A LEAN LOGISTICS FRAMEWORK: A CASE STUDY IN THE WOOD FIBER SUPPLY CHAIN

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(Received August 2019)

Abstract. There are opportunities for improvement within the wood fiber supply chain. A significant amount of these opportunities are related to waste reduction. The body of the literature focuses on what are the causes of waste and supply chain inefficiency. Conclusions suggest this is partially due to improper supply chain management and collaboration. There is a gap within the research regarding applications of lean tools in the wood fiber supply chain, especially tools that help suppliers and consumers work together to reduce waste. A value stream map (VSM) tool that focused on identifying lean waste in logistic operations was developed and applied. The VSM for the paper mill case study includes three processes: supplier, transportation to the wood yard, and receiving operations at the wood yard (consumer mill). Once the tool was applied, the following cost reductions were projected: the inbound logistics cost was reduced from $2.8 million to $2.3 million and the inventory carrying cost was reduced from $98,400 to $79,600 annually. The possible annual savings reported totaled $320,000 approximately by the introduction of lean principles that reduce the waste in transportation and carrying cost.

Keywords: Supply chain, value stream map, lean logistics, wood, cost reduction, wood fiber supply industry.

INTRODUCTION

There is strong evidence in the literature of the critical problems affecting the wood fiber supply chain related to waste. The diagnoses and analysis of the current state of the problem exist. However, there is a gap in the literature regarding tools or methodologies to help forest products companies identify their own waste and diagnose their current status, opportunities for improvement, and what areas need reinforcing. The objective of this study was to introduce a lean manufacturing tool in the wood fiber supply chain to identify and reduce waste by developing and implementing a lean logistics value stream map (VSM). The wood fiber supply chain faces a significant amount of challenges that have been identified in various reports (Greene et al 2002; Taylor 2012; Rodgers et al 2002). These challenges identified are consistent throughout different sources and discussed in the following subsections: overcapacity of suppliers, loss of production due to market factors, current planning process that is primarily reactive rather than proactive, and recognition of impact of consumer actions.

Overcapacity of Suppliers

Forest harvesting operations are always highly susceptible to wet weather. Logging contractors

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Wood and Fiber Science, 52(1), 2020, pp. 117-127
https://doi.org/10.22382/wfs-2020-010

could lose as much as 20% of their logging capacity to weather-related factors alone. Stock risk at a wood products manufacturing facility is unacceptable because of the high cost associated with downtime. This risk can lead to overcapacity of suppliers (LeBel and Carruth 1997). Greene et al (2002) reported significant overcapacity, presented reasons for it, and estimated its cost to the supply system. Twenty years later, the industry is still facing the issue of how to define the appropriate logging force needed for a given procurement area. Therefore, it is still common to see companies, including dealers and large woodland owners, contracting their logging operations to large numbers of suppliers.

Loss of Production Due to Market Factors

How wood fiber consumers handle their supplier–consumer relationships affects the logging operations directly, for example, these relationships determine if the logger can proactively plan their operations or if they will plan reactively because of lack of information from the consumer company. Wood order constraints continue to provide a threat to lean in the wood fiber supply chain. The supply stream is stressed because of the reactive market environment. Low and variable quotas affect the financial status of loggers and their capacity to keep their businesses afloat. Loggers who consistently face a constrained market environment, face real hardships. Greene et al (2002) discussed missed production per week. Market factors were the most recurrent cause of lost production (ie quota,[1] mill handling, and mill closures). The study found that there were approximately 3.5 loads of lost production per week (an estimated 26 m^3 per load). Quota losses contributed to 1.9 loads; mill handling and mill closures assigned 1 load and 0.6 loads, respectively (Greene et al 2002). A decade later, the Supplier/Consumer Relationship Study Southeastern Region Report again identified the loss of production due to breakdowns in the consumer/supplier interaction. Breakdowns refer to unfulfilled negotiations, joint-planning, feedback, or communications—problem solving. This could potentially represent 2.6 million tons annually or a loss of 15% of production. Ineffective interactions between suppliers and consumers have an impact on overall productivity, affecting the efficiency of the supply chain and its cost (Taylor 2012).To recognize the importance of stability to the loggers and how situations mentioned earlier can affect the economic stability Greene et al (2002) argued how sensitive a logger's break-even level can be. If 1 d of production is missed, the crew can fall below the break-even level. For example, if the production target in a 5–working day week is 72 loads (20% above the break-even point), then not working 1 d (daily production is 14.4 loads) places the crew below the break-even point (Greene et al 2002).

