Quality Measurement in the Wood Products Supply Chain

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Abstract

In this article we report the first in-depth investigation of quality measurement practices from a supply chain perspective. Quality measurement in a wood products supply chain was studied in great detail with the objective of increasing the understanding of quality performance measurement practices in a secondary wood products supply chain. Opportunities for improvement were also identified. A single-case study was used as the main research approach, with 30 interviews and observation as major data collection methods. Findings revealed a high degree of internal integration in the focal company, made possible in great part by a continuous improvement effort that expands all of its facilities. Opportunities for improvement were found in external integration, particularly regarding supplier quality management. A disconnect was identified between supply chain members in regard to quality information; particularly, there was a lack of true supply chain quality measures reflecting the contribution of each entity to the overall quality. Results from this research highlight the importance of adopting a systems perspective when designing a supply chain performance measurement system. Poor quality at any point in the supply chain is detrimental to customer satisfaction, hurts profitability, and eventually translates into higher costs for downstream business segments and for the final customer; the end result is a decline in competitiveness of the entire system.

Supply chain management (SCM), the ''performance measurement revolution,'' and the quality movement are three of the most significant developments in business management in the last decades (New 1996, Tan et al. 1999). SCM can be defined as ''the strategic coordination of business processes within an organization and across businesses within the supply chain, with the objective of improving performance of individual organizations and of the entire supply chain'' (Li et al. 2005, p. 618). According to the SCM paradigm, companies no longer compete as single entities, but rather as parts of large, complex networks. Businesses that adopt this view have better chances of success. SCM practices have been found to be associated with superior product quality, delivery reliability, process flexibility, cost leadership, and higher levels of design and conformance quality (Rosenzweig et al. 2003, Fynes et al. 2005).

Organizations have also realized that substantial improvements are only possible when an effective measurement system is in place, hence the growing interest in formal performance measurement systems among organizations and researchers (Neely 1999). Some of the causes for the performance measurement revolution are increasing global and domestic competition, continuous improvement initiatives, national and international quality awards, changing demand, and developments in information technology (Neely 1999). The most common challenges when designing performance measurement systems are the following (Beamon 1999, Bourne et al. 2002, Van-Aken and Coleman 2002).

- Achieving a balanced set of quality and business performance metrics. Commonly, metrics are disproportionally concentrated on financial performance.
- Aligning such metrics with strategic goals (e.g., if the goal is high customer satisfaction, metrics should reflect customer needs).
- Avoiding inappropriate metrics that drive the wrong behavior (e.g., metrics focused solely on throughput will probably lead to a decline in quality performance).
- Facilitating the access to required information, and ensuring the measurability of data (e.g., if ''aesthetics''

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is to be measured, efforts should be made to stipulate how to measure this dimension based on specific attributes).

Performance production measures traditionally used by the wood products industry quantify either financial performance or resource utilization (e.g., *overrun,* the ratio between the amount of lumber recovered from a set of logs to the volume of those logs, or *rough-mill yield,* the ratio between the amount of usable parts and the volume of lumber input).

Growing domestic and global competition and a more sophisticated customer have driven companies to focus on quality assurance and improvement. Many firms have implemented continuous improvement programs, and some trade associations and government agencies have started quality award programs (such as the International Organization for Standardization's ISO 9000 quality standard, the Kitchen Cabinets Manufacturers Association's Performance & Construction Standard for Kitchen and Vanity Cabinets, and the Baldrige National Quality Award Program). Three specific approaches for improvement, Six-Sigma, Lean Manufacturing (LM), and Lean Six-Sigma, have received great attention (Cumbo et al. 2006, Anonymous 2008). Six-Sigma was introduced by Motorola in the early 1980s (Raisinghani et al. 2005); it is an improvement methodology that focuses on extensive data collection and statistical tools to eliminate defects and reduce variation and provides standardized process for problem solving. The ultimate goal of Six-Sigma is to have a process that produces only 3.4 defects per million opportunities. LM has its origins in the Toyota Production System and focuses on the elimination of manufacturing waste (like excessive inventories, unnecessary movements or transportation, or defective products) and on increasing manufacturing flexibility, to generate the greatest possible value in the eyes of the customer (Goldsby 2005). Many companies use a combination of Six-Sigma and LM, known as Lean Six-Sigma, because it is believed that LM alone cannot bring statistical control and Six-Sigma cannot improve process speed radically (George 2002). Sixty percent of respondents to a 2006 survey among US manufacturers cited Six-Sigma, LM, or Lean Six-Sigma as their primary improvement method (Blanchard 2006).

