Evaluation of Supply Chain Performance Metrics for Lithuanian State Sawmills

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Puodžiūnas M., Fjeld D., Wästerlund I. 2003. Evaluation of Supply Chain Performance Metrics for Lithuanian State Sawmills. *Baltic Forestry*, 9 (2): 20–28.

The aim of this study is to evaluate metrics of supply chain performance for Lithuanian state forest enterprise sawmills. The metrics are used to quantify supply chain performance for 6 state forest enterprise sawmills. These sawmills were randomly sampled from groups of high, medium and low economic potential. Based on the monthly flow volume per aggregated assortment, the following indicators were used to quantify performance of the supply chain: flow variability (coefficient of variation for flows), average inventory cover time (in terms of production time), degree of supply chain dynamics (cross correlations between monthly flows) and supply variability quotients (ratios between coefficients of variation for monthly flows).

The mills of high and medium potential were primarily focused on the main products assortments (boards, planks). The low potential mills were primarily focused on by-products (pallet wood). The metrics for main and by-products exhibited four main differences. First, the supply variability quotient ($\omega_{s/r}$) and degree of supply chain dynamics ($\rho_{s/r}$) were both higher for the main products than by-products. Second, the degree of dynamics (ρ) was higher where the coefficient of variation for final sales (CV_S) was high. The degree of dynamics (ρ) was also higher where the size of the supply chain buffer capacity (ICT_{sc}) was small. Finally, the average supply chain responsiveness was higher for the main products than by-products, indicating a higher degree of synchronisation for the main products than for by-products.

Key words: sawmill, supply chain, variability, inventory, dynamics, responsiveness, main products and by-products

Introduction

After a period of recession from 1994 to 1997 the Lithuanian forest industry has been in a state of steady growth. After regaining the independence in 1991, the Lithuanian timber sector redirected exports from eastern to western markets (Anon. 2002 (2)). According to the statistics 16 state sawmills were operating in 2001. The capacities of sawmills varied from 2.000 to 16.000 m³ of the annual sawn wood production. Approximately 70% of the production consisted of palletwood products. Altogether these sawmills generated profit of 7,7 mil. Euros. At present, approximately 2/3 of all sawmilling production is exported (Anon. 2002 (1)).

The situation in the state sawmilling sector, however, is still difficult. Production in the sector has been declining and closure due to bankruptcy or financial complications is increasing. One of the reasons, which have led to this situation, is inability to react appropriately to the changing market situations. The restitution of forestland to former owners has also caused changes in the raw materials market. This has resulted in a cheaper source of round wood for many private sawmills. The restructuring, which should have resulted from these transitions, has been quite slow.

Supply chain strategies in the forest sector

The connection between the market environment, enterprise strategy and success has been examined for a number of sectors. Fisher (1997) developed a dichotomy describing efficient and market responsive supply chain strategies for typical manufactured products. Lehtonen (1999) adopted Fisher's dichotomy to Nordic paper industry environment. Lehtonen (1999) names these strategies efficient and flexible. Enterprises with an efficient strategy gain from high utilization of production capacities and having even-flow of materials and standard product range. For enterprises with a flexible strategy the priority is given to high customer service level resulting in a more uneven flow of materials and wider product range. The study on analysing marketing strategies of sawmills in Lithuania was carried out by Gaizutis (2000). According to this study Lithuanian sawmills fall into five distinctly different strategic groups where the first group consists of sawmills with the highest annual capacities and highest productivity. Sawmills, which fall into the second and third group, are similar by their nature specializing in construction, furniture and packaging sectors and having very low productivity rate. The fourth group of sawmills usually have no strategy and the survival of such sawmills depends on the immediate radical changes inside them. The fifth strategic group consists of newly established sawmills, which already have relevant technical facilities enabling them to produce cheap sawn wood products. Finally, Gaizutis (2000) states that almost half of analysed sawmills "had no definite marketing strategies determining their business activities with all due consequences". The Finish researchers Hameri and Nikkola (1999) describe the prevailing production management strategy in Scandinavian paper industry as still being based on high volumes with long production cycles resulting in very long average supply chain (SC) throughput times. So far no supply chain dichotomy has been developed for typifying production strategies in the sawn products sector. However, Lehtonen's description of efficient and flexible strategies may also be applicable here.

