicated analytical tools based on strategic network design normative models such as the ones described in Goetschalckx (2000) have been proven to provide, in some cases, tremendous improvements. Usually, these decisions are conducted once every one to three years or when the acquisition of another company or facility requires the rationalization of the entire distribution network.

Finally, related to the merger and acquisition of companies, a major challenge common to all industrial sectors concerns the ability to integrate heterogeneous legacy systems. This challenge is generally costly to face.

### *Distribution and logistics challenges for business and research*

Many business and research challenges related to distribution and logistics still need to be addressed by forest product companies. Although OR and simulation technologies have been used since the late 1980s to build normative decision support models dedicated to forest products transportation problems (Epstein *et al.* (1999)), many efforts still need to be made to increase distribution and logistics efficiency and adapt to new constraints. For instance, the overall ability of companies to distribute their products could benefit from the synchronization of production and distribution activities regarding what and when to transport and what and how to produce accordingly. In practice, it is very common in the industry to separate production and distribution decisions by building large enough inventory and time buffers in order to consider both decision making problems as only loosely coupled. This coordination is not particularly challenging when the expected response time to market is long. However, when this response time becomes shorter, it is more challenging because the entire production-distribution system becomes leaner (i.e., less time and inventory wasted), which requires more accurate demand forecasts as well as new specific analytical tools to support the joint organization of distribution and production activities (see Bredström *et al.* (2001) cited in Rönnqvist (2003) and Martel *et al.* (2005) for examples in the paper industry).

Another IT-enabled approach to improve logistics efficiency concerns the use of both transactional and analytical ICT tools to allow companies to pool their needs for transportation and share their transportation capacity. Such a combination of technologies, which is based on entirely new collaborative business models, is often referred to as e-hubs because they aim at matching many customers with many service providers or suppliers. This type of e-business technologies enable companies to share information about their transportation needs and offers, either directly or through a third-party service provider, in order to be more efficient at transporting and distributing their products. For instance, in the case of logistics management, e-hubs could be used to take advantage of the pooling of resources in order to improve the overall productivity of an industry's transportation resources. In other words, such an e-hub could enhance the ability of companies to take advantages of backhauling opportunities enabling their trucks to fulfill more than their sole transportation needs. A project at the FOR@C Consortium, Université Laval, Canada, aims at developing the tools required to support such a business model. Such tools generally include (1) a web-based platform to enter transportation needs and availabilities and inform transportation companies about proposed transportation routes, and (2) an optimization tool whose role is to match transportation needs with efficient routes.

Finally, another even greater challenge concerns companies' ability to jointly make decision regarding supply chain event management in order to collectively solve contingency situations that could harm overall performance. SCEM is currently employed in its simplest form, which is to monitor a set of events, such a delay or a machine breakdown, and alert those companies that could be affected by them. More advanced solutions of SCEM propose to learn from past events and how they were solved to improve the management of new events. However, monitoring and alerting do not guarantee a fully coordinated response to an event as each company still has its own way to handle it. Companies need to consider the collaborative management of such events. Although it is easy to say, a coordinated response that could bring an improved overall response is far from being trivial as companies must be able to jointly make decisions regarding what is the most appropriate and fair response to an event.

### c. Manufacturing

Manufacturing in the FPI refers to the activities of transforming raw material into semi-finished products, referred to as *primary transformation*, and transforming these semi-finished products into more complex and usually engineered or assembled products, referred to as *secondary transformation*. Manufacturing involves many decisions to be taken from the execution level up to the strategic level, as shown in Figure 1 for the lumber industry. The strategic level includes decisions that are usually addressed concurrently with distribution strategic decisions (e.g., facility location, technologies selection, production capacity setting). The normative decision models reviewed in Goetschalckx (2000) mentioned earlier are used to address both problems simultaneously. Because these decisions must take into account large amounts of variables, they are based on information aggregated in terms of product family, production capacity, market zone and time bucket. At the tactical level, information is less aggregated and production is generally planned over one full demand cycle in order to smooth the effect of seasonal variations on capacity requirements. General production policies and weekly/monthly production and inventory targets are specified. At the operational level, detailed schedules and lot-sizes are specified so as to match real capacity and production constraints with demand requirements. Finally, execution involves the operational control of schedule execution and the possible adjustments with regards to unplanned events.

