Assessing the Supply Chain Efficiency of Hardwood Sawmills in New York State through Case Study Analysis and Data Envelopment Analysis Modeling

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Abstract

Hardwood sawmills throughout the United States were under severe financial pressures during the 2007 to 2009 recession. This was attributed to demand weakness, profitability challenges, and supply chain inefficiencies. The focus of our study was on hardwood sawmills in New York State. A supply chain assessment tool was created to evaluate the supply chain processes of 15 sawmills that had the capability to produce from 3 to 20 million board feet of lumber per year and accounted for 31 percent of the hardwood lumber produced in New York. We collected data that allowed us to rate each sawmill's supply chain and computed their relative efficiency using a mathematical modeling technique called Data Envelopment Analysis. We then used a Pearson correlation analysis to compare our sawmill assessment scores and the relative efficiency score from each sawmill and found a significant correlation of 0.716. The assessment tool we developed can help hardwood sawmills find opportunities to improve their supply chains, allowing their business to save money and improve profit margins.

The hardwood sawmill industry is transitioning to a sector characterized by narrow profit margins and commodity products, leaving little room to absorb inefficiencies in the supply chain (Parhizkar et al. 2009). Companies across various industries are using specific concepts of supply chain management to maximize productivity and profits (Guide and Wassenhove 2006). Supply chain management is defined as managing the set of activities that create goods and services by transforming inputs into outputs with the purpose of adding value to products or services for the customer at the lowest cost (Heizer and Render 2011).

Ford and Proctor & Gamble are two examples of companies that have flourished by utilizing the supply chain as a core strategy (Gartner Group 2013). These two companies constantly reengineer their supply chains, especially when demand is weak. This keeps them competitive and allows them to become opportunistic in the face of new business opportunities. As the sawmill sector emerges from the 2007 to 2009 recession (Hamilton 2011), it is an opportune time to analyze and examine the hardwood sawmill supply chain process. In New York State, there are about 175 hardwood sawmills, of which 79 annually produce at least 1 million board feet (MMBF) of lumber. These sawmills consumed more than 352 MMBF of logs in 2010 (Crawford 2010). The goal of this study was to analyze the supply chain of hardwood sawmills in New York State. The study goal was supported by the following objectives:

- Identify characteristics of the supply chain specific to hardwood sawmills that contribute to efficiency
- Utilize data envelopment analysis (DEA) to determine the relative efficiency of the sawmills in the study
- Develop a supply chain assessment survey tool to determine the efficiency of a hardwood sawmill's supply chain

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- Determine if there is a correlation between the assessment tool and our DEA data to see if the tool would be of benefit to the hardwood sawmill industry
- Determine what supply chain tactics could potentially help sawmills reduce costs in the future

Study Rationale

The 2007 to 2009 recession had a negative impact on the wood products industry (Espinoza et al. 2010). It was particularly tough on sawmills producing less than 1 MMBF of lumber annually. Numerous sawmills closed, went off-line, or were purchased by other sawmills (Espinoza et al. 2010). Many sawmills in North America lost money for most of 2008 and 2009 due to declining market conditions (Johnson 2009). The situation was exacerbated by global competition in the marketplace; Asian sawmills were buying whole logs and producing their own lumber, thus reducing the demand further (Salehirad and Sowlati 2006). The economic situation that continued to confront the sawmill sector can be effectively described using Porter's (2008) five forces of competition: rivalry among existing companies, supplier leverage, customer leverage, substitute products, and potential of entry. These forces can combine to reduce revenues and profits. Evidence suggests that there has been no time in history in which the five forces were more potent, particularly with respect to supplier and customer leverage (G.C. & Potter-Witter 2011). From the supply side, stumpage and log prices remained relatively high, while lumber prices and production (Fig. 1) dropped dramatically (Luppold and Bumgardner 2010), resulting in narrow profit margins, even disappearing profits, and leading to operating losses (Parhizkar et al. 2009). Customers gained tremendous leverage due to high supply and low demand. In fact, the recent recession brought about a fundamental change in how sawmills serve their markets. Customers are now requesting sawmills to ''customize'' their lumber requirements to meet their specific product needs (Grushecky et al. 2006). In order to move product, many sawmills are selling mixed truckloads with multiple species, thicknesses, and grades, whereas in the past they would sell full truckloads of the same grade and species (Buehlmann et al. 2010). Given this new dynamic in the marketplace, the need to improve supply chain management in the sawmill sector has never been greater (Espinoza et al. 2010).