Current Planning Process is Primarily Reactive Rather than Proactive

Rogers et al (2002) stated that the planning process in the wood supply chain is primarily reactive rather than proactive. This is due in part to the high degree of uncertainty faced by the forest and logging industries in today's business practices that can introduce inefficiencies in the wood supply chain. This reactive environment can be explained by the unpredictable situations that the industry faces, but traditional business practices also contribute. In 2002, more than 75% of contract loggers claimed being informed less than 1 wk in advance of the location and characteristics of the next tract, and 37% indicated that they received poor or bad information on the expected demand (Rodgers et al 2002).

The redirection in loaded transport vehicles continues to promote waste in the supply chain. The short notice to loggers regarding changes in the location and haul distances is another example of waste. This was seen throughout this study and found in the previous literature. WSRI's Supplier/Consumer Relationships Study also identifies the practice of suppliers having to drive further distances, which incrementally increased logistics

[1] A consumer-imposed maximum load can be brought in by the supplier (logger).

costs because of the current reactive planning process that introduces inefficiencies to the system (Taylor 2012). A list of examples of the consequences of the reactive planning process stated by Taylor (2012) include: 1) loggers may not plan capital expenditures or resources efficiently, 2) consumer's ability to coordinate volumes according to inventory levels is compromised, and 3) fragmented communication not only impacts tract allocation (mismatch of production capacity to tract) but also introduces inefficiencies for transportation. These practices provide small or no planning horizon for the suppliers.

Recognition of Impact of Consumer Actions

Before strategies to combat the present issues can be designed and implemented, consumers must understand these issues. In 2002, consumers still had not recognized the importance of a strong supply chain. The majority of consumers interviewed did not see the added advantage of having a logging contractor that was profitable, much less one that had adequate cash reserves to "wait out" a rain event (Rodgers et al 2002). In 2012, the number one issue identified by southeastern suppliers was the lack of recognition of conditions that were having an economic impact on the suppliers at the time (inflation and rising fuel costs) (Taylor 2012). Both factors demonstrate the opportunity to strengthen relationships between consumers and suppliers to protect the wood supply chain from inefficiencies that cause waste.

MATERIALS AND METHODS

A descriptive qualitative study was performed. Yin's definition of a descriptive case study is an intervention or an occurrence in its real-life context (2009). A case study approach was selected because it uses experience or observation to investigate a contemporary phenomenon in depth and within the real-life context. The contextual conditions surrounding the phenomenon and the boundaries between the two are not clearly evident (Yin 2009). A case study provides information which is only intended to describe the specific group (Hancock and Algozzine 2006).

A lean logistic VSM was applied to the case study company—a paper mill. Pulp, paper, and paperboard mills represent the second largest number of manufacturing facilities (343 facilities) in the paper manufacturing sector of the industry. VSM is a lean manufacturing or lean enterprise technique that uses simple visualization to represent the value stream and enables gathering, analyzing, and presenting information. This tool allows all stakeholders, from the newest collaborators to the highest ranked collaborators, a graphic way to visualize a process, making it easier to understand (Nash and Poling 2008). It also serves as an effective way to benchmark a current process's effectiveness; this is carried out by removing realistic wastes and showing how the process may look, if waste is removed (Hines et al 1999). The VSM included the major inventory points from stumpage to the log yard. The major inventory points are supplier's inventory, inventory transported, and the inventory at the consumer's log/wood yard.

RESULTS AND DISCUSSION

Case Study: Paper Mill

The data required to elaborate the current state VSM for the paper mill case study performed were collected through interviews, direct observation, and data provided by the case study company's procurement personnel. In addition, the research team visited a harvesting site to interview the manager and owner of the logging crew. The logging business was a supplier to the paper mill. The VSM was applied to three supply chain elements: 1) the supplier,[2] 2) the inbound transportation, 3) the paper mill's receiving operations. The interviews and visits to the paper mill and harvesting site were conducted in June 2017. The VSM for the paper mill case study includes three processes: supplier, transportation to the wood yard, and receiving operations at the wood yard or consumer mill. The following sections explain how the necessary data for the VSM were collected and prepared for the paper mill case study firm.