Invariably, quality improvement programs involve a performance measurement system because improvements are very difficult, if not impossible, if there is no system in place to measure progress toward a goal. Quality assurance and improvement practices vary widely in the wood products industry, but in general such practices lag behind other manufacturing sectors (e.g., automotive and electronics). There is a concentration toward conformance with product standards (e.g., the National Hardwood Lumber Association [NHLA] grading rules) and not much attention to intangible dimensions of quality like service and responsiveness.

The US wood products industry has been severely hit by the great increase in international trade. Global sourcing is considered the main reason for a great number of domestic companies closing down manufacturing operations. Others have turned to quality-improvement and cost-reduction programs in order to achieve sustainability and growth, with mixed results. Most firms in this sector, however, have not yet leveraged the benefits of SCM to improve operations (Buehlmann 2004). These benefits include cost reduction, inventory reduction, and improved delivery time performance, among others (Towill 1996, Mason-Jones and Towill 1997, Berry et al. 1999, Tan et al. 1999, Lambert and Cooper 2000, Petersen et al. 2005). Relatively long lead times and large inventories still prevail in the industry. These developments motivated the research project described in this article, in which the application of SCM principles to improve quality measurement in a wood products supply chain was investigated.

A literature review showed limitation for specific aspects of quality management in the supply chain, particularly quality measurement. Some authors suggest supply chain measures of performance, mostly focusing on logistics performance (e.g., lead time, filling rate, and backorders). Little can be found on how poor quality impacts the entire supply chain. This is especially important to avoid suboptimization, caused by adversarial relationships between supply chain members pursuing different targets that are not necessarily aligned with the final customer's needs (Hassan 2006). Likewise, although research has been conducted concerning SCM principles applied to wood products enterprises (Simpson and Wren 1997; Fontenot et al. 1998; Vlosky et al. 1998; Buehlmann 2004; D'Amours et al. 2004, 2008; Carlsson and Rönnqvist 2005; Beaudoin et al. 2007; Frayret et al. 2007; Sasmohapatra 2009), very little exists about supply chain quality measurement in this industry.

Objectives

It is well established in the literature that (1) companies are better off when collaborating and integrating with their supply chain partners, (2) performance measurement systems should be carefully designed to avoid suboptimization, and (3) quality is a powerful strategic tool to achieve competitive advantages (Towill 1996, Mason-Jones and Towill 1997, Berry et al. 1999, Tan et al. 1999, Lambert and Cooper 2000, Petersen et al. 2005). The research described here combines these ideas in order to investigate current quality measurement practices in a supply chain environment and the potential for improvements. The study focused on the potential of combining SCM principles and effective quality performance measurement practices as an approach to improve the competitive position of wood products manufacturers. A basic assumption in this research was that significant improvements in quality performance are possible when there is a high degree of integration between buyers and suppliers for planning, controlling, and improving the quality of products and services provided.

The objective of this research was to increase the understanding of quality performance measurement practices in a secondary wood products supply chain. To accomplish this, quality measurement practices in a wood products supply chain were studied and the impact of these practices on the supply chain's performance was evaluated.

Methodology

A single-case study was conducted; a wood products supply chain was examined using data collection techniques consisting of on-site visits, field studies, and semistructured interviews with key personnel. The first step was the selection of a supply chain, which in this case was composed of an integrated manufacturer of assembled wood products (e.g., furniture, kitchen cabinets, door and window manufacturers), its suppliers of raw material, and the retailers that sell end products to final customers.

To have a manageable unit of study, the process suggested by Jones and Womack (2002) was followed, i.e., a product component (e.g., furniture frame, cabinet door) was selected and followed throughout its conversion process, since inefficiencies identified in the flow analysis of one component will very likely replicate in the manufacturing of other components of the product. After selecting the unit of study, a research protocol and instrument were developed, which consisted of a set of semistructured questionnaires, checklists, and graphic tools (for a more detailed description of the methods, see Espinoza 2009). A summary of the information collected is presented in Figure 1. In total, 30 visits and interviews were conducted. The positions of the interviewees were continuous improvement coordinator, traffic manager, material manager, quality control manager, rough-mill supervisor, sawmill manager, lumber purchasing, project coordinator, quality assurance, office manager, and branch manager.