Supply chain performance

The performance of the supply chain should support the chosen supply chain strategy. There are three basic levels of indicators for economic success. These include revenue, which minus costs yield profit, which when considered in relation to capital use yields the rate of return on investment. Lehtonen's (1999) efficient and flexible strategies place different weight on these indicators. An efficient strategy aims primarily at reducing costs by increasing capacity utilization. A flexible strategy aims primarily at increasing revenues through adjusting production towards the highest value alternatives in the production palette and reducing capital tied up in production through reducing inventory.

Table 1. Supply chain strategy according to Lehtonen (1999), with economic effect and production characteristics

Strategy	Economic effect	Production characteristics	
Efficient	Cost minimization	High utilization of facilities	Even flow, standard products, large inventories
Flexible	Value-added maximization	High customer service	Uneven flow, wide product range, low inventories

The consequences of these strategies are most clear in the context of the generic stock decision model (GSDM) presented by Ford and Sterman (1998). This model is based on locally available information and recognizes three motives for ordering O_t at time t. These motives include: replacing expected losses from stock (L_t^e), reducing discrepancies between desired and actual stock (AS_t=adjustment to stock), and reducing discrepancies between desired and actual supply line of unfilled orders (ASL_t=adjustment to supply line). This model also takes into consideration the expected acquisition time lag (λ_t^e) to receive adjustments.

$$O_t = L_t^e + AS_t + ASL_t + \lambda_t^e$$

An efficient supply chain strategy assumes less consideration to coordinating demand and supply within specific periods. This strategy is based on prognosis levels of losses with a higher level of stocks to even out eventual discrepancies. A flexible strategy, however, demands that supply meet the actual demand for each palette of production with corresponding adjustments of stock and supply line.

Sources of industrial dynamics

The potential consequences of demand uncertainty and pull control in industrial supply chains, termed *industrial dynamics*, were first analysed by Forrester (1961). Using simulation models he demonstrated how small variations in consumer demand can be amplified upstream in the supply chain, initiated by slow order handling, lack of downstream sales information and immediate corrective actions for inventory discrepancies. Numerous terms have been suggested for this phenomenon (bullwhip effect, flywheel effect, demand amplification). In essence, the effect involves a *distortion* of demand signals, as a vendor is unaware of how much of the received order constitutes real demand, and how much constitutes strategic decisions on changes in inventory levels. *Demand distortion* refers to the effect itself, while the result of the distortion is referred to as *amplification of demand variation*. Hameri and Nikkola (1999) were the first to study these effects in supply chains for paper mills. According to Hameri (1996) the demand for products is transmitted along the series of inventories using stock control ordering and estimates. With this supply chain configuration, the demand variation will increase with each transfer. Hameri and Nikkola (1999) state that the existing reaction time for market demand information is not being explored and that production allocation is not being well matched with real demand. They conclude that mills close to main markets do have an advantage over those located far away, but it is also shown that this advantage could be overtaken by shorter production cycles and better integrated supply chain operations that add up to reliable operational performance with no safety margins and buffers.

Most studies of industrial dynamics have been aimed at controlling demand distortion and amplification. However, supply variability is also an important factor influencing the overall performance of the supply chain. In other sectors supply variability appears when manufacturing predictability deviates through poor yield, supplier and carrier delivery performance and manufacturing lead times that cause additional disruptions. Supply variability is a typical characteristic for wood supply because of the uncontrollable conditions of forest production. Figure 1 shows typical patterns for monthly round wood delivery from Lithuanian state forest enterprises and sawn wood sales from state sawmills.

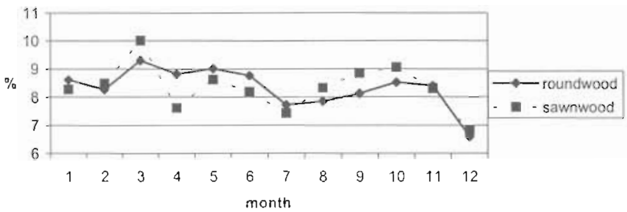

Figure 1. The distribution of monthly round wood delivery and sawn wood sales in the Lithuanian state forest sector in 1998-2001

There are many factors, which affect the flow of goods in the forest sector supply chain. The GSDM can be used as a framework (Figure 2) to show the relationship between flow variation and factors resulting in varying delivery (expected acquisition rate) and demand (expected loss rate).