[2] The supplier in this case study firm represents a district within the consumer's wood basket.

Choosing a value stream for mapping. The research team was advised by the case study company to select hardwood pulpwood sourced from a location denominated as District A as the value stream for the VSM. District A represents the kilograms (tons) that are hauled directly to the mill from a specific geographic area within their wood basket. The value stream selected represents about 20% of the total wood fiber delivered to the company in 2016. Based on data (December 2016) provided by the paper mill, the amount of wood incoming to the value stream was estimated as 1.01 million (kg/d) $(1122.5[\text{tons/d}])$. Table 1 shows the total amount of wood fiber delivered to the case study firm during 2016 from all suppliers.

Table 1. Wood fiber supply volume during 2016 for the case study firm.

Wood delivered during 2016	Total (kg)	Total (tons)
Pine pulpwood grand total	1.26×10^8	139,965
Pine chips grand total	1.31×10^5	145
Hardwood pulpwood grand total	5.98×10^8	659,743
Hardwood chips grand total	3.86×10^8	426,559
Hardwood logs grand total	9.20×10^7	101,435
Pine logs grand total	1.61×10^6	1778
Wood chips	1.28×10^8	141,278
Total	1.33×10^8	1,470,903

Supplier process. The selected value stream was sourced from an area called District A where there were 10 tracts of timber, totaling 291 hectares (720 acres). Standing timber inventory in District A was 291 hectares. The company indicated that, on average, 0.4 hectares (1 acre) produces 36,200 kg (40 tons) of wood and the consumption of wood from District A was 1.08 million kg (1200 tons) per day. Therefore, the amount of inventory in days for District A forestland was:

$$\text{ADOH} = \frac{2.9\,\text{million m}^2(720\ \text{acres}) * 8.96\dfrac{\text{kg}}{\text{m}^2}\left(40\dfrac{\text{tons}}{\text{acre}}\right)}{1.08\,\text{million}\dfrac{\text{kg}}{\text{d}}\left(1200\dfrac{\text{tons}}{\text{d}}\right)} \approx 24\,\text{d}.$$

The paper mill indicated that it takes approximately 40 d to deliver a request for hardwood pulpwood from District A (order to shipment). This time includes the time that it takes to issue the request from the procurement office and the time that it takes to harvest the requested wood. The minimum order quantity to be harvested from a tract of standing timber in District A was not available. Therefore, the assumption was 362,000 kg (400 tons), which is a value that was obtained from a logging company. In addition, the minimum transportation batch was a truck load that weighed 22,600 kg (25 tons) on average. The price per ton of standing timber (stumpage rate) at District A's location is $0.003 per kilogram ($3 per ton), according to the procurement department. Therefore, the average annual value of the standing inventory for District A is estimated as:

$$\begin{aligned}\text{Value of inventory} \\ &= 2.91\ \text{million m}^2(720\ \text{acres}) \\ &\quad * 8.96\frac{\text{kg}}{\text{m}^2}\left(40\frac{\text{tons}}{\text{acre}}\right) * \$0.003/\text{kg}\left(3\frac{\$}{\text{ton}}\right) \\ &= \$86,400\end{aligned}$$

The annual carrying cost of this inventory was estimated at a 10% of the annual value of the inventory, making the annual carrying cost $8640. The carrying cost includes the following items: capital investment, insurance, obsolescence, damage, and shrinkage of the inventory.

Transportation. Transportation was the second process for this case study. Transportation is the movement of wood from the supplier (harvesting site) to the wood yard of the consumer (paper mill). As mentioned before, the minimum batch size is a truck payload of 2260 kg (25 tons). The distance from the harvesting site to the wood yard was 88.51 km (55 miles), according to company sources. If an average speed of 88.51 km (55 miles) per hour is used, a truck should take 1 h to cover this distance or 0.061 d (1 working day equals to 16.5 h).