After the data collection phase was completed, the quality measurement practices in the supply chain were compared with best practices according to what is reported in the literature. Linear regression analysis was used to find correlation between major quality indicators throughout the supply chain.

Results and Analysis

Supply chain structure

The structure of the supply chain was studied first (Lambert and Pohlen 2001, Womack 2006). The supply chain structure consisted of supply chain entities, material flows, and information flows as shown in the extended value stream map in Figure 2.[1] A value stream map can also show the processing steps and times, defect rates, inventory size and location, and transportation links. Flow of materials typically runs from left to right and information flows in the opposite direction in the form of customer orders, as Figure 2 illustrates. The company uses a centralized scheduling system, which receives orders from the retailer and sends them back to the company's facilities. The facility that manufactures product components (hereinafter referred to as the components plant) places orders to lumber suppliers on a monthly basis. Operations scheduling is demand driven from the customer to the retailer and from there to the assembly plant, meaning that production happens only

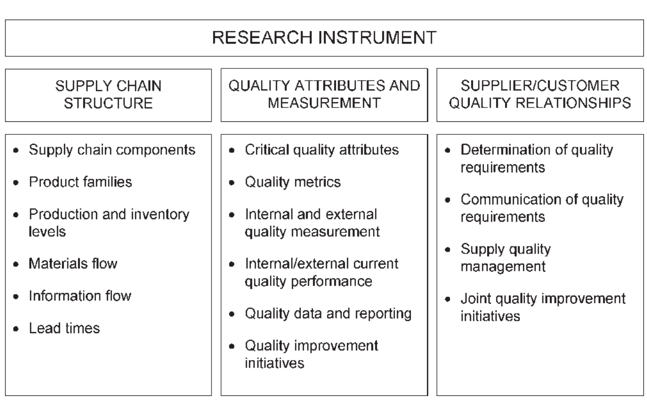

Figure 1.—Summary of critical information collected by research instruments.

based on firm orders from the final customer and very little or no inventory is kept at these points in the supply chain. However, from the assembly plant to the lumber supplier, production is scheduled mainly to replenish the stock of components and subassemblies (a small percentage of orders is expedited through the system to meet urgent needs) and significant inventories accumulate, with the associated maintenance costs.

A value stream map is useful to identify wasteful activities, and thus opportunities for improvement. The total time required for a product to reach the customer is 125 days, but the value-adding time is only 29 days, meaning that 76 percent of the time materials are sitting in inventory or being transported, which does not add value to the product from the customer's perspective (Figure 2). Furthermore, if the 25 days required for lumber drying are not considered, value-adding time is reduced to 1.2 percent of the total time. Also important, a value stream map helps to picture where inventories are located and their magnitude. Note, for example, that the company stores a total of 1 month's worth of finished parts and subassemblies at the components and assembly plants, which could be targeted for reduction.

Quality measurement practices

Once the structure of the supply chain is known, the next step in the data collection phase was to learn about the quality measurement practices at every step in the transformation process. At the time of data collection, these practices varied greatly among the supply chain components, ranging from no formal quality measurement program, to an internet-based database dedicated to quality-related reporting and feedback, to systematic quality control and improvement procedures using Six-Sigma improvement methodologies (e.g., DMAIC projects, Pareto charts, capability analysis) and defect rate targets set at a corporate level. These practices were captured in a ''supply chain causes map'' (Figure 3), a graphic representation summarizing the major quality indicators in use at the time of the study (shown in boxes), their components or causes (the defect categories leading to the major quality indicators), and the contribution of each component to the defect rate (shown as percentages). For example, at the components plant level, there are two major quality measures: an internal defect rate and the on-time shipment rate. The former is the proportion of items that are found to have some defect at the final inspection. Defects can fall in 1 of 11 categories, half of which are wood-related defects. This facility also calculates the level of service that is provided to its immediate customer in the supply chain, the assembly plant. This is measured by the on-time shipment indicator, which is simply the percentage of orders sent to the assembly plant on, or before, the due date specified in the order. There are four recognized causes for not meeting shipments on time, with downtime and quality issues being the most common (54% and 25% of the total, respectively, during the case study period).