The main factors influencing delivery are seasonal (predictable) capacity restrictions and stochastic (unpredictable) factors. The seasonal capacity restrictions include stand accessibility (stands with moist ground conditions are accessible only during winter time), the summer holiday period and quality-related aspects (reduction in wood quality during summer time). Stochastic factors include insect attacks and wind- or snowstorms. Demand is influenced by forecast error, which is mainly due to incorrect information about downstream actors and price fluctuations. Lead time variation is a factor influencing both delivery and demand sides of the GSDM. Lead times and delivery precision for wood supply to Lithuanian state forest enterprises have been examined by Puodziunas and Fjeld (2002). They estimated that delivery precision was low and lead times varied considerably between different components of the production palette. Differences

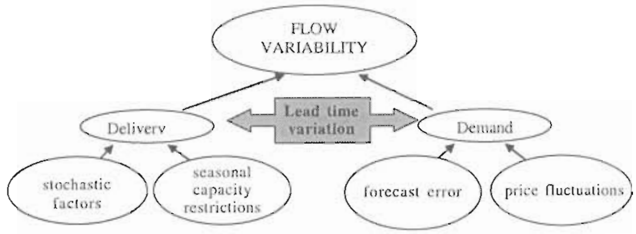

Figure 2. An adaptation of the GSDM to factors influencing flow variability in the Lithuanian state forest sector

between enterprises, however, were determined primarilly by the products they focused on.

An aspect of wood supply, which is particular for only a few other sectors, is the diverging product identities, which results from industrial processing. Harvesting initially results in two primary classes of round wood; saw logs and pulp logs, depending on the quality characteristics as judged by the outside of the log. The most valuable of these two classes is saw logs. For this reason saw log demand is the dominating factor for overall harvesting levels and therefore the resulting flow of pulp logs. When the saw log arrives at the sawmill the same logic may be applied again. The price for main products processed from the centre of the saw log is highest, and demand for these is therefore the dominating factor for the flow of by-products from the outer cylinder of the log. It is first when the planks and boards are visible that the final quality characteristics are known. Divergent flow in wood supply and processing makes complete coordination of supply and demand difficult to attain. This should also lead to a lower degree of dynamics for sawn by-products than main products.

Aim

In order to evaluate supply chain performance a number of indicators must be developed and estimated. The aim of this study is to evaluate metrics for quantifying supply chain performance in the Lithuanian state sawmilling sector. These metrics will be compared for main and by-products. These will then be examined for their relevance to supply chain strategies.

Materials and methods

The study examines supply chain performance for 6 state forest enterprise sawmills. All state sawmills are classified according to high, medium and low economic potential (Anon. 2002 (2)). The sawmills studied were grouped according to their product focus. Production in mills 1 to 4 focus on production of assortments often characterized as the main products of wood supply. Production in sawmills 5 and 6 focus on the lower quality assortments normally characterized as the by-products of wood supply. Two sawmills per class were chosen at random in order to get a complete coverage of different sawmills. The sample of these six sawmills represents 40% of studied population. The economic result for two years is shown below (Table 2).

Table 2. The round wood consumption and primary economic results for the 6 studied sawmills in 2000 and 2001

Sawmill number	1000 m^3 round wood in 2000/2001	result for 2000 / 2001 (1000 €)			Assets (1000 €)
		revenue	cost	profit	
H 1	27.2 / 27.1	1809 / 1586	1785 / 1247	37	774
2	10.9 / 11.1	678 / 639	675 / 839	1	1406
M 3	19.5 / 25.2	888 / 778	888 / 733	0	585
4	12.5 / 17.2	543 / 572	530 / 605	66	572
L 5	6.1 / 7.1	259 / 269	259 / 278	0	120
6	3.5 / 3.6	220 / 165	214 / 152	76	129

Monthly product flows were collected for each sawmill. These data were available for one calendar year of operations. The monthly statistics included

- volume of received round wood (R), processed sawn wood (P), and sold sawn wood (S) per month
- volume of inventory levels for round (InvR), sawn wood (InvP) and supply chain (InvSC = InvR + InvP) at the end of each month (Fig. 3)

The calculations were done for two different upstream intervals of the supply chain: from sawn wood sales to sawn wood processing (S/P) and from sawn wood sales to round wood received (S/R).