An analysis of the data for December 2016 for tons received at the wood yard by the company was conducted to estimate the amount of wood in transit per day. The research team estimated the tons in transit per day as 1.01 million kg per day (1122.50 tons/d). The procurement team at this case study firm indicated that the value of the wood in transit was \$0.039 per kilogram (\$34.36 per ton), the logging, trucking, and stumpage included in the cost per ton. Therefore, the value of the inventory in transit is calculated as:

$$\begin{aligned}&\text{Value of Inventory}\\&=1.01\,\text{million}\frac{\text{kg}}{\text{d}}\left(1122.50\frac{\text{tons}}{\text{d}}\right)\\&\quad*0.037\frac{\$}{\text{kg}}\left(34.36\frac{\$}{\text{tons}}\right)\\&=\$38,569.\end{aligned}$$

The carrying cost of the inventory was estimated as 10% of the annual rate. Therefore, the carrying cost for the inventory in transit was estimated as \$3857 per year. Finally, the delivery frequency was estimated as 45 loads/day, each load weighing 22,600 kg (25 tons/load). There was no information available to estimate perfect-order execution metrics[3] for the transportation process.

Receiving operations. The third process in this value stream is receiving operations at the wood yard. Once wood has been transported from the harvesting site to the wood yard, it waits for further processing. During 2016, the average hardwood inventory carried and the average daily mill consumption estimated by the procurement personnel were a 22 million kg (25,000 tons) and 1.08 million kg (1200 tons), respectively. As indicated in the supplier process, the daily consumption of the selected value stream (hardwood pulpwood from District A) was 1.08 million(kg/d)(1200 [ton/d]) at the paper mill. Therefore, the average days on hand inventory is calculated as:

$$\text{ADOH}=\frac{22\text{ million kg }(25,000\text{ tons})}{1.08\text{ million kg/d }\left(1200\frac{\text{tons}}{\text{d}}\right)}\approx 21\,\text{d}.$$

Eq 4. shows the metrics for this process of the VSM. The company indicated that the value of 907.185 kg (1 ton) of wood at the wood yard is \$0.039 per kilogram (\$34.36 per ton); this rate is the logging, freight, and stumpage cost together. Therefore, the value of the average annual inventory of the selected value stream at the wood yard is

$$\begin{aligned}&\$0.039/\text{kg}*(\$34.36/\text{ton})*22\\&\text{million kg}\,(25,000\text{ tons})=\$859,000.\end{aligned}$$

The carrying cost of this inventory was calculated at a 10% annual rate so that the annual carrying cost of the wood yard inventory was \$85,900. Because the company processes roundwood using a continuous batch process set-up, an estimation of the lot size and delivery frequency to the production line did not apply in this case. Finally, of the eight perfect-order execution metrics intended to be measured for the receiving operations process, the company only tracked the quality of the inbound wood. This quality metric determined that 35% of the wood purchased was out of specification. Figure 6 displays a 65% quality metric (100-35% metric). These data were provided by the company and not measured.

Analysis of the VSM for Paper Mill

The value-added time or total process time for this value stream is 40 d. The non–value-added time for this VSM is 45 d. Therefore, the total lead time for this value stream is 85 d, which

[3] The perfect execution metrics are the percentage of the following criteria: right quantity, right product, right place, right time, right quality, right cost, and right service out of the total amount for each criterion. The overall perfect execution metric is the multiplication of all the metrics. If all are not available, the remaining are multiplied.

implies that about 52.8% of the total lead time is considered NVA time (time spent in inventory is non–value adding because the product is not being transformed). The VSM also indicates that the value of the annual average inventory for this value stream (only hardwood pulpwood from District A) is $984,000, with an annual carrying cost of $98,400. Other significant metrics from the VSM are as follows:

1. The average days on hand at receiving operations is 21 d, with 22 million kg (25, 000 tons) of inventory at the consumer's wood yard.
2. The minimum batch size for the harvesting site is 362,000 kg (400 tons).
3. The frequency of delivery is 45 truck loads per day.
4. The distance from the harvesting site to the receiving operation (wood yard) is 88.51 km (55 miles).
5. The quality perfect-order execution metric at the receiving operations is 65%.

Table 2 lists the type of waste identified based on the interviews, site observations, and document analysis. The interview with the logging crew manager supplying wood to the paper mill was critical for understanding some of the major waste generated in this value stream. The supplier recognized that tree markings were sometimes confusing. The supplier said that the notice for when and where the next tract would be was a short timeframe.