From a technological perspective, during the last decades the FPI has evolved into a highly automated industry. Major *Original Equipment Manufacturers* (OEM) have developed highly efficient equipment for the lumber, paper, panel and value-added products industries. Most of these equipments are today controlled electronically, providing managers with real-time data used to control the execution of many processes. This type of operational ICT is now commonly used in forest product companies.

### *Manufacturing opportunities for the FPI*

A particular opportunity for the FPI is directly related to the adoption of both descriptive and normative models to support managers to make the most profitable planning and execution decisions. Forest products and their related transformation processes are indeed subject to the very nature of the forest, the trees and the wood, which is highly heterogeneous. Because no log and no board is similar to another, each transformation requires the acquisition of information about each log to saw and each board to cut in order to make the best transformation decision (e.g., bucking or sawing pattern selection). Also, the planning of such transformations with the objective of fulfilling a particular demand during a given time period requires that companies must be able to make concurrently all these decisions (i.e., for each log or board to transform during the time period) in order to make sure that demand will be fulfilled at the end of the time period. An approach that optimizes the transformation of each log individually does not indeed guarantee that demand will be fulfilled because each transformation decision is taken locally without regard to the demand.

Finally, to make things more complicated, forest products transformation is a divergent process (discussed previously), which, combined with this heterogeneity, makes it a stochastic process in terms of output mix. In order to face this challenge and take advantage of the opportunity to outperform the competition, companies in Northern Europe countries tend to minimize these stochastic factors by categorizing raw material (i.e., logs) into classes for which they accurately know the output mix if processed with different patterns. On the contrary, in eastern North America, where log diameter is somewhat less convenient to such practices, companies use scanning technologies more extensively in order to control these stochastic factors throughout the production line. However, because planning in such a context is a complex activity, many of these companies have abandoned the idea of planning their manufacturing processes according to their customers' needs. Instead, these companies still prefer to push raw material through their production lines while optimizing throughput value and selling products only when produced. This *make-to-stock* strategy can be efficient, even in a divergent process context such as lumber production when all products can be sold whenever and when market prices are fairly good.

Unfortunately, this control strategy is no longer adequate for the new economic context. Recent economic pressures are indeed forcing companies to monitor not only their productivity but also their ability to meet customer expectations. In order to develop this ability, these companies must adopt new customer-centered planning and control tools, which require the integration of operational ICT (e.g., sensors, scanners, controllers and execution databases) and analytical ICT (e.g., planning decision support systems). Furthermore, the new economic context requires companies to also be able to quickly react to any event that could harm their performance and to control their supply chain in order to both fulfill long-term contracts with customers and manage their customers' inventories (i.e., VMI). The make-to-stock strategy does not allow companies to easily do this, especially when resource and process constraints, as well as demand, are stochastic. Such technologies represent the back-office required to enable companies to jump into the e-business world. Indeed as it is advocated in this paper, e-business is far more than the simple ability to buy and sell wood products over a digital media. It is the ability to connect companies' activities and decision makers so as to create virtually integrated supply chain networks through the sharing of real-time information and collaboration business processes.

In the specific context of the FPI, most planning tools designed for flow shop or job shop contexts that are available commercially are not suitable to handle both a divergent and a stochastic production process. New analytical ICT tools exploiting proper descriptive and normative models of wood processing characteristics are emerging from the academic community. Many efforts, among others in Canada, Chile and Sweden, are ongoing to address some of these production planning challenges. Yet much effort still needs to be made.

### *Manufacturing challenges for business and research*

One of the IT-related challenges regarding manufacturing, concerns supply chain partners' ability to integrate their decision making processes concerning what to produce and when.

Among other aspects related to collaborative operation planning (i.e., ability to synchronize partners' manufacturing operations) and supply chain event management (discussed previously), this ability includes the capacity to integrate new product development and design with production planning. As in many other industries, value-added forest products lifecycles tends to be much shorter than what is usually considered as normal in the FPI. In this context, a supply chain's ability to develop, produce and deliver new products to customers may represent tomorrow's most important challenge. To do so, supply chain partners need to improve their ability to (1) develop new products, (2) integrate their design activities with their suppliers, especially if their suppliers are involved in designing sub-components, in order to accelerate the overall order fulfillment cycle time, and (3) coordinate new product introduction with partners. From the raw material suppliers' point of view, this may mean being able to produce various volumes of customized products specific in terms of dimensions, quality, moisture content, etc.