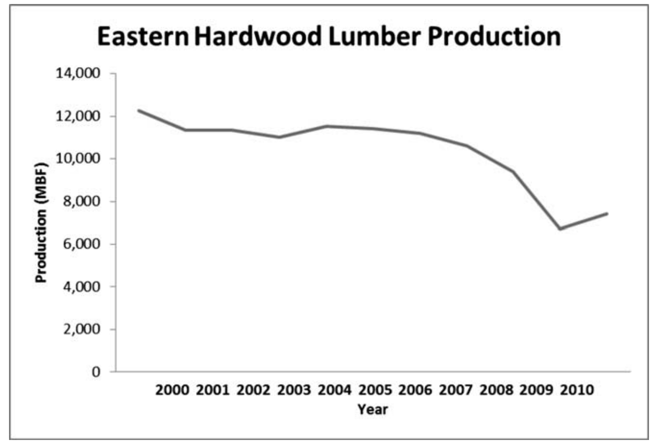

Figure 1.—Eastern hardwood lumber production (Luppold 2011).

Methods

Observational case study

This study was based on observations and interviews made during hardwood sawmill site visits from August 2010 to March 2012. The sawmills were identified from the Directory of Primary Wood Using Industry in New York, published by the New York State Department of Environmental Conservation (2009). According to the directory, there are 170 sawmills that process less than 3 MMBF of hardwood per year. Some of these mills are run as a regular business, and others ''start up and shut down'' based on demand and can change ownership frequently. Approximately two-thirds of eastern hardwood lumber is processed by mills cutting more than 3 MMBF (Luppold et al. 2000); therefore, we decided to focus on those sawmills producing more than 3 MMBF. Per the directory, 42 hardwood sawmills had the capacity to produce 3 to 20 MMBF of lumber per year. We contacted all 42 mills, and 15 agreed to participate in our study. In 2010, these 15 sawmills produced 88 MMBF of lumber, or roughly 25 percent of the lumber produced in New York State (Crawford 2010). We developed a 113-question supply chain assessment survey instrument that was divided into the following seven categories: operations planning, procurement, production, transportation, warehousing and inventory management, ergonomics and innovation, and environmental practices (Table 1). The purpose of our questionnaire was to analyze each of the different categories within the supply chain. The interviews were conducted with the sawmill manager and/or company executive responsible for the sawmill operation (Eisenhart 1989). Each category above was given a weight per its importance to the business. The weights were determined through discussions with experienced managers from four different sawmills (Table 2) representing various degrees of capabilities and strategies to ensure that we covered all aspects of the hardwood sawmill supply chain (Hedrick et al. 1993). We used the survey instrument to guide the on-site interviews. The survey was sent ahead of our on-site visit to give respondents opportunity to prepare for our questions. The interviews lasted 2 to 3 hours and were followed by a tour of the sawmill operation. Two interviewers attended the sessions, and each took notes to record impressions, context, and observations. During analysis of the data, the lead author followed up with each sawmill to update and clarify their respective responses. Each survey question was scored using a Likert-type scale (Table 3). The sawmills received a copy of the completed assessment score of their sawmill's supply chain process. The data were collected from three researchers with written record of the conversations and observations of the sawmills. This research design allowed us to use the process of triangulation, defined as combining observations from multiple researchers and data from multiple sources in order to mitigate biases and enhance reliability and validity (Jick 1979).