[1] A value stream map is a graphic tool that allows one to portray and understand the relationships between supply chain entities and provides information useful to identify potential sources of waste (waste in this context is any activity that does not add value from the customer's point of view).

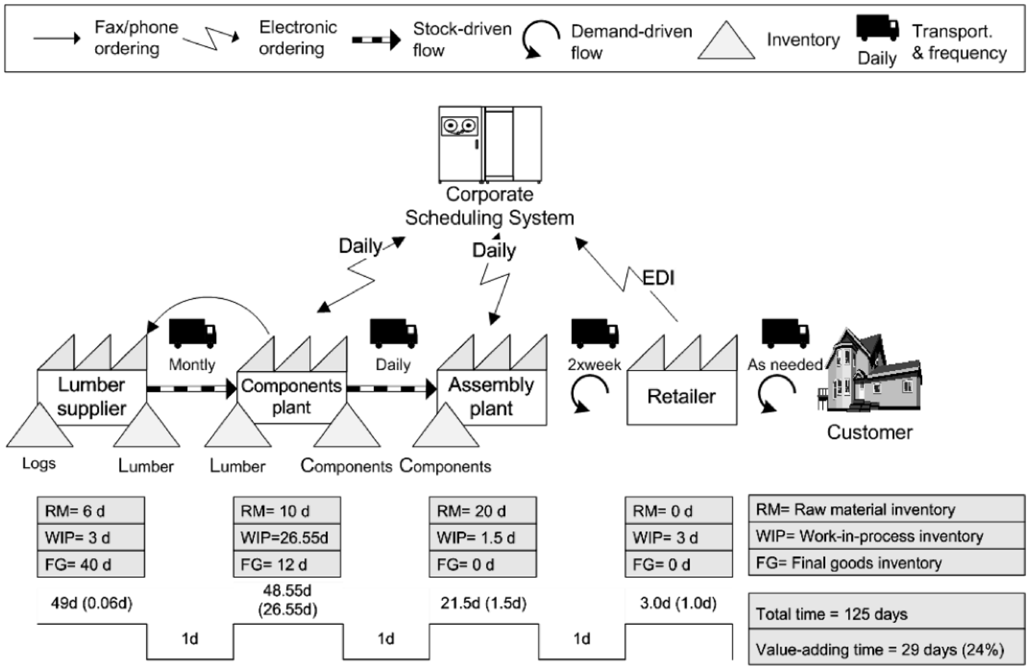

Figure 2.—Extended value stream map.

Regression analysis was performed between quality indicators at different positions in the supply chain, with the purpose of investigating how quality at any point in the supply chain affected downstream quality. The statistically significant correlations thus found are represented by bold lines in Figure 3 and regression parameters in Table 1.

For example, the backorder rate at the assembly plant was found to be positively correlated with the production volume at the components plant (i.e., the higher the production volume at the components plant, the higher the backorder rate at the assembly plant), suggesting that during periods of high demand, the source plant has some difficulty meeting 100 percent of its shipments on time. This relationship between production volume and quality performance was very consistent throughout the supply chain and not unexpected, since it is well documented that higher workload pressure can lead to more errors and lower performance (Teigen 1994, Oliva and Sterman 2001, Repenning 2001, Ford and Sterman 2003, Abdulmalek and Rajgopal 2007). Nevertheless, quantifying the drop in quality performance from workload pressure can help to better target improvement actions.

Also represented in Figure 3 are the causes that were not part of the formal quality measurement system at the time of the study. These relationships represent potential improvements and are shown using broken lines. For example, final customer claims were predominantly related to color variations and wood defects; however, these were not reported as a major quality indicator at the retailer level. Color variations were caused by, in decreasing order of frequency, process conditions, finishing materials, and variations in the substrate, as shown in Figure 3.

In the next sections of this article, critical aspects of the supply chain, as they relate to quality measurement, are analyzed. This was accomplished by comparing current practices at the time of the study with best practices as reported in the literature.