This is particularly true in the housing industry which tends to adopt new business models based on the *engineered-to-order* strategy. In this industry, many companies are involved to develop and produce value-added products such as wood composite beams and panels used to build house sub-components such as flooring-systems, in turn used to prefabricate customized houses and assemble them on site. In such a supply chain of raw material suppliers, value-added product producers, prefabricated house manufacturers and assemblers, new product development and design, manufacturing operations, and assembling must be well integrated so as to make sure that new product introduction is coordinated and order fulfillment is effective and efficient.

### d. Logging

In the FPI, supplying raw materials to mills includes all operations necessary from forest harvesting, to material sorting and handling, to log or full length stem transportation to one or several mill yards. This part of the forest products supply chain is sometime referred to as the *wood procurement system*. Wood procurement systems are composed of all logging operations (i.e., harvesting and hauling), wood buyers and coordinating agents, whose role is to coordinate logging operations and insure that wood is available in the desired quantities, in a timely fashion and to the right location. This section particularly addresses logging operations and coordination.

In most countries, logging operations are usually conducted by small business units which are distinct from larger transformation companies (i.e., sawmill, paper mill, furniture plant, etc.) in terms of ownership structure. Due to the labor shortage and the financial requirements related to intensive mechanization of the 1970s, large transformation companies in many regions of the world have outsourced their forest operations to a multitude of independent contractors, also called entrepreneurs. There are many kinds of entrepreneurs in terms of operational capacity and level of vertical business integration. In certain countries, logging is carried out by groups of single machine entrepreneurs, while in other countries larger logging businesses operating one or more crews are the norm. An entrepreneur may establish business relationships with only one client (i.e., a forest company) or with several. Also the size and number of clients of an entrepreneur has an impact on its profits and its technical efficiency (LeBel and Stuart (1998), Mäkinen (1993)), as well as its need and ability to adopt ICT to support its business practices.

### *Logging opportunities for the FPI*

One of the first ICT opportunities related to logging concerns the adoption of ICT to support entrepreneurs with simple transactional operations, which are still too frequently carried out manually. From the FPI perspective, the management of the forest products supply chain would certainly benefit from the automation and integration of various transactional tasks between entrepreneurs and forest companies such as demand expression or harvesting operations status reporting. Such specific e-business practices are still yet to develop in most countries, though

Northern Europe companies are implementing advanced forms of such applications based on mobile technologies. However, in other countries this is rather a challenge as the implementation of this type of transactional ICT requires the development of a technological infrastructure that would enable the exchange of data between entrepreneurs, spread over large and often remote areas, and forest companies. Furthermore, even regions already benefiting from full data transmission coverage have encountered difficulties in convincing entrepreneurs to adopt it, because it is difficult to demonstrate short term gains that may justify such an investment in terms of technology deployment and training.

Another opportunity concerns logging flexibility to better satisfy demand. Forest companies face the need to provide their customers with more volume and product type flexibilities. In turn, this pressure is forwarded to forest operations and particularly to logging activities. This pressure requires the need to quickly adjust the logging workforce both in terms of localization and capacity throughout the year. Because the information regarding entrepreneur availability at the regional level is not known and shared, it would be, for instance, interesting to consider the use of on-line e-business platforms (i.e., e-hubs) to buy and sell logging services where entrepreneurs and forest companies could share information about logging capacity and demand. Such an e-hub could also be geared up with optimization tools whose function would be to improve the overall utilization and allocation of the entrepreneurs' capacity using real-time communication.

Another opportunity concerns the environmental friendliness of forest operations. ICT has indeed the potential to be used to more efficiently manage all environmental information in regard to site sensitivity. For instance, a company could track on a real-time basis the location of forest machines on the territory and assess the risk for soil damage given weather and ground conditions. Navigational information with GPS has already been implemented in some areas to control cutting plans, respect buffer zones and improve post-harvest reporting. On-board GPS, when combined with forest stand information in a *Geographic Information System* (GIS) can be used to provide instructions to guide harvesters to specific cutting block sections and even provide bucking instructions. As mentioned previously, this type of IS can contribute to product tracking from the stump to the mill. Accurate and automated product tracking is indeed needed for certification and management purposes. Furthermore, log scanning and tagging technologies provide a more transparent certification system. From the entrepreneurs' perspective, improved product tracking provides also the ability to (1) capture and report real time production data and (2) track in-forest and landing inventory in real-time. From the forest companies' perspective, this information is even more crucial to their operations. Therefore, a mechanism should be developed to encourage or compensate entrepreneurs who have to invest time and resources to acquire and operate such tracking technologies.