Modeling study

Through our observational case study, we were able to receive operational information on each sawmill. We used DEA to determine which sawmills were most efficient. In this case, efficiency is defined as getting the maximum

Table 1.—Partial list of supply chain assessment questions.

Operations planning	
1.a	Does the operations organization meet with salespeople on a regular basis to discuss issues and opportunities?
1.b	Do salespeople actively work with the operations and procurement organizations on new requests from customers?
1.c	Do salespeople and the operations organization collaborate on new product opportunities?
Procurement	
2.1a	Do you have any log supply agreements?
2.1b	Do you measure your suppliers' performance (delivery, cost, quality, and service)?
2.1c	Do you own any standing timber?
Production	
3.1a	Do you invest in new equipment each year? How much (average)?
3.1b	If business were to increase, could you handle a 20% increase in demand?
3.1c	Do you measure overrun and scrap?
3.1d	Do you have programs in place to reduce degrade?
Transportation	
4.1a	Do you analyze your freight costs (logs and lumber)?
4.1b	Do you use any software to maximize the shipments of your freight?
4.1c	Do you monitor your fleet's fuel efficiency?
4.1d	Do you calculate the cost of freight ?
Warehouse and inventory management	
5.1a	Do you measure inventory turns or days on hand (logs)?
5.1b	Do you measure inventory turns or days on hand (lumber)?
5.1c	Do you actively try to reduce inventory?
5.1d	Do you divide your inventory species and grade?
Ergonomics and innovations	
6.2a	Do you have a computer system that captures your operations information?
6.2b	Have you ever used continuous improvement tools (i.e., Lean or Six Sigma) to improve your processes?
6.2c	Have you invested in equipment to improve your supply chain processes? On average, how much on a yearly basis?
Environmental practices	
7.1a	Does the company measure the cost of energy use?
7.1b	Does the company use renewable energy?
7.1c	Is there an energy reduction plan in place?

output with the smallest amount of input possible (Charnes et al. 1978). DEA is a nonparametric mathematical modeling tool that can be used for the evaluation of production efficiency (Nyrud and Baardsen 2003). It determines the relative efficiency of a decision-making unit (DMU) based on inputs and outputs (Charnes et al. 1978). One of the useful attributes of DEA is that the inputs and outputs can be left in their original units without using a common denominator (Molinero and Woracker 1996). We used Excel 2013 to create a DEA program that determined the efficient frontier of the hardwood sawmills (DMU) we used for the study. The DEA program automatically assigns weights to the input and outputs used in the analysis (Liu et al. 2000). This program then generates an efficiency score between 0 and 1 for each DMU. Any DMU that scores a 1 would be considered on the efficient frontier. This would mean that compared with the other DMUs, they do not provide any evidence of inefficiency (Charnes et al. 1978). In this study, the output was annual lumber production, while the inputs were number of employees during the year, square footage of the sawmill and log yard, and dollar cost of energy used. We attempted to use cost of logs purchased, but many of the sample sawmills remarket logs (often the lowest and highest grades), making it difficult to place a consistently specific accurate cost on processed logs. We used the following equation and notations to determine relative efficiency (Hof et al. 2004):

$$\text{Maximize } z_o = \sum_r u_r y_{ro}$$

subject to

$$\sum_i v_i x_{io} = 1$$

$$u_r, v_J \geq 0$$

$$\sum_r u_r y_{rj} - \sum_i^n v_i x_{ij} \leq 0$$

where

z_o = the DEA efficiency score for DMU *o*,
u_r = the weight assigned to output *r* (choice variables),
y_{ro} = the amount of output *r* produced by DMU (lumber production),
v_i = the weight assigned to input *i* (choice variables),
x_{io} = the amount of input *i* used by DMU (no. of employees, size of sawmill, and energy costs),
y_{rj} = the amount of output *r* produced by DMU *j*, and
x_{ij} = the amount of input *i* used by DMU *j*.