Lack of coordination between the procurement team of the case study firm and the logging crews could cause unnecessary waiting and idle times for the logging crews. For example, if there was miscommunication between these parties, logging crews could move equipment to the wrong harvest tract. Another example that could cause delays and waiting for the logging crews was the wrong marking of trees to be felled. When this happened, the logging crew manager needed to contact the forester to get issues clarified. Inefficient communication between the logging crews and the consumer mill causes a lot of waste because it impacts waiting times, causes unnecessary transportation, excessive movement, defective product, and lower material yields. For example, every time a logging crew waits or idles equipment, there is a significant increase in cost per kilogram or ton, as fixed cost does not depend on production volumes. As Greene et al (2002) concluded, the cost of idled equipment averages $0.0029/kg ($2.70/ton), already in 2018 present

Table 2. Identified waste in VSM for case study firm.

Type of waste	Logistics area impacted	Specific issue
Inefficient use of human resources	Supplier collaboration	Errors when marking trees at harvesting sites caused delays that could cause the logger to cut down the wrong trees.
	Procurement	Loggers are seldom considered for strategic planning decisions.
Unnecessary transportation	Inbound transportation	Trucks travel longer distances between harvesting and wood yard sites.
Excessive movements	Wood yard management	Unloading of trucks causes delays to logging crews.
	Supplier	How the logger determines the layout of the cutting operations may increase the amount of movements necessary.
Excessive waiting times	Supplier collaboration	An excessive amount of turn time.
	Supplier collaboration	Logging crews need to idle equipment and personnel because of lack of demand. Wood quotas and how they are distributed may be a cause.
Overproduction	Supplier	Logging crews harvest more than planned to take advantage of good weather conditions.
Inventory holding	Supplier and wood yard management	The carrying cost of inventory.

value considering an annual inflation rate of 3%. In addition, these delays, due to lack of coordination and communication among procurement and the logging crew, could be one of the most significant causes of waste, explaining that 52% of the total lead time is NVA time. Another cause of waste, in the form of unnecessary waiting and idled equipment, is extra movements at the wood yard operation. Poor scheduling of truck arrivals, lack of space at the wood yard, lack of visual controls to quickly identify storage areas for logs, scheduling of inexperienced loader operators, and lack of standard procedures to efficiently unload trucks are main sources of waste in this situation. Every extra minute a truck waits for unloading can be translated to an opportunity cost of $1.72/min or $103.13/h (considering a round trip of 55 miles (88.51 km) at 55 mph (24.58 m/s), with a cost of $0.00025/kg per kilometer ($0.15/ton per mile). Unnecessary transportation is also a source of waste and cost as indicated by the logging crew manager and the procurement team at the paper mill. When distances to transport the raw material are increased, the logging crews or the procurement team need to add extra capacity in transportation equipment to move the same amount of wood. For example, the average distance from the harvesting site to the wood yard is 88.51 km (55 miles), and 45 truck loads are delivered per day for the selected value stream. But if the distance changes to 110 miles, then the transportation capacity needs to be increased to haul the same amount of wood, and the cost per ton per mile will increase by 100%. It is worth mentioning that quota management (changes in demand of wood fiber) is a critical source of waste that the suppliers (logging crews) face. When mills impose quotas, changes must be made by suppliers to adjust to these requests. As indicated earlier, idle or unused equipment increases the cost per ton. Also, it impacts the management of the logging crew as some personnel are not needed when demand decreases or on the contrary, loggers need to rush to find additional logging workers.

Weather also plays a key role in terms of waste along the value stream. For example, when weather is good, loggers tend to harvest more than required, hoping that the extra inventory of logs will help to meet demand when weather conditions worsen. Overproduction at this point of the value stream also means an increase in the carrying cost of the inventory because the carrying cost of the inventory at the wood yard was estimated at an annual rate of $0.0037/kg ($3.44/ton). The consumer mill understands that once the logs are received from the logger, the company needs to absorb the inventory's carrying cost. The procurement team would rather have the logger holding the inventory until it is needed at the wood yard.