Integration in the supply chain

Integration is a recurring theme in SCM literature. Integration is ‘‘the coordinated management of business processes and functions inside the organization, through a common set of principles, strategies, policies, and performance metrics’’ (Barki and Pinsonneault 2005, p. 166). This definition can be extended to a supply chain system (external integration) when the extended value stream is considered. Research abundantly supports a positive association between internal integration, external integration, and supply chain performance (Stank et al. 2001, Closs and Savitskie 2003, Rodrigues et al. 2004, Sanders and Premus 2005, Germain and Iyer 2006, Lee et al. 2007).

Internal integration.—The focal company of this study has deployed a company-wide continuous improvement effort, and quality improvement is part of this strategy. Some practices worth mentioning are listed below.

- Six-Sigma and LM techniques are part of the operations philosophy and are used in all of the company's facilities.
- A single-piece flow (the ideal state, according to LM philosophy, where parts are manufactured one at a time, in response to demand) was a common goal shared among the managers interviewed for the study.
- Quality control and measurement practices were prescribed at the corporate headquarters with great detail and goals were set for major quality indicators. For example, corporate headquarters dictated the sampling procedures and the dimensional tolerances to be observed throughout the production process.
- Quality performance information was used to evaluate managers and supervisors, and the performance of each facility was compared with goals during periodic assessments.
- The company maintained a ‘‘dashboard’’ (a visual display of critical performance information, designed in a way that it can be monitored in a glance), with measures in