Results

Observational study

Our assessment tool reviewed seven areas of a sawmill's supply chain process**.** Each section received a score based on 100 points (0 = lowest score, 100 = best score). Sawmills that scored between 90 and 100 percent in a category were considered to be showing proficiency or excellence in those areas. A score of 80 to 89 percent indicated adequate performance in those areas, while a score below 80 percent suggested opportunity to improve in those areas. Table 2 is a summary of our scores for each section and sawmill. The following sections provide highlights from each one of the supply chain categories.

Operations planning

This section looked at the organizational structure, goals and objectives, sales, and operations planning and forecasting. The scores ranged from 54 to 92 percent, with an average of 77 ± 10 (SD) percent. Only one sawmill had written objectives and a formal organizational chart on the company. In discussing the lack of formal goals and organizational charts, the sawmill managers stated that the goals and objectives were known throughout the organization (i.e., cut lumber and profit) and that they did not need to be formally stated. The sawmill managers also emphasized

Table 2.—Supply chain assessment scores.

Sawmill weight	Operations planning (15%)	Procurement (30%)	Production (25%)	Transportation (10%)	Warehousing and inventory management (10%)	Ergonomics and innovation (5%)	Environmental practices (5%)	Overall assessment score
A	92	91	100	100	100	100	68	94
B	54	89	95	80	80	80	88	91
C	90	86	77	80	78	80	74	80
D	80	80	96	97	96	92	55	87
E	86	96	79	89	75	64	97	86
F	74	90	69	89	87	68	85	80
G	72	84	88	100	100	72	62	85
H	62	94	91	71	80	76	88	82
I	70	98	76	77	75	72	87	82
J	88	86	93	97	91	80	88	90
K	80	80	80	48	78	72	77	74
L	82	88	89	97	88	80	80	87
M	82	88	87	97	88	80	80	88
N	77	70	75	100	100	84	95	80
O	72	91	64	92	70	56	78	77
Avg.	77	87	83	88	86	77	80	84

that the size of their operations did not warrant an organizational chart.

The sawmill managers did indicate that they worked with salespeople on a daily basis and discussed the challenges of placating customers when they required ''special'' services, such as mixed loads and special cuts. All the respondents scored very low on forecasting. In fact, only one sawmill in our study employed a forecasting methodology that looked at past sales to determine future requirements. The remaining sawmills felt that a formal forecasting process was not necessary due their understanding of what was needed on a daily basis for their respective sawmills.

Procurement

The procurement questions focused on how each sawmill managed log supply. The scores ranged from 70 to 98 percent, with an average score of 87 ± 7 percent. None of the sawmills had a formal supplier performance program in place with their suppliers, and they usually resolved issues with suppliers as needed. The sawmills were all active in trying to reduce costs but did not formally measure actual year-to-year cost savings. Three sawmills were buying tree-length logs and bucking in the log yard to maximize log grade and promote better lumber grade recovery. During the interviews, it was noted that several smaller sawmills stated that larger mills were overpaying for logs and stumpage and were perplexed on how these larger operations were making any money.

Table 3.—Survey scoring methodology.

0	=	No; none; unsatisfactory; improper
4	=	Insufficient; inadequate; limited application/usage; little effort made
6	=	Minor effort made; beginning stages; needs major work or improvement to complete
8	=	Major effort made; almost fully developed; needs slight amount of work or improvement; mostly completed
10	=	Yes; satisfactory; complete; fully developed; in place and being used
N/A	=	Not applicable[a]

[a] Any line items that are determined to be not applicable are marked N/A. Each N/A is scored as 0 and is not included in the point total.