A particular issue related to holding inventory at the supplier end is that standing timber might also be considered a product itself and not necessarily inventory. Standing timber in the forestland continues to grow as time passes, so the value increases over time. Therefore, instead of considering that standing timber is an inventory owned by the supplier that carries inventory holding costs, standing timber could be seen as an ongoing product that has associated production costs and other administrative expenses leading to a profit. In this case, the project team treats standing timber as an inventory that has an associated carrying cost. In fact, the research team has estimated other related logistics costs for this value stream including procurement, harvesting, inbound transportation, supplier collaboration, and wood yard management. These costs are presented in the next season with the intention of being used as a cost baseline to quantify cost improvements when the future VSM is discussed.

Fulfillment cost of case study 1. In addition to calculating the inventory annual carrying costs for the three processes in the analysis, the research team also estimated additional logistics costs for this value stream. The value stream was divided into the following logistics activities: harvesting, inbound transportation, procurement, wood yard management, and supplier collaboration. These cost calculations are important because they represent a baseline when considering future improvements to the value stream being analyzed.

The harvesting cost was provided by the case study company. The total cost per kilogram is $0.039 (or $34.36 per ton) which is divided into the following costs (the percentages represent the proportion of each of the following activities compared with the entire cost per kilogram and per ton):

1. logging cost $0.025/kg or $23.00/ton (67%),
2. transportation cost $0.0093/kg or $8.50/ton (25%), and
3. stumpage is $0.003/kg or $3.00 per ton.

Therefore, the cost of harvesting is 1.01 million kg per day (1122.5 tons/d) for 251 d is just less than $6.5 million. The harvesting cost is the highest cost (63%). The costs of the other logistics activities are shown in Table 3. The second largest cost is transportation with $2.87 million (28% of total cost) for transporting 255 million kg (281,747 tons) more than 88.5 km (55 miles), at $0.15 per ton per mile (company source rate per ton/mile). The procurement cost (material ordering) was estimated to be $534,000 (5% of total cost). The annual carrying costs was $98,400 (the carrying cost in the current state map includes the stumpage carrying cost), which represents less than 1% of the logistics annual cost. The annual wood yard management cost was estimated as $332,060 (3% of total costs). Therefore, the total annual cost of fulfillment for this value stream was estimated as $10,318,436 or $0.040 per kilogram ($36.62 per ton), for 281,747 tons per year. No data were available to estimate the cost of supplier collaborations for this value stream.

Table 3. Total cost of fulfillment for case study firm.

Logistics impact annualized	
Wood yard cost	
Personnel: raw material handling	$207,240
Material handling: equipment	$1,162,025
Tons out of specification in 2016	$17,180
Overhead cost (20%)	$273,853
Current subtotal (annual)	**$1,660,298**
Current subtotal (20% of annual)	**$332,060**
Procurement cost	
Personnel: ordering and planning	$444,968
Overhead cost (20%)	$88,994
Current subtotal	**$533,962**
Harvesting cost	
Harvesting cost	$6,480,193
Current subtotal	**$6,480,193**
Inbound logistics	
Transportation: inbound from supplier	$2,394,853
Overhead cost (20%)	$478,971
Current subtotal	**$2,873,825**
Supplier collaboration	
Personnel	
Overhead cost (20%)	
Current subtotal	
Inventory carrying costs	
Current subtotal	**$98,397**
Total cost of fulfillment	
Current subtotal	**$10,318,436**

Future VSM: Recommendations

The following recommendations and suggestions are presented based on their potential impact in reducing waste in the value stream of wood fiber supply. These recommendations have given a potential economic impact based on the fulfillment costs estimated in this report and in addition consider the previous body of the literature.

Wood flow planning and communication. It was highly recommended that the case study firm implements a strategy to improve their wood flow planning to eliminate or decrease sources of waste in their value stream by 1) reducing carrying cost of inventory, 2) considering loggers in strategic planning decisions, and 3) providing formal communication, or planning horizon for the loggers (to eliminate the reactive environment). To decrease waste, the industry dynamic between suppliers and consumers must change. Suggested strategies would include collaboration and information sharing between the supply chain partners. Taylor (2012) proposes the changes to

Table 4. Suggested savings as indicated by Rodgers et al (2002) potential savings in case study 1.