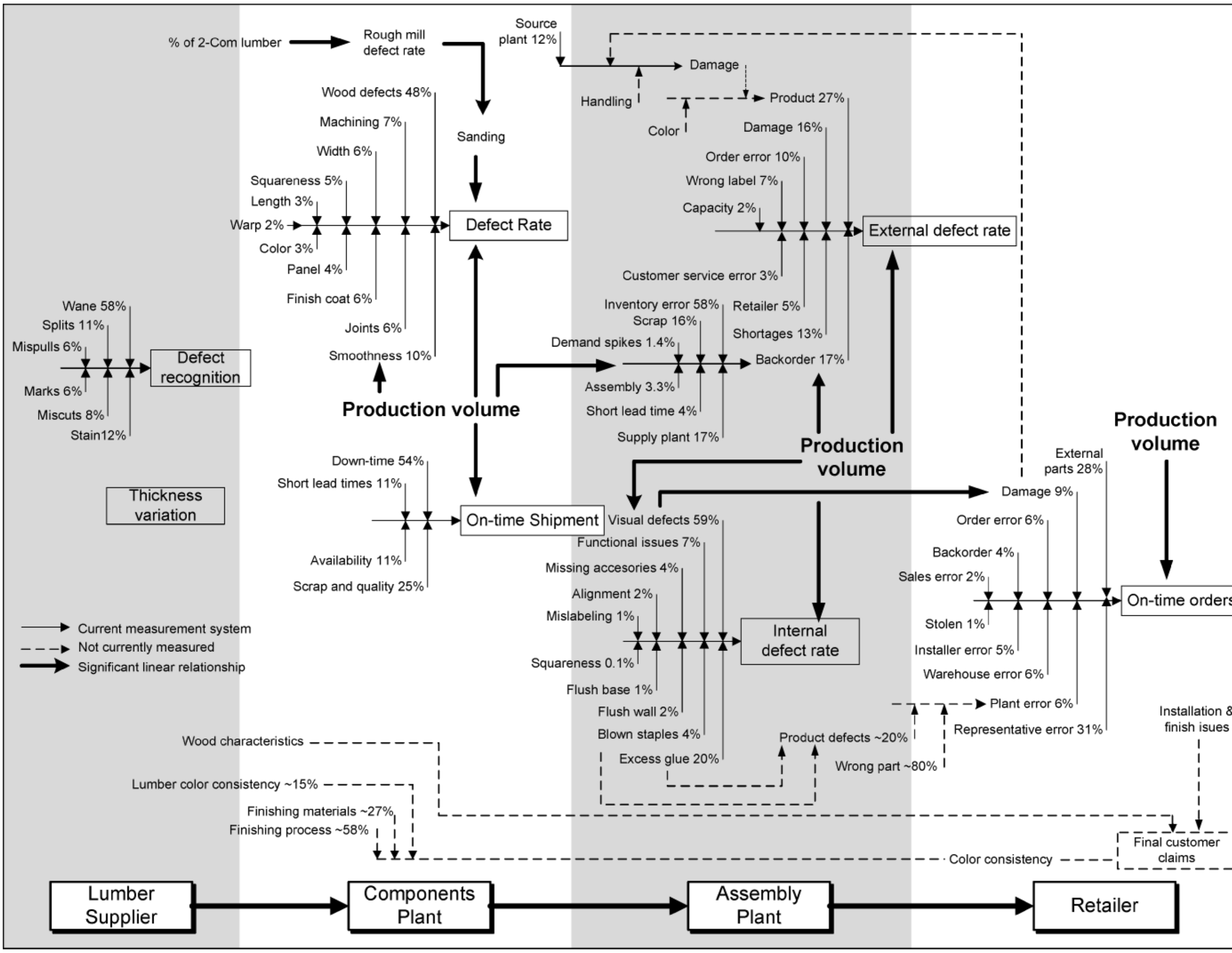

Figure 3.—Supply chain causes map.

key performance areas, one of which is quality. At the shop floor level, large displays showed the main performance indicators for each production area.

- The number of quality improvement projects that each plant had to carry out is stated in the company's strategy, and these projects were performed by teams that included staff members from different areas.

The role played by corporate headquarters facilitates internal integration and is consistent with some of the drivers of integration proposed by Pagell (2004); namely, top management support, consensus on strategy among functional managers, real-time informal communication between managers of different functional areas, and use of cross-functional teams. However, although internal integration greatly facilitates reduced inbound and outbound costs, reduced warehousing costs, and increased turnover; it does

Table 1.—Regression analysis parameters for relationships in supply chain causes map.[a]

Independent variable	Dependent variable	P	b	a
Lumber grade content	Pick line defect rate	0.01	1.7×10^6	82,758
Pick line defect rate	Sanding	0.05	0.896	109,667
Sanding	Components plant defect rate	0.03	0.107	13,404
Production volume	Components plant defect rate	0.02	0.08	8,967
	Backorder rate of assembly plant	<0.01	0.037	−3,154
	On-time shipping to assembly plant	0.02	-1.0×10^{-7}	1.024
Orders to assembly plant	Visual defects	0.01	6.145	−11,033
	Backorder rate	0.04	0.853	−1,594
	Assembly plant internal defect rate	0.01	9.471	−5,290
	Assembly plant external defect rate	0.03	-1.0×10^{-6}	0.954
Orders to the retailer	On-time completion	0.01	−0.001	0.942

[a] Equation in the form $Y = bX + a$.

not alone guarantee high supply chain performance. To achieve the later, external integration with suppliers and customers is necessary (Germain and Iyer 2006, Lee et al. 2007, Aryee et al. 2008).

External integration.—External integration in the supply chain of study was analyzed in light of what Levy et al. (1995) suggested as the four characteristics of a joint quality management relationship, namely, growing confidence in supplier's quality, reduction in inspection of incoming materials, greater responsibility for suppliers in assuring quality, and no double handling with reduced need for storage. The following observations were made at the time of the study.

- There were no formal programs for inspection of interplant shipments.
- Each plant was evaluated individually by corporate headquarters and was responsible for sending high-quality products to the next internal or external customer.
- Regarding handling and storage, however, the company held significant quantities of parts and subassemblies at its plants, and double handling inevitably occurred. This is typical of an assemble-to-order supply chain strategy, in which customization is postponed until final assembly. Although intermediate inventories helped the company to shorten the lead time, they can hide quality problems and production scheduling inefficiencies.
- Integration was also limited when external suppliers were considered. All the incoming lumber was graded and tallied at the components plant. Immediately after grading, lumber was presurfaced to homogenize thickness. Although these practices helped to ensure the quality of incoming materials, they made the receiving plant responsible for the lumber's quality.
- Disconnect was identified between the components plant and its lumber suppliers because they were not integrated in the quality management system of the company. This disconnect is more profound as stored inventory between supply chain members increases because stocks mask scheduling and quality issues.

The relationship between the components plant and its lumber suppliers was, in general, long term and based on trust, and there were relatively few suppliers. However, some features of a more traditional approach were observed, like inspection of lumber loads upon receipt, purchasing plans independent of the customer's business plan, and a focus on price. A strategic approach to the purchasing process is more conducive to supply chain integration because it leads to partnerships in which supplier and buyer work for mutual benefit. Such an approach can have positive implications for buyer–supplier relationships, financial performance, and product development time and can improve product quality and assure continuing supply (Carr and Pearson 1999, Batson 2008).