Production

Our assessment of sawmill production specifically focused on production capabilities, capacity, and flow. The scores ranged from 64 to 100 percent, with an average of 83 ± 10 percent. Much of that production was in low-grade lumber—lower than the prior few decades. This change in grade is putting more stress on sawmills to remain profitable because they are selling this lumber at a lower price. All but one of the sawmills stated that they reduced their capital purchases during the recession. Much of the technology in place at these sawmills is 10 to 15 years old. Sawmills are customizing more orders for their customers, and this is negatively impacting their production capacity (small mixed lots and special cuts). For instance, to meet customer needs, the respondents were cutting multiple hardwood varieties in 1 day and were willing to cut any type of hardwood species. All of the sawmills had ample capacity and were sized to produce more than their current lumber production. Many of these sawmills did not scale back their existing production footprint to meet the declining production volumes during the recession. Several sawmills had unnecessary conveyors throughout their sawmills and excessive travel distances when moving material. Fourteen of the 15 sawmills employed a maintenance program and, depending on the location of the sawmill, kept key spare parts on hand to reduce downtime. All of the sawmills also had a logical flow of processing logs within their sawmills. One sawmill was using Lean and Six Sigma (Liker 2004) to improve their sawmill operations. Three sawmills we assessed expressed concern over the impending hydraulic fracturing natural gas industry and how it could impact their operation. Their biggest concern seemed to be over potential employee turnover due to the gas-drilling industry offering higher wages. Another concern expressed by two sawmills was the capabilities and work ethic of younger employees.

One anecdotal comment expressed frustration over regular texting and the use of this personal communication technology while people were supposed to concentrate on productive work.

Transportation

The transportation scores ranged from 48 to 100 percent, with an average of 88 ± 14 percent. Some sawmills subcontract their freight needs to third-party logistics providers, while others own their own trucks and some use a combination of the two. Fuel costs continue to increase, and many sawmills that use third-party logistics providers are seeing fuel surcharges on their freight bills. No sawmills were using software to analyze shipping and transportation costs. Many are negotiating flat-rate haul costs from their transportation providers in order to control freight expenses.

Inventory management and warehousing

Inventory management and warehousing scores ranged from 70 to 100 percent, with an average of 86 ± 10 percent. Each sawmill (based on what they produced) handled inventory management and warehousing differently. Green-lumber sawmills rarely had any lumber on hand and were focused on not processing logs until they received a customer order. Sawmills with kilns were more apt to carry inventory. One sawmill used air-drying sheds to reduce their kiln expenses and were warehousing a large amount of inventory. Sawmills that carried inventory were inefficient with regard to how they moved inventory throughout their operation. We commonly witnessed excessive handling and movement of material.

Ergonomics and innovation within the supply chain

In this section, the scores ranged from 56 to 100 percent, with an average of 77 ± 10 percent. The sawmills performed quite well with respect to ergonomics. We noted excellent safety conditions for employees and adherence to Occupational Safety and Health Administration standards. Innovation, however, was not a strong suit among our sample sawmills. Four of the sawmills did not utilize any advanced software packages or scanning systems for optimizing log breakdown on their head rigs. With the exception of one, none of the sawmills employed continuous improvement tools, such as Lean or Six Sigma. Only 1 of the 15 sawmills used automated stackers on the green chain; the balance were all stacking by hand. The manager representing the mill with the automated green chain stated that it did improve their sorting and handling efficiency. Many advances within these hardwood sawmill supply chains have come from equipment purchases versus streamlining processes.

All of the sawmills were focused on resolving problems and reducing costs within their operations. For example, one sawmill placed its entire maintenance department underneath their sawmill, rerouting all of their air hoses and power lines underneath the sawmill in order to better utilize space and prevent hoses and lines from being damaged. Another sawmill used the heat created from its sawmill equipment to heat the sawmill operation during the winter, allowing savings on fuel costs.

Environmental practices

On environmental practices the sawmill scores ranged from 55 to 97 percent, with an average of 80 ± 11 percent. There were three areas in this section that we analyzed: energy use, environmental costs, and hazardous materials. Energy was an interesting topic for many sawmills. All of the sawmills used diesel fuel for their trucks, while two used it to run generators that electrically powered their sawmill operations. Thirteen sawmills were on the electric grid, and three were using biomass to supplement their thermal energy use. All of the sawmills had low environmental waste and hazardous costs and have been working to eliminate harmful chemicals used within their processes. Four of the sawmills were Forest Stewardship Council (FSC) certified and stated that they are not receiving any additional price premiums from FSC wood. All four sawmills were questioning whether they should continue with this program.