Future VSM		Lower scope gain (%)
Wood flow planning: mill management Tract allocation: procurement Communication: mill management, procurement, and supplier	Inventory carrying costs (transportation and wood yard)	21%
Truck scheduling coordination: mill management Tract allocation: procurement	Inbound logistics	10%

improve wood flow planning and communication; these include 1) delivering a yearly plan of consumption and inventory levels should be available for procurement and suppliers and 2) a second communication should be provided within 2 to 4 wk with an immediate supply and specification plan, which should be given to the procurement department. Critical information about supply requirements such as predicted changes, volumes, and specifications should be available for stakeholders. Taylor (2012) pointed out that a more stable operating environment is necessary to provide better information to loggers in terms of future demand for wood, given their high levels of capital costs in harvesting and transportation equipment. Similar to an improvement in wood flow planning, waste can be reduced through better communication between the supply chain partners. This would include 1) recognition of impact of consumer actions and 2) considering loggers in strategic planning decisions. Important communications include 1) future mill supply needs, 2) lead time, 3) information on shutdowns, 4) current supply levels and inventory levels, and 5) foreseen changes that have the potential to affect productivity of the operation. Furthermore, the supplier must also communicate with the consumer company about their operations.

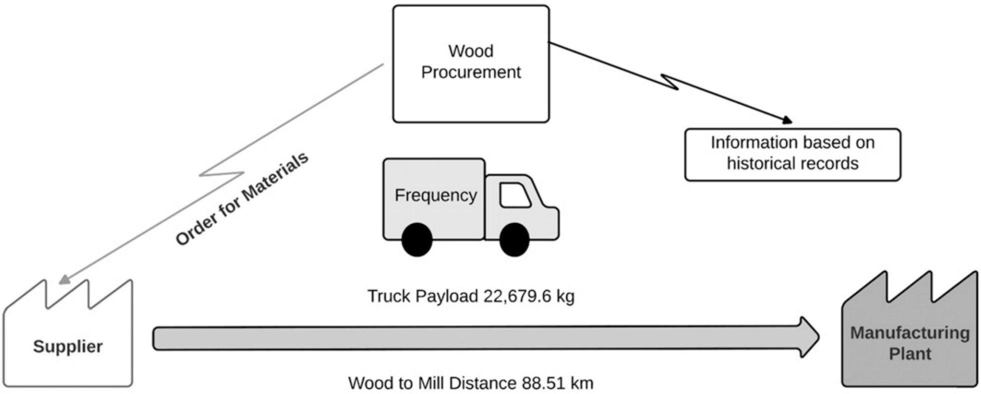
Data-driven core logger systems—tract allocation. Based on the case study analysis, performance of wood fiber supply chain is impacted by the lack of knowledge on the logger's quantity of standing timber and by the overcapacity of suppliers. If more information from the suppliers is available, the procurement teams of the consumer mills will have more data to better allocate demand to suppliers. For example, if data on wood flows from tracts (type of timber, terrain parameters, etc.) and capacity of loggers are known, each tract can be allocated to a supplier based on these characteristics. Each tract should have the required information: location, volume (by product), type of system required to harvest, and the operability window during which the tract is harvestable. The supplier should play a key role in effective tract allocation. "Each portion of the operation that the supplier is left out of greatly eliminates the ability to accurately plan a harvesting or trucking system to satisfy the needs of the consumer without building inefficiency into the system" (Rodgers et al 2002).

Companies operating a preferred supplier system should give 80% of annual consumption to those suppliers. The remaining percentage can be either open market or given to preferred suppliers. Communication plays a vital part for optimization of supply chains. More than two-thirds of loggers carried unused capacity in their harvesting operation, 50% specifically to increase productivity, in case quota was to be introduced (Rodgers et al 2002).

Decrease in inventory. Determining the right amount of inventory at each point of the supply chain is critical for all parties involved. An

Table 5. Suggested savings as indicated by Rodgers et al (2002) potential savings in case study 1.