In addition to physical flow, integration must also be achieved for information flow; this facilitates integration by reducing transaction costs, which are composed of coordination costs and transaction risks (Vickery et al. 2003). In the case study, the reach of quality information was consistently limited to the immediate supply chain partners, and very little interaction occurred beyond that. There was little or nonexistent communication, for example, between the retailer and the components plant. This has the potential of slowing down the response to customers' concerns. Similarly, potential for improvement was identified regarding information sharing between the company's plants and their external suppliers. For example, the information flow between the components plant and its lumber suppliers was unidirectional and limited to purchase order terms (grade mix, color, and length specs) and a grade bill. At the other end of the supply chain, although externally acquired parts were an important source of variances at the retailer (Fig. 3), there was little participation of external suppliers in the definition of requirements or purchase order specifications.

The company collected data about quality performance from all of its plants and posted this information on a corporate dashboard. This reporting allowed identifying gaps between performance and goals and making comparisons between plants. It did not provide, however, feedback about the contribution of each supply chain entity to the company's overall quality performance. Moreover, external suppliers' quality was not included in the computation of performance measures, limiting the efficacy of these indicators to point at the exact source of inefficiencies in the system. In this sense, quality performance measurement in the case study lacked a systems perspective and supply chain context (Hassan 2006). According to Chan (2003), ''a supply chain must be treated as a whole entity and the measurement system should span the entire supply chain.'' Thus, the quality measurement system did not foster external integration.

Supplier quality management

One important process in SCM is the strategic management of suppliers. Three main components of strategic management of suppliers are supplier relationship, supplier evaluation, and supplier development (Carr and Pearson 1999), which were analyzed in the case study.

Supplier relationship.—During the last decades, the prevailing trend in some industries has been to reduce the number of suppliers to a few competent ones (i.e., ''rationalize'' the supplier base), and help to improve the efficiency of those suppliers that are left. Research supports the development of collaborative rather than traditional adversarial relationships.

- In the case study, relationships with lumber suppliers were long term. However, although there was a relatively small number of suppliers, it was far from what is considered ''best-in-class'' by some authors (15% of suppliers accounting for 80% of expenditures in materials, according to Minahan 2005).
- The case study company had long-term and close relationships with its lumber suppliers, and conflicts were solved directly and expediently. However, the flow of information about quality issues with lumber suppliers was mostly unidirectional. The components plant, for example, specified lumber grades and other requirements in the purchase order, and sent back a grade bill to the supplier. Occasionally, entire loads of lumber were rejected for excessive amounts of off-spec lumber, and rejection of individual boards was common. Although the company did not pay for these rejections, reducing the amount of rejections by improving the internal processes of the suppliers could surely benefit both sides.
- Suppliers did not participate in the development of purchase order terms, which could potentially reduce waste and improve overall quality.

Supplier evaluation.—Notably, the company did not have a formal program for supplier evaluation in place at the time of study. There is ample support in the literature for the development of formal supplier evaluation programs (Fram 1995, Carr and Pearson 1999, Muralidharan et al. 2002, Chen et al. 2004), and authors state that these programs are positively associated with higher financial and market performance. Lumber delivered to the components plant was graded and presurfaced, and batches that were judged significantly below the minimum requirements were rejected. Evaluating suppliers based on rejections does not reflect the potential problems defective materials cause when processed (Chen et al. 2004). Presurfacing incoming lumber facilitates uniform drying and reduces warp, but it is costly and the plant missed some information that could be used to assess the capability of the supplier's process, for example, by monitoring thickness accuracy.

Supplier development.—The third element of supplier quality management, supplier development, can be defined as a systematic effort to create and maintain competent suppliers (Hahn et al. 1990). Supplier development can range from selecting suppliers based on conformance (narrow perspective), to efforts by the customer to improve the capabilities of suppliers (broad perspective), which usually benefit both parties (Rogers et al. 2007). Most automotive original equipment manufacturers in the United States have a supplier development program in place. Examples of supplier development activities are recognizing supplier with certifications or awards, providing technical assistance, and enhancing communication with suppliers (Lo and Yeung 2006).