Modeling study

In our survey instrument, we asked each sawmill for the following: annual output of lumber, number of employees during the year, square footage of the sawmill and log yard, and amount of energy used annually. This information allowed us to run a DEA analysis on the sawmills. Sawmills B, G, J, and M had a relative efficiency score of 1, which would place them on the efficient frontier of our DEA model (Table 4). We decided to explore our findings further to understand why each of these four sawmills was on the efficient frontier and what was their specific competency. Upon further analysis, we determined that Sawmill B is the only operation on the efficient frontier based on the volume of lumber it cut and the size of its sawmill. This sawmill combined high production, energy efficiency, and space utilization to qualify as a ''frontier'' operation. Sawmill G earned a spot on the efficient frontier because it had the lowest energy costs of all the sawmills. Sawmill J combined high production with relatively low energy costs to be on the efficient frontier. Sawmill M earned frontier status with the lowest ratio of labor to lumber production. Sawmills B, J, and M were the three largest producers of lumber in our sample. We can deduce from this exercise that volume and the associated economies of scale play a significant role in the efficiency of the sawmill. This may explain some of the price premiums presumably paid by large sawmills for logs and stumpage. If all of these sawmills were to focus on reducing labor, energy costs, and footprint of their sawmills, they could see a significant reduction in costs.

Correlation between assessment scores and DEA relative efficiency

Using the Stata 11 statistical software package, we ran a Pearson correlation analysis between the DEA relative efficiency and the average overall sawmill assessment scores. We found a significant correlation between the two variables at 0 .716 on both sides of the curve ($P = 0.003$). This verifies that the assessment tool we created would be an accurate indicator of a hardwood sawmill's efficiency and could be utilized by other sawmills to gauge their efficiency (Table 5).

Discussion

Our study confirmed that the hardwood sawmill industry in New York State is undergoing a transformation. Demand

Table 4.—Operational information and relative efficiency scores.

Sawmill	2010 production (board ft)	No. of employees	Size of sawmill and log yard (ft^2)	Energy costs ($)	Relative efficiency	Assessment score (%)
A	7,602,000	25	8,000	290,000	0.93	94
B	15,384,392	27	15,000	415,670	1.00	91
C	5,000,000	25	10,890	100,000	0.77	80
D	7,289,538	22	21,680	245,440	0.70	87
E	3,907,962	24	27,155	135,000	0.47	86
F	1,100,000	7	16,875	96,000	0.30	80
G	4,700,000	30	17,000	36,000	1.00	85
H	4,789,312	21	11,200	161,155	0.60	82
I	5,000,000	31	17,500	143,000	0.50	82
J	17,820,000	61	35,000	193,000	1.00	90
K	3,500,000	32	10,500	153,258	0.46	74
L	5,900,000	10	25,625	301,000	0.98	87
M	9,672,000	16	19,000	333,050	1.00	88
N	800,000	13	11,000	140,000	0.13	80
O	2,500,110	16	9,000	72,500	0.49	77

is shifting from high-grade lumber to low-grade lumber. Many downstream users in the United States are using less high-grade lumber, which has adversely impacted many sawmills, in some cases leading to acquisition or closure (Buehlmann et al. 2010). Sawmills that are processing smaller batches of lumber must develop other sources of revenue within the wood products industry in order to stay in business. Some of the sawmills we visited were producing pallets, flooring, and pellets to be used for energy.

Survey assessment tool

The supply chain survey assessment tool can help sawmills improve their operations. Every hardwood sawmill should be evaluating their supply chain on a yearly basis and looking for areas of improvement. This is a good business exercise to employ, especially in today's competitive environment.