ICT in forest operations is still in its infancy in many regards. Independent entrepreneurs have very limited resources. It seems therefore crucial that partnerships be established between entrepreneurs, forest product companies and ICT specialists to provide the support services that will help the implementation of advanced technology in the forest.

### *Logging challenges for business and research*

ICT "at the stump" can help run the forest supply chain more efficiently. But more important, it also provides opportunities to considerably change the design of the supply chain. For example, the ability to utilize harvesters' data to assess inventory predictions for various cutting schedules in order to adjust order fulfillment expectations will certainly render the wood procurement system much more accurate and agile. This can only be achieved if robust descriptive models of log production can be developed and implemented at the harvester's level. The complexity of forestry systems, which includes both ecological and market variability, poses a great challenge to optimization modelers (Rönnqvist (2003)). Furthermore, these optimization models require the development and use of on-board technology by harvesters, both in terms of execution (i.e., real-time logging operations optimization) and data acquisition to improve the accuracy of the descriptive models used to optimize planning decisions, such as defining harvesting blocks with regard to the uncertainty of the demand and the variability of the forest. Such a technology would turn the natural forest into a fully accessible and well organized living warehouse.

Finally, from the ICT community perspective, ICT personnel will have to accompany the FPI in its efforts to better educate and train entrepreneurs in the use and maintenance of sophisticated tools. With little to no support staff available to them, entrepreneurs must increase their own ICT expertise as they had to recently adapt to more sophisticated hydraulic and mechanical systems in their production machinery. This will indeed require a concerted effort between the FPI, ICT companies, training specialists and the entrepreneurs themselves.

### e. Forest Assessment

In the modern forest supply chain, the forest can be considered as a dynamic and living warehouse. Because it is the ultimate source of raw material used to meet consumers' demand now and in the future, forests, on the opposite side of the demand, must be assessed in terms of volume availability and specificity, location and accessibility. Forest assessment is the process of gathering raw data about trees, land, and soil conditions in order to estimate the volumes and the variability of available supply both in the present and the future. It is crucial as managing demand as it affects a forest company's ability to satisfy the demand and realize its objectives.

#### *Forest assessment opportunities for the FPI*

One role of ICT in such a context is to facilitate the collection and management of the data used to predict the availability of the supply at the strategic, tactical, annual, monthly and weekly planning levels to allow forest companies to (1) be better prepared to satisfy consumer demand

and (2) manage co-production. Tools such as GIS, GPS and laser distance devices will surely see expanded use in this collection and management of data. As mentioned previously, data acquired by on-board computers during harvesting can also play a significant role in data collection.

In addition to this role of data collection, descriptive models about forest growth are also required to extrapolate the collected data both in space (i.e., what is available in unassessed lands?) and time (i.e., when will it be available?).

In the modern supply chain, Forest assessment must support the shift from a production driven supply chain to one that emphasizes meeting customer orders. Because demand tends to be more complex and dynamic, supply needs to be characterized by dynamic models that allow the timber volume to be estimated for a variety of potential logs grades. One of the first tools developed to determine the volume based on the desired log characteristics and allow the volume estimates to be influenced by log type price was the *Method for the Assessment of Recoverable Volume* (MARVL). MARVL allows the stem to be characterized by a single stem attribute, such as sweep, knot size or an attribute that combines multiple attributed into a single value. Logs are defined using these characteristics such as desired length, minimum and maximum small and large end diameters, determined from the taper model and allowable attributes. Volume by log type is assessed by assigning prices to each log type so as to calculate, using dynamic programming, the volume for each log type to be harvested the each stand (Manley *et al.* (1987)). One drawback to MARVL has been that it requires the inventory forester to visually estimate stem description. PhotoMARVL was developed to quantitatively measure stems using terrestrial photogrammetry techniques, but this requires significant special skills (Firth *et al.*

(2000)). Along this line, *remote sensing*, which include satellite, fixed-wing and helicopter imagery, can also provide companies with improved forest assessment[8].

Another drawback to systems such as MARVL is that log type is described based on a single attribute. This attribute may include a combination of sweep class and knot size. Recently, there have been tools such at *Yield Generator* (YTGEN) and *Atlas Cruiser Suite* that allows multiple attributes to be collected for each segment on the stem, such as knot size, sweep, length of clear wood between knot whorls (Rawley (2001); Forest Research (2002)). This improved stem description allows for a better prediction of the potential log volume from a stand and can lower some of the sources of variation. Like MARVL, these tools still calculate the volume for an unconstrained market. A first improvement of such approaches would be to include a market constrained model that would limit the volume for a particular grade and allow material from high quality products to be made into lower value products to satisfy the demand. Such models will certainly allow foresters to determine a more realistic potential worth of stands based on price and capacity, for given markets.