The focal company did not have a supplier development program at the time of the study. The NHLA grading rules were the main standard for specifications, and quality improvement was only motivated by a desire by the supplier to comply with purchase order requirements and avoid rejections. Since the company paid suppliers according to grade and tally as determined at its facilities, and presurfaced all incoming material, there was no real incentive to improve suppliers' internal process performance. Lumber suppliers could potentially benefit from the company's expertise in process improvement methodologies, and the company could benefit from reduced variability in its lumber inputs.

Alignment of current measures with customer needs

One of the questions proposed for this research was whether current quality measures are aligned with the end-customer needs. It has been established in SCM literature that quality management needs to be aligned with the customers' requirements to significantly contribute to the supply chain success. This issue can be analyzed by looking at the use of lumber grades as the main standard for raw material purchases. NHLA lumber grades are based on the amount and size of ''clear cuttings''; lumber of higher grades yield a larger percentage of defect-free parts than lower grade lumber. Some provisions in the grading rules deal with species-specific characteristics, such as color specifications in maple, which set the minimum percentage of sapwood for individual boards. However, the main focus remains on maximizing yield, not final product quality as seen by the end-customer. In part to address this issue, some lumber manufacturers offer ''proprietary grades,'' catering to very specific uses and niches.

In the case study, by stipulating a specific grade mix for each species in the purchase order, the purchasing plant was basically making a trade-off between yield at the rough-mill and cost, and was not necessarily considering quality from the customer's point of view. Color, for example, which was found to be an important issue at the final customer's end, was inspected visually by lumber graders when the material arrived, but without any formal reporting of issues found. At the retailer level, color issues were not included in the final inspection checklist, and it was not listed as a separate attribute in the major quality performance metric. Likewise, the assembly plant did not include color among the attributes for its internal and external quality metrics. Therefore, apart from the inspection at the receiving end of the components plant, lumber color was not systematically evaluated and recorded. Several audits were conducted to control color consistency between product components at the components and assembly plants, but this evaluation was more likely to detect finishing process or materials variances, rather than lumber color consistency issues.

Summary and Conclusions

Quality management practices in a wood products supply chain were studied in great detail, which allowed an in-depth understanding of current quality management practices. The focal company of the study had in place a quality control and improvement system that spanned all of its facilities. The manufacturing philosophy implemented was conducive to the early identification of defects and their causes and elimination. The adoption of quality standards required the facilities to have rigorous documentation practices. These practices were found to be consistent throughout the firm. Each plant was evaluated by its performance and measured on the same scale (defects per million, costs of quality, scrap), and goals for the improvement of these measures were set at the corporate level.

Studying the supply chain as a system, however, allowed identifying some opportunities for improvement. Most notably, there was a lack of a formal supplier development program. Particularly, lumber purchases were carried out with very little participation of suppliers in the development of quality requirements and limited or nonexistent information sharing of production plans. The corporate performance reporting system did include quality-related measures for each one of the company's facilities, but this reporting was internally focused, lacking a systems perspective, and did not reflect the relative contribution of each plant to the overall performance. Also, the performance reporting system in use did not include external suppliers and customers, which does not capture performance across the supply chain, a necessary attribute for an effective supply chain performance measurement system (Beamon 1999, Lambert and Pohlen 2001).

Regarding quality measurement, although the metrics currently used were instrumental in identifying and correcting defects at each facility, they did not facilitate the rapid identification of causes when these originated farther upstream than the immediate supplier. Likewise, quality performance information was shared only with the immediate supply chain partners. Lastly, great effort was invested in maintaining a consistent color, mostly by inspecting color matching with master samples; surprisingly, however, no company-wide measure of this attribute was in use. Although final customers' claims were mostly related to color and wood issues, these were not included in the retailer's set of performance measures.

The results of the research described here highlight the importance of adopting a supply chain view for quality measurement. Poor quality at any point in the supply chain translates into higher total supply chain costs due to scrap and returns, which in turn can hurt profit margins or cause customer dissatisfaction. As a result, competitiveness of both individual companies and of the entire supply chain is affected. Companies planning to incorporate their customers and suppliers in continuous improvement process could benefit from the recommendations in this research.

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