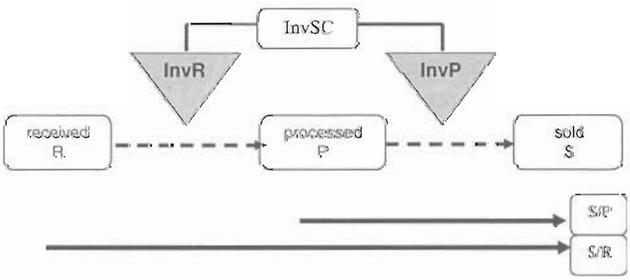

Figure 3. The monthly flows recorded along the supply chain for each of the studied sawmills. R, P and S represent received round wood, processed sawn wood, and sold sawn wood, respectively. The supply chain inventory (InvSC) is the sum of inventories for round wood and sawn wood

For round wood, volumes were recorded for up to ten different species. For sawn wood, volumes are recorded for different quality assortments (deciduous and coniferous boards in pallets, unedged and edged qualities). For tracing the monthly flows different levels of resolution are possible. For this study, the volume per aggregated assortment is used. Two classes of aggregated assortments are defined: main products (all unedged and edged sawn wood of coniferous and deciduous species) and by-products (pallet wood of all species).

Using the basic statistics described above, four indicators of supply chain performance are estimated for main and by-products. The first is coefficient of variation for monthly volumes within the operating year (CV). This metric is specific for one position (n) within the chain and is calculated as the variance divided by the mean.

$$CV_n = \sigma_n / \mu_n$$

The second metric is average inventory cover time (ICT). The inventory cover time is calculated as the annual average of inventory volume expressed in terms of how many days of processing production it represents. The cover time is specified for round wood inventories (ICT_r), sawn wood inventories (ICT_p) or the sum of inventory within the defined supply chain (ICT_{SC}).

The degree of dynamics between upstream and downstream positions is quantified as the third indicator. This is done by the cross correlation between time series of flows at the respective positions. The correlated pairs of positions include sawn wood sales to received round wood (S/R) and sawn wood sales to processed sawn wood (S/P). When necessary, varying time lags (whole months) were introduced. The degree of dynamics between positions is indicated by the cross correlation coefficient ρ where:

$$\rho_{n/m} = cov / (\sigma_n \sigma_m)$$

The subscripts for ń represent the positions of the supply network being correlated.

Most time series patterns can be described in terms of two basic classes of components: trend and seasonality. The former represents a general systematic linear or (most often) nonlinear component that changes over time and does not repeat or at least does not repeat within the time range captured by our data (e.g., a plateau followed by a period of exponential growth). The latter may have a formally similar nature (e.g., a plateau followed by a period of exponential growth), however, it repeats itself in systematic intervals over time. Those two general classes of time series components may coexist in real-life data.

Finally, a supply variability quotient (ω) is estimated. This quotient is based on the ratios of the coefficients of variation between sawn wood sales and received round wood (S/R) and between sawn wood sales and processed sawn wood (S/P). The ratio of monthly flow variation upstream to monthly flow variations downstream is intended to quantify the relative supply variability at different positions of the supply chain. The supply variability quotient (ω) is measured as:

$$\omega_{n/m} = CV_n / CV_m$$

Again, the subscripts for ω represent the positions of the supply chain for which the coefficient of variation is used in the numerator (n) and the denominator (m) of the quotient. The same or related metrics have been used by Fransoo and Wouters (2000) and Haartveit and Fjeld (2003) to quantify demand amplification under the assumption that upstream supply variations are driven by downstream demand variation.

Results

A comparison of the proportion of processed volume showed that the percent of total production volume consisting of main and by-products varies between the different mills (Fig.4). The share of main products was higher for sawmills in high and medium economical potential groups compared to the low group.

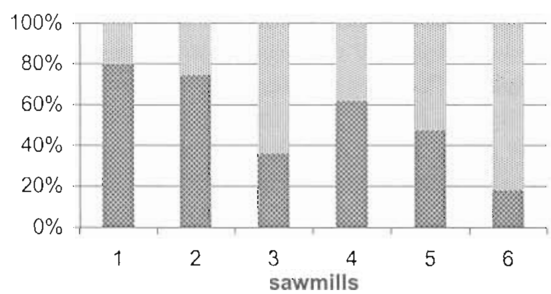

Figure 4. The share of main and by-product classes of product quality in 6 sawmills. Bottom part of column represents main products and upper part represents by-products. The sawmills previously classified as having highest economic potential are on the left and right, respectively

