# Performance indicators in the wood products industry – a review and study of a saw mill supply chain

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## Abstract

There is a need for customized tools capable of providing more holistic, integrated information about forest-based SCs. This study evaluates uses (current and potential) of performance indicators (PIs) for enhancing SC management in the wood industry. Literature on PIs in SCs is reviewed, and current use of PIs is analyzed in a survey study. The review distinguished PIs may be related to strategic, tactical or operational levels, and associated time horizons. As illustrated in Table 1, they may be financial (largely related to strategic goals) or non-financial (largely related to operational performance and the behavior of actors). Frameworks and methods for developing PIs depend vary according to the purpose. Goals of performance monitoring are described on retailing, processing and rounwood procurement levels. The case study reveals a clear negative correlation between customer orientation and distance from the market, i.e. a high degree of 'responsiveness' at the retailer end and concentration on efficiency at the supplier end of the supply chain. Further studies, including mapping exercises,and the combined effort to identify key performance areas, and developing performance indicators and measurements, are suggested.

## Introduction

Since the 1990s Swedish saw mills have shifted from producing mainly commodities to offering more value added and customized products (Staland 2002, Hugosson and McCluskey 2008, Roos et al 2008) through expanding supply chains (SCs) and vertical integration. A major driving force for the changes is that improving coordination and cooperation among partners in the SC is becoming increasingly important to maintain competitiveness. Thus, the companies now have much closer direct contact with their main customers and end-users.

For similar reasons, the industry has made strenuous efforts to improve productivity, efficiency and cost-effectiveness throughout the SC: in silviculture, harvesting, transportation, as well wood processing and manufacturing final products in the mills. Major efforts have been concentrated on each step in the chain (Hansen and Juslin 2011). Inventories are kept low, but this carries risks due to uncertainties and variations in both supply and demand. The drive to cut costs has been very successful in improving units' efficiency (Ager 2012), and it remains highly important to continue efforts to minimize production costs to ensure competitive survival. However, performance measurements are mostly focused on minimizing costs of specific units or steps in the process chain. Much less attention has been paid to monitoring and improving the performance of the wood-based industry overall, i.e. the total costs and profitability for all actors in the SC.

This raises several questions regarding the optimal ways to ensure that future wood SCs meet new criteria to maintain competitiveness in a changing environment; the potential importance of applying a more holistic perspective; the potential need to improve the alignment and agility of SCs, and if so the required changes. According to Haartveit et al. (2004), enhancing control of the wood SC would cut costs, improve supply accuracy, provide opportunities for further product development, and improve the competitiveness of wood compared to the substitutes. This indicates that the focus should be shifted to the performance of the entire wood SC. Better measures and feedback from operational units involved at every step would enable managers to improve both the efficiency and agility of the entire chain. It would also help organizations to focus attention on the most crucial improvements. Key challenges are to identify the operations or processes that are most critical for the efficiency of

the chain and appropriate indicators of their efficiency (both individually and holistically). Another is to identify ways to compensate players if, for instance, meeting higher quality requirements would adversely affect a supplier, but improve overall profitability. However, this is beyond the scope of the present study.

Despite the importance of supply chain management (SCM) in the forest sector, relevant performance indicators (PIs) and the key variables (metrics) to monitor have been poorly researched, and there is a need for customized tools capable of providing more holistic, integrated information about forest-based SCs (Espinosa et al., 2010). Such tools should be based on a thorough understanding of wood SCs and provide timely knowledge of the flows and variations in both supply and demand, as improving the match between supply and demand would improve overall efficiency and profitability (Chopra & Meindl 2013). Thus, to improve the competitiveness of wood-based SCs there is a clear need to improve, develop, adapt and validate SC PIs.

## Aims

This study evaluates uses (current and potential) of PIs for enhancing SC management in the wood industry. The aims are to improve knowledge of PIs and the possibilities for enhancing the monitoring and control of wood-based SCs, by reviewing state-of-the-art performance monitoring, PIs and their applications then evaluating current performance and potential enhancements in a real life example.

## Outline

In the following section a deductive approach is applied to identify suitable methods for adaptation and application to assess performance in wood SCs: literature on PIs in SCs is reviewed and summarized. Then the current use of PIs and practitioners' perceived needs of enhancements are empirically and abductively analyzed in an interview-based case study of the SC of a saw mill in Sweden. The findings are then summarized, conclusions are drawn, and suggestions for further studies are presented.