So far, forest assessment relies on the judgment of the inventory forester to visually estimate the various stem attributes. Advances in laser technology have allowed for the development of tools such as *GeoSmart Tree Attribute Profiler*™, a laser tree attribute tool that can accurately develop a three-dimensional view of a tree including upper stem diameters, sweep and knot size based on quantitative measurements, eliminating the visually estimates for knot size, as well as allow for upper stem diameters to be measured instead of estimated using a taper function.

Finally, in a rather different context and from an e-business perspective, another potential role of ICT would be to support both land owners and forest companies to advertise surplus volume to

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[8] The interested reader is referred to technologies such as the approach proposed by the CLC-Camint (http://www.clc-camint.com/).

other companies and seek additional supply sources to meet their orders. Such a role is complementary to seeking logging services and could be carried out through e-hubs for instance.

### *Forest assessment challenges for business and research*

In the domain of forest assessment, one important challenge of ICT is to delve further into the use of more accurate descriptive models of the forest that will allow for an improved characterization of the trees to better meet markets. Indeed, most forest assessment tools limit their description to the tree's surface characteristics. For lumber to better compete with steel or masonry products, it must be able to guarantee its performance during use. Structural products need high strength or stiffness measurements. Products like *SilvaScan* 1 and 2 can currently produce estimates of density, microfibril angle, and wall thickness (Downes *et al.* (1997)). Near-infrared spectroscopy has been shown to strongly correlate with pulp yields (Downes *et al.* (1997)). Additionally, acoustic sampling has been shown to detect log stiffness, which could be combined with descriptive models that could be exploited to improve the yield of particular consumer products (Ridout *et al.* (1999). Such tools will have to be more intensively used to assess forests.

Furthermore, because yields have mainly been described as logs, decision support tools and normative models will need to enhance the conversion from log yields to lumber yields (i.e., consumers rarely purchase logs; they purchase lumber, panels, and paper products). For instance, in the models proposed in Maness and Adams (1991) and Todoroki and Ronnqvist (1999), forest bucking and sawing decisions are linked to provide the optimal solution to meeting market demands. However, such models need to be expanded in order to include more detailed log and wood property descriptions to determine the type of lumber that can be produced from each log given a set of customer orders. Products like *AutoSaw*™ and *StandPak*™ (New Zealand Forest Research Institute Limited), *Optitek*™ (Forintek Canada Corporation) or *SAWSIM*™ (Halco

Software Systems ltd) are able to link the forest assessment to lumber yield using sawing simulators. This will allow stands to be valued based on the anticipated markets or demand for consumer goods, and not just for logs. In other words, yields need to be based on both lumber and log yields to allow companies to determine the value of a stand based on demand and market capacity.

Finally, another challenge of forest assessment concerns the development of sampling protocols and technologies that will allow for the collection of statistically valid inventory data using both surface and wood quality attributes. This will permit forest products companies to understand the variability of the supply and accordingly manage the risk of not meeting orders. Along this line, quantitative tools such as tree attribute lasers need to be utilized to minimize sampling biases.

## IV. Conclusion

The world of research in the fields of supply chain management and the management of information systems dedicated to the forest products industry are very promising as there are many challenges that still need to be addressed. As we outlined some of these numerous challenges, we realized they can be classified into three generic categories. The first category refers to the development of decision models, including both descriptive and normative models, in order to (1) better understand the numerous sources of variability in the FPI; and (2) improve the quality of decisions throughout the supply chain. Many initiatives around the world, some of which have been reported in this chapter, have already undertaken some of these challenges. However, many more challenges need to be addressed by the academic community and the numerous centers of expertise that dedicate their research to the FPI. The second category of challenges refers to technological and the implementation aspects of deploying such approaches in the industry. In particular, though many e-business solutions are technologically available on the market, they still need to be adapted to the many potential industry specific uses described in this chapter. Furthermore, the need to integrate back-office application (when they exist) with such e-business solutions will be another important challenge to face. These challenges directly concern the ICT solution providers and the technological companies that will provide forest products companies with technological solutions that match their particular needs.