Table 3. Coefficients of variation for sales (CV_S) and inventory cover times (ICT in days) for the main (m) and by-products (b) of the five studied sawmills. ICT_P=inventory cover time for processed sawn wood. ICT_{SC}=accumulated inventory cover time for whole SC

	sawmill		2	3	4	5	6
CV_S	M		0,2	0,16	0,17	0,45	0,68
	B		0,28	0,22	0,26	0,22	0,58
ICT	M	ICT_P	25,6	14,7	9,8	52,7	52,3
		ICT_{SC}	35,1	23,5	16,8	63,4	92,2
	B	ICT_P	8,1	11,6	11,4	13,7	13,4
		ICT_{SC}	18,6	22,7	20,8	27,5	19,6

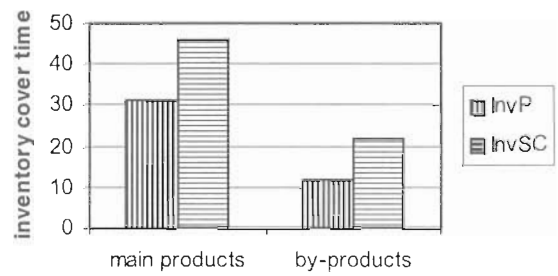

Figure 5. The average inventory cover times (days) for processed sawn wood (ICT_P) as well as for the accumulated cover time for the whole supply chain (ICT_{SC}) for main products and by-products.

The coefficients of variation for monthly sawn wood sales (CV_S) also varied considerably between sawmills. The highest coefficient of variation was estimated for sawmill No. 6 within the low economical potential group. The lowest coefficient was for sawmill No. 3, which belongs to medium economic potential group. The inventory cover times (ICT) also varied between main and by-products. (Table 3).

Generally, buffer volumes were higher for main products than by-products (Figure 5). For main products most of the supply chain inventory is accumulated as processed sawn wood. For by-products processed sawn wood constitutes roughly 50 % of the supply chain inventory.

The next step in the analysis was to estimate the cross correlation coefficients, which indicate the degree of dynamics (ρ) in the SC. The calculations were done for two different echelons in SC: sawn wood sales to processed sawn wood (S/P) and sawn wood sales to received round wood (S/R). This was done for all sawmills except for no. 1, because of incomplete data.

The main products tend to have a higher degree of the dynamics between positions than by-products. The degree of the dynamics was also higher for sawn wood sales to processed sawn wood (S/P) than for sawn wood sales to received round wood (S/R) (Figure 6).

Table 4. Degree of dynamics (ρ) between sawn wood sales and processed sawn wood (S/P) as well as between sawn wood sales and received round wood (S/R) for main (m) and by-products (b) in five studied sawmills (2-6)

	sawmill		2	3	4	5	6
ρ	M	S/P	0,91	0,83	0,84	0,64	0,81
		S/R	0,59	0,7	0,51	0,50	0,48
	B	S/P	0,93	0,78	0,6	0,64	0,63
		S/R	0,51	0,42	0,22	0,72	0,33

The next step was to find the relationship between inventory cover time (ICT) and degree of dynamics (ρ). This was done using simple linear regression analysis.

Lower inventory cover times (ICT) were correlated with an increased degree of dynamics (ρ). The

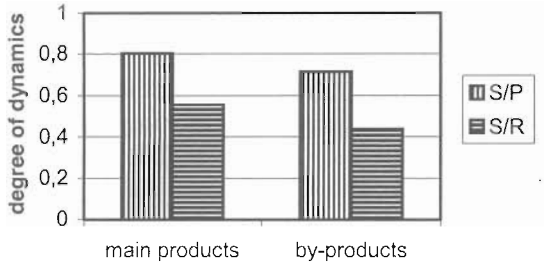

Figure 6. Degree of dynamics (ρ) for sawn wood sales to processed sawn wood (S/P) and sawn wood sales to received round wood (S/R) for main products and by-products

coefficient of variation for sales (CV_S) was also taken into consideration where higher CV_S lead to higher dynamics in the supply chain. The initial formula tested for this relationship included both the standard intercept and slope for simple linear regression. While the first analysis yielded an R^2 of 56%, the level of significance for the intercept was ρ=0.40. With the removal of the intercept constant, the new formula has a significance level of ρ< .001:

$$\rho = \frac{\beta}{ICT} * CV_S$$

where:
ρ=degree of dynamics,
β=slope (regression coefficient).
ICT = inventory cover time (days)
CV_S = sales variability

The formula simply implies that a high variation in sales combined with a lower buffer capacity results in a high degree of dynamics. It also implies that a low variation in sales combined with a large buffer capacity results in a low degree of dynamics. The basic logic in this case is that the degree of dynamics expresses the degree of synchronization in the supply chain, where small buffer capacities force greater dependence between the different parts of the supply chain.