Component of logistics cost	Current cost	Future cost
Inbound logistics	$2,800,000	$2,500,00
Inventory carrying cost (transportation and wood/log yard)	$98,400	$79,600
Total savings	$320,000	



Order to Shipment	40 d				
Inventory (ADOH)	24 d	Transit Time	0.061 d	Inventory (ADOH)	21 d
Value of Inventory	$ 86,400	Value of Inventory	$ 38,589	Value of Inventory	$ 859,000
Carrying Cost (10%)	$ 8,640	Carrying Cost (10%)	$ 3,857	Carrying Cost	$ 85,900
Truck Payload	22,679.6 kg	Planned Order Frecuency		Lot Size	
Minimum Order Quantity	22,679.6 kg	Planned Delivery Frecuency	45 trucks/day	Delivery Frecuency to Line	
Perfect Order Execution	0%	Perfect Order Execution	0%	Perfect Order Execution	65%

Figure 1. Current VSM.

excessive amount of inventory could help protect against variability, but the carrying costs of the inventory should be also considered. Each company needs to dedicate enough resources and time to make sure the right inventory models are implemented, based on several factors such as customer service levels, market fluctuations, available space and equipment, and cost considerations.

Potential Savings of Recommendations

The design of a future VSM implies making assumptions regarding the potential benefits from the implementation of recommendations and improvements. Baseline percentages, as developed by Rodgers et al (2002), are used to quantify the potential benefits of implementing the recommendations described earlier, in a future VSM for the case study firm (see Table 4). The application of the potential benefits is reflected in the value of the inventory, the inventory carrying cost, and the inbound logistics fulfillment cost.

The following section shows the conservative potential savings by applying the recommendations mentioned previously. The inventory carrying cost reduction is applied only in the transportation and wood/log yard cost section.

In the future state cost reductions, stumpage was not reduced, as it may be considered an investment. Only transportation and wood/log yard carrying costs are reduced.

Table 5 shows the inbound logistics costs were calculated as $2.8 million annually and $98,400 for the inventory carrying cost. Inbound logistics is reduced by $300,000. The inventory carrying cost reduction is $18,900 A conservative estimate for total savings annually would be approx. $320,000.

CONCLUSIONS

1. The study found a lack of information sharing from distinct parties within the supply chain. This supply chain information gap provides a reactive environment for the industry. These current state results are consistent with the literature.
2. The main causes for waste include lack of communication among supply chain partners,

weak supplier collaborations, demand variability, quota management, and poor inventory management.

3. The main differentiation factor in the lead time is the amount of inventory (stumpage + wood/log yard inventory) that is held in the wood fiber supply chain.
4. The fulfillment cost for case study 1 firm (a paper mill) was estimated to be $10 million for a daily consumption of 1.01 million(kg/d) (1122 tons/d). In this case, the lead time was estimated as 85 d.
5. The inbound logistics cost could be reduced if the recommendations were implemented from $2.8 million to $2.5 million. The inventory was reduced in transportation operations and at the wood/log yard. The inventory carrying cost was reduced from $98,400 to $79,600 annually. The possible annual savings reported totaled $320,000 approximately by the introduction of lean principles that reduces the waste in the transportation and carrying cost.

ACKNOWLEDGMENTS

The authors would like to express their sincere gratitude to the Wood Supply Research Institute (Washington, D.C.) for providing the funds necessary for the development of this study, as well to practitioners from the case study companies and academics for providing valuable information for the development of this study.

REFERENCES

Greene DW, Mayo JH, de Hoop CF, Egan AF, Chumbler JM, Ulmer J, Sanders J (2002) Causes and costs of unused wood production capacity. The University of Georgia, Center for Forest Business, Athens, GA.

Hancock DR, Algozzine B (2006) Doing case study research. Teachers College Press, New York, NY.

Hines P, Rich N, Esain A (1999) Value stream mapping a distribution industry application. Benchmarking (Bradf) 6(1):60-77.

LeBel L, Carruth S (1997) Simulation of woodyard inventory variations using a stochastic model. For Prod J 47(3): 52-57.

Nash MA, Poling SR (2008) Mapping the total value stream. CRC Press, New York, NY.

Rodgers B, Visser R, Shaffer R, Gallagher T (2002) Planning and Communication: State of the Forest Industry and Opportunities for Improvement in the Wood Supply Chain. Virginia Tech. Wood Supply Research Institute, Blacksburg, VA.

Taylor DR (2012) Supplier/consumer relationship study region report. http://wsri.org/tech-papers/SoutheastReport.pdf (20 October 2017).

Yin R (2009) Case study research, 4th edition. Sage, Thousand Oaks, CA.