Finally, The third and maybe most important category of challenge concerns the FPI itself, as it deals with its ability to manage change and to adopt new innovative approaches to manage its supply chain. In many countries, the FPI is still traditional and the adoption of innovations may seem rather difficult. Many methods do exist to transfer research and technological knowledge to an industry. In the Chilean FPI (Epstein *et al.* (1999)), successful methods have been employed since the end of the 1980s. However, many aspects of knowledge transfer and management need to be better understood to improve ICT adoption in the FPI. Research in knowledge management (Van Horne *et al.* (submitted)) are consequently very important to facilitate this transition to the e-nabled forest products supply chain.

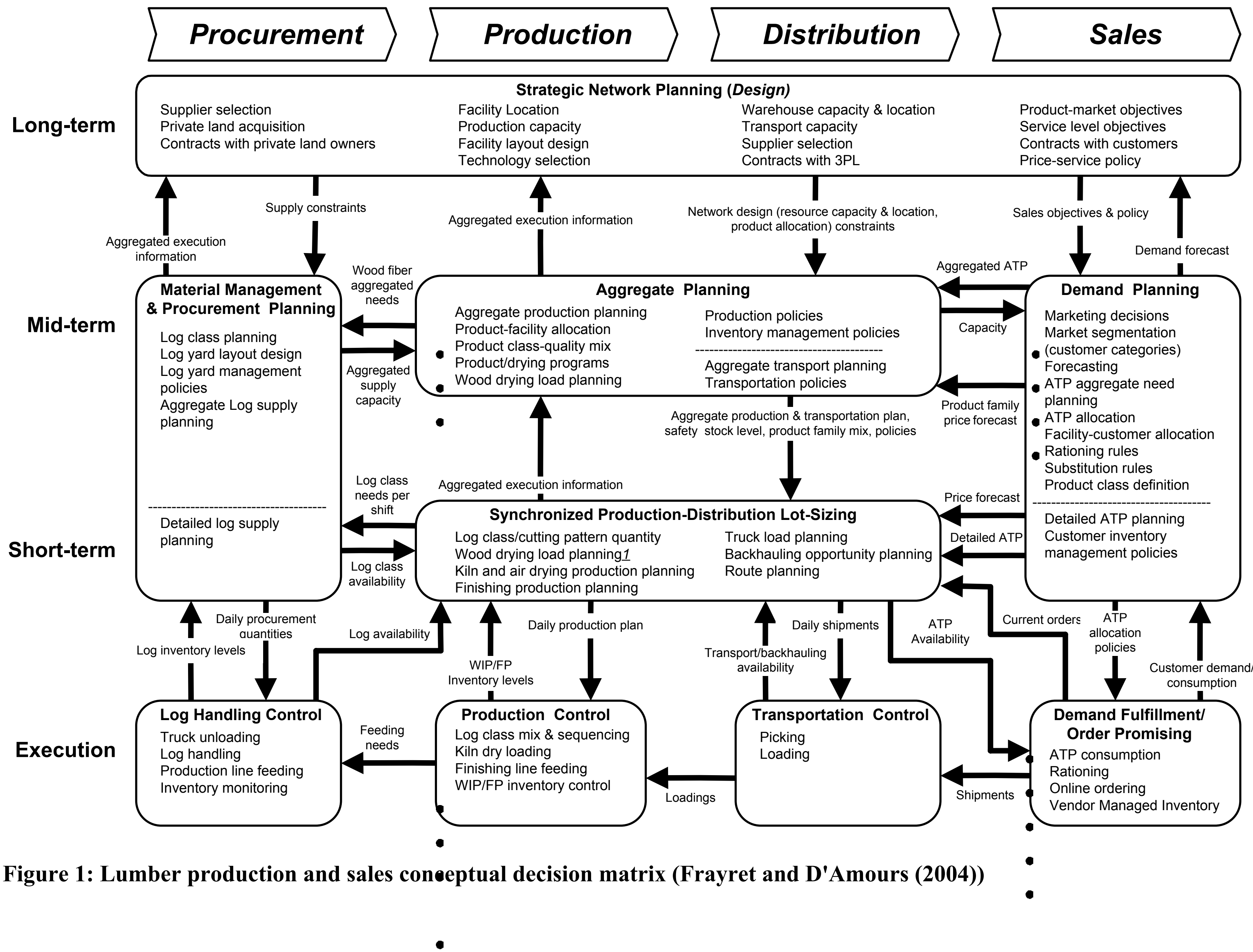


**Figure 1: Lumber production and sales conceptual decision matrix (Frayret and D'Amours (2004))**

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