Slope (β) is dependant on the product and for main products is equal to 64 and 32 for by-products.

The quotients of supply variability (ω) were also estimated (Table 5). These varied from under 1.0 to over 2.0. The highest quotients were found for main products and sawmills in higher classes of economic potential.

The combinations of average values for supply variability quotients and degree of dynamics for main and by-products can be seen in Figure 7. Main products have higher quotients of supply variability (ω) and higher degree of dynamics (ρ) than by-products. The degree of dynamics (ρ) is higher and supply variability quotient (ω) is lower for sawn wood sales to processed sawn wood (S/P) than for sawn wood sales to received round wood (S/R).

Table 5. The quotients of supply variability (ω) for sawn wood sales to processed sawn wood (S/P) and sawn wood sales to received round wood (S/R) for main (m) and by-products (b)

	sawmill		2	3	4	5	6
(ω)	M	S/P	1,81	1,26	1,26	0,76	1,24
		S/R	2,24	2,05	1,74	0,9	1,09
	B	S/P	1,36	1,08	0,62	0,93	1,04
		S/R	1,27	1,91	0,82	1,67	0,52

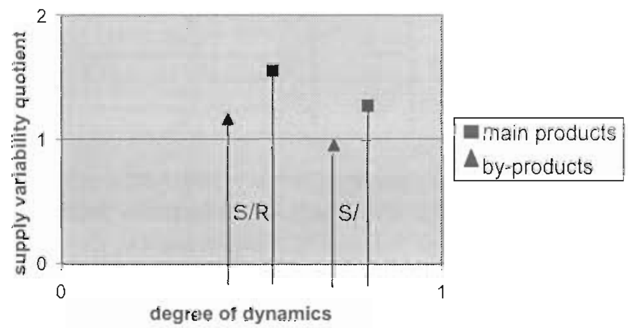

Figure 7. The average values of supply variability quotient (ω) and degree of dynamics (ρ) for sawn wood sales to processed sawn wood (S/P) and sawn wood sales to received round wood (S/R) for main and by-products

Discussion

The study has estimated four metrics of supply chain performance for 5 sawmills as well as for their main- and by-products.

The capacities of high and medium economic potential sawmills were in certain cases up to 8 times larger compared with low ones. The product palette in the two first groups of sawmills was much wider. The first three sawmills were equipped with wood drying facilities enabling them to produce more varying products. The second sawmill produced more than 20 different products while the 4th sawmill produced 12. The situation in the third group was totally different. They produced only basic products and the number in both sawmills reached 6. Many of the differences between mills are associated with willingness to make new investments in order to improve the performance of the mill. The investments in low potential sawmills reached only about 0.5 mil. Lt. in year 2001, whereas, the corresponding average figure in high and medium groups were about 3 mil. Lt.

From a supply chain perspective, the reduction of product diversity to two classes constituted a significant simplification of the chain structure. The estimates of supply chain performance for the two groups are summarized below.

Table 6. Summary of supply chain performance indicators for the sampled sawmills (CVs refers to sawn wood sales, while ICT_{sc}, $\rho_{s/r}$, and $\omega_{s/r}$ refer to the supply chain between round wood delivery and sawn wood sales

Indicator	Sawmill	Main-products	By-products
Focus	2-4	**63 %**	37 %
	5-6	33 %	**67 %**
CV_s	2-4	**0.17**	0.25
	5-6	0.56	**0.40**
ICT_{sc}	2-4	**25**	21
	5-6	78	**24**
($\rho_{s/r}$)	2-4	**0.60**	0.49
	5-6	0.38	**0.53**
($\omega_{s/r}$)	2-4	**2.01**	1.00
	5-6	1.33	**1.10**

This summary shows a lower variation in sales for the focal products of mills 2-4 (63 % main products) compared to mills 5-6 (67 % by-products). The same comparison shows approximately the same inventory levels for both groups' focus assortment. The degree of dynamics and supply variability quotients for mills focused on main products, however, were higher than mills focused on by-products. For both groups the sales variation is larger and the degree of dynamics is lower for the mills non-focused assortments.