DEA model

The results of our DEA model indicated that 26 percent of the sawmills we measured were considered efficient (i.e., on the efficient frontier). Large mills were more efficient than the smaller mills, most likely due to economies of scale. The DEA modeling also supports our supply chain assessment tool results. Several of the sawmills are changing their business operations faster than others to meet this new business dynamic of smaller customized orders and products. The key operational and cost factors that contribute to improved sawmill productivity are as follows: purchasing logs, energy costs, efficiency of the operation, size of the operation, and labor.

Table 5.—Correlation between assessment scores and relative efficiency.[a]

Pearson correlation	1	0.716**
Significance (2-tailed)		0.003
n	15	15
Pearson correlation	0.716**	1
Significance (2-tailed)	0.003	
n	15	15

[a] ** = correlation is significant at the 0.01 level (2-tailed).

Purchasing logs

The high price of logs was an important theme across the sample. During periods of high demand, the larger sawmills often outbid their smaller counterparts. Unfortunately, without supply, many of these sawmills are unable to cover the fixed costs of their operations. Hardwood sawmills will need to be more deliberate and multifaceted with respect to long-term log supply. A multipronged strategy should include the following: buy more fee land, purchase timber easements, develop more aggressive landowner assistance programs, buy more stumpage than gate wood, and develop business relationships with private landowners to develop sources of log supply.

Energy costs

Energy costs are impacting the profitability of all sawmills. The cost of energy varies widely for many sawmills. Some sawmills were paying 3 to 4 cents per kilowatt, while others were paying 12 to 13 cents per kilowatt hour. Hardwood sawmills, which have a high thermal demand for energy, should expand the use of wood or biomass boilers within their operations. In the next 10 years, petroleum-based energy products are predicted to continue to climb in cost (Leder and Shapiro 2008). All New York hardwood sawmills should request a free energy audit by the New York State Energy Research Development Authority to make sure they are as energy efficient as possible. Sawmills using electricity can reduce their energy costs by staggering the start-up of equipment within a sawmill so as not to be charged at the surge rate by the utilities. Using energy-efficient equipment and lighting can also reduce energy costs. Long-term contracts may be another opportunity to reduce diesel fuel costs by locking into lower prices for a specific time span.

Efficiency of the operation

Log yard size and location should be strategic to minimize log movements after delivery. Log skidways should be situated as close to the sawmill log deck as possible to save on time and energy costs, especially if demand is less. Hardwood sawmills should evaluate the conveyor systems used throughout their operations, looking for ways to reduce or eliminate conveyor length during times when demand is reduced. The reduction of the sawmill footprint would reduce material movement throughout the sawmill and could be a significant cost-savings opportunity. Implementing sensors wherever possible to turn conveyors on and off would save on energy use. Reducing the size of motors operating conveyors could also reduce energy consumption.

Labor

The hydraulic fracturing natural gas industry is anticipated to eventually have an impact on the retention of labor at sawmills, especially in New York State. Sawmills will need to develop a plan to keep and attract workers. A potential opportunity is to institute a pay-for-performance program in which employees are paid on the skill sets that they bring to the sawmill. Another option is to develop an incentive plan on the performance of the sawmill whereby employees share in the sawmill's profits. Automation is another option sawmills should investigate when determining labor needs, especially with sorting and stacking lumber. The use of part-time labor in less skilled areas is another way to reduce costs.

Conclusions

Assessing a hardwood sawmill's supply chain is the first step in improving supply chain performance. Our study showed that high-performing supply chains are more efficient and likely more effective as well as more profitable. In recessionary periods or periods of low demand, hardwood sawmills have to focus on making their supply chains as cost effective as possible. In today's business climate, being cost effective is a necessity for survival.

Limitations of the Study

This study only focused on 15 sawmills in New York State. Ideally, we would have liked to have expanded our study, but it was difficult to gain access to a larger sample due to time and cost issues. Nonetheless, similar valuable case studies of supply chain management included even smaller sample sizes (Pagell and Wu 2009).

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