If we compare the above indicators for the two sawmill groups, we see some differences, which are parallel to differences between Lehtonen's (1999) supply chain strategies for paper mills. For the sawmills focusing on main products, this would be a result of focusing on the most valuable part of the production palette, which is associated with a *flexible* strategy. Assuming that the dynamics are demand-driven, the higher level of dynamics ($\rho_{s/r}$ = 0.60 cf. 0.53) would also be the expected result of a flexible strategy. According to the literature on supply chain dynamics, the higher supply variability quotient ($\omega_{s/r}$ = 2.01 cf. 1.10) would then be interpreted as a measure of the demand amplification. If, however, we assume that these dynamics are driven primarily by supply variability, which is a typical characteristic of wood supply, alternative interpretations of the performance indicators are possible. In this case, the higher supply variability quotient ($\omega_{s/r}$ = 2.01 cf. 1.10) and lower variation in sales (CV_s = 0.17 cf. 0.40) could then suggest the aim of achieving an even flow of products to the market, implying an *efficient* strategy.

The interpretation of supply chain performance indicators for quantifying strategy is therefore dependent on whether upstream variation leads downstream variation, indicating dynamics dominated by supply variability or the opposite, indicating demand-driven dynamics. The cross correlation analysis of the monthly fluctuations in round wood delivery, processing and sawn wood sales showed that in most cases there was neither lag nor lead in the time series data. This may, however, be a result of the insufficient number of positions along chains (from received raw material to processed sales) in this analysis. In this study the lead time between positions is most probably less than the observed time unit (one month). For both mill groups, the accumulated supply chain buffer (received round wood and sawn wood) was just under one month production. Assuming supply-driven dynamics, this situation would have shown one month downstream lags in volume fluctuations. A statistically valid test of lags or leads within time series, however, requires a longer data collection period than was available in this study. However even national statistics for sales of round wood and sawn goods (Figure 1) show simultaneous seasonal fluctuations.

An analysis over a wider portion of the supply chain could perhaps help quantify the time lags or leads. Earlier studies of delivery precision in wood supply from Lithuanian state forest enterprises indicate that yearly or quarterly agreements are rarely good indications for the final monthly volumes actually delivered to specific mills (Puodziunas and Fjeld 2002). For enterprises considered having a flexible strategy, only 20 % of customers actually purchased volumes close (monthly volume within 20 %) to those agreed to earlier. The corresponding figure for an efficient strategy was 40 %. In this study, lead times (here defined as time from harvest to delivery) variation was correlated with the focus product, not the enterprise. The focus product for the enterprise with the flexible strategy (veneer logs) was associated with a lead time of less than 20 days. As non-focus product, the same product had a lead time of 50 days in the enterprise with the efficient strategy. The focal product of the enterprise with the efficient strategy (pallet wood) was associated with a lead time of 50-55 days. Again, as non-focus product the same assortment had a longer lead time (65 days) in the enterprise with the flexible strategy. In this study, most agreements were confirmed on short time horizons. The longer lead times for pallet wood help us explain the higher delivery precision for the efficient enterprise (Table 7).

Looking at the cross correlation coefficients, which describe the degree of dynamics (ρ) in the supply chain, it was observed that the closest positions had the best correlation of flows. The correlation analysis demonstrated that the degree of the dynamics increased with increasing variation in final sales (CV_S) and decreased with increasing inventory cover time (ICT_{sc}). This is logical given that large inventory buffers easier absorb fluctuations in supply and demand without having to call on resources at neighbouring supply chain positions. The fact that the correlation coefficient β is higher for main products (β=64) than by-products (β=32) indicates that the supply chain responds more to fluctuations in main products than by-products.

Varying supply chain responsiveness to fluctuations in different parts of the production palette is a point of particular interest. This knowledge is important for understanding industrial dynamics in any sector with diverging product identity. Gaming studies of an integrated forest sector supply chain by Fjeld (2000) and Haartveit and Fjeld (2003), have shown that the divergent structure of the forest products provide a higher potential for demand distortion if the supply chain processes are demand driven by a "pull" (according to present demand) principle. Declining supply chain performance may, however, also be caused by supply variability. The short period of data collection in this study make it difficult to accurately estimate lead or lag times, which could be used to clearly identify "push" or "pull" reaction patterns in the monthly flows between positions. In this study, therefore, we assume that the observed dynamics are driven primarily by supply variability.

Comparing the indicators in Tables 6 and 7 we see that many are related to the characteristics described earlier in Lehtonen's classification of supply chain strategies. The same characteristics may be applied to wood supply organizations (see Table 7). Applying these metrics to both wood supply and processing would increase the width of the analysis and therefore its relevance. However, the seasonal variation of wood supply due to long-term biotic or seasonal capacity limitations would still prevent the upstream positions of the supply chains from becoming market-driven.

Conclusions

The estimation of 4 performance metrics during one operational year showed the following results:

1. For main products, more of the SC buffer capacity is accumulated as processed sawn wood while for by-products it is more evenly distributed between round wood and sawn wood.

2. The estimates of supply chain dynamics ($\rho_{s/r}$) and supply variability quotient ($\omega_{s/r}$) were both higher for main products than by-products

3. The degree of supply dynamics (ρ) was higher in cases with high variation for final sales (CV_s). The degree of dynamics was lower in those cases with larger supply chain buffer capacity (ICT_{sc}).

The supply chain responsiveness (correlation coefficient β) was higher for main products (β=64) than by-products (β=32).

The tested performance metrics give logical results in the context of sawn wood products. Their estimated values seem to support the assumptions of the different supply chain strategies associated with main and by-products. While the data collection period for this study is limited, the results indicate that the metrics are suitable for further development. Testing over a large number of echelons and different supply chains with longer time series is desirable.

Acknowledgements

We would like to thank the chief managers of studied sawmills for ability to collect relevant data for this study. We also appreciate a financial support from the Royal Swedish Academy of Agriculture and Forestry.

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Table 7. Summary of supply chain performance indicators from Lithuanian state forest enterprises with assumed supply chain strategies. The results for wood supply are from Puodziunas and Fjeld (2002). The results for sawmilling are from the present study

Supply chain strategy	Wood supply study			Sawmilling study		
	Focus assortment	Lead time (forest-to-mill)	Delivery Precision (% filled)	Focus assortment	Variability quotient ($\omega_{s/r}$)	Supply responsiveness (β)
Flexible	Veneer logs	20 days	20 %	Boards/planks	2.01	64
Efficient	palletwood	50 days	40 %	Palletwood	1.01	32

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Received 18 August 2003

ОЦЕНКА ФУНКЦИОНИРОВАНИЯ ЦЕПИ ПОСТАВОК В ГОСУДАРСТВЕННЫХ ЛЕСОПИЛЪНЯХ ЛИТВЫ

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Резюме

Целъ этого исследования – оценитъ функционирование цепи поставок в государственных лесопилънях Литвы. В этой статъе исследование цепи поставок проводилосъ в шести лесопилънях государственных лесничеств. Они были отобраны из груп высокого, среднего и низкого экономического потенциала. Для определения цепи поставок исполъзовалисъ следующие индикаторы: переменчивостъ (коэффициент вариации месячных потоков), время покрытия запасов (в смысле продуктивных дней), динамика цепи поставок (коеффициент кросс-кореляции между месячными потоками) и коеффициент вариации поставок (ратио между коеффициентами вариации месячных потоков).

Лесопилъни высокого и среднего потенциала специализировалисъ на производстве основных продуктов - досок. Лесопилъни низкого потенциала уделяли внимание вспомогателъным продуктам (тара). Анализ основных и вспомогателъных продуктов продемонстрировал три разные тенденции. Первая: степенъ динамики цепи поставок ($\rho_{s/r}$) и коэффициент переменчивости поставок ($\omega_{s/r}$) были выше по отношению к основным продуктам по сравнению с вспомогателъными. Вторая: степенъ динамики (ρ) была прямо пропорционалъна коэффициенту переменчивости продаж (CV_S) и наоборот пропорционалъна уровню запасов цепи поставок (ICT_{sc}). Третъя: реакция цепи поставок выше по отношению к основным продуктам с связи высокой текучей (сегодняшний спрос) динамикой спроса на основные продукты по сравнению с вспомогателъными.

Ключевые слова: лесопилъня, цепъ поставок, переменчивостъ, запасы, динамика, реакция, основные и вспомогателъные продукты