## Literature review

Relevant literature was identified by internet searches via Google Scholar and Web Of Science using combinations of the terms 'performance indicators' or 'performance measurement(s)', 'supply chains' or 'wood supply chains', and 'saw mill(s). From more than 100 000 "hits" previous reviews and textbooks with some connection to the wood industry were chosen for closer study. Thus, the following review is based on a sample of the literature and should not be regarded as comprehensive.
Rushton (2010) classifies uses of PIs in decisions related to three organizational levels and time horizons: strategic, tactical and operational. *Strategically*, they are used for top-level management decisions concerning, for example, financial plans, competiveness and strategies for meeting company goals and plans. *Tactically*, they are used to allocate resources and facilitate efforts to meet strategic targets. *Operationally*, PIs are applied to acquire fresh, accurate data to help supervisors and workers set and meet routine and tactical objectives.

According to Maskell (1991), financial indicators are generally used in strategic planning, while non-financial indicators are applied in operational contexts to control day-to-day production and distribution. Regardless of type, Schroeder (1986) recommends use of PIs that are easily understood throughout the whole SC and difficult to manipulate. Other authors emphasize the importance of a holistic approach, since efficiency will not be maximized if the actors in an SC pursue individual goals (Lee and Billington, 1992) and use of accurate indicators covering the whole SC will enhance efficiency, cooperation and integration (Gunasekaran et al., 2004). These authors also stress the need for the PIs used to truly capture organizational performance, and recommend use of a few PIs that are critical for success, rather than the many frequently advocated by employees and consultants.

Gunasekaran et al. (2004) also presented a framework for studying PIs and metrics used in an SC environment, classifying them according to their application in four sequential SC activities identified by Stewart (1995) and Gunasekaran (2001): planning, sourcing, making/assembling, and delivering (to customers). These four classes of PIs are divided into 12 sub-classes according to their applicability at strategic, tactical and operational levels. In a case study of British companies the authors found that for strategic purposes, respondents considered non-financial performance metrics the most important for evaluating competitiveness. For example "level of customer perceived value of product" and "customer query time" were ranked highly important. "Supplier delivery performance" was the most highly ranked of all supplier link-related metrics. "Supplier ability to deliver goods in a timely fashion" was regarded as more important than price, because "Price has become the "order qualifier" rather than the order winner". "Percentage of defects", and "cost and capacity utilization" were top ranked among production metrics. A need for better forecasting techniques to eliminate (or minimize) uncertainties in the SC was emphasized. The authors conclude that monitoring performance at specific points of a SC does not necessarily improve it. To achieve positive results performance measurements and improvement studies throughout the SC are required. In addition, a good SC management program should include cross-functional and intra-organizational process and control, as well as being designed to be used and understood by all participants.

According to Lambert and Pohlen (2001), most performance metrics are company-or unit-specific, such as lead-time, fill rates and on-time delivery rates. Thus, they provide little information about the overall performance of processes in the whole SC. Metrics developed and used for a single actor (firm or unit) in the SC network do not capture the overall performance of the SC, or effects of each actor on it. Furthermore, many firms apply metrics to set rewards or incentives internally, thereby promoting an internal focus and potentially reducing overall profitability. The cited authors conclude there is a need to develop better SC metrics and overcome the implementation barriers. They advocate the development and application of more holistic metrics (aligned with strategic objectives), integrating financial and non-financial PIs, and hold that translation of such metrics into shareholder value is critical for resolving conflicting objectives and supporting trade-offs between SC actors. They also constructed a seven-step framework for developing aligned PIs in a link-to-link approach (firm-to-firm) to maximize shareholder value for an entire SC. It involves mapping the whole SC, identifying key linkages and analyzing each link to determine where additional value can be created. Finally, Lambert and Pohlen (2001) conclude that overall profitability can be maximized by using customer and supplier reports (profit and loss statements) to optimize profitability at each link, and non-financial metrics to align the behavior of individual actors with overall objectives and financial goals.

Various authors (e.g. Beamon, 1999; Bourne, 2002; Van Aken and Coleman, 2002) have identified key challenges when designing a performance measurement system, including: choosing a balanced set of metrics that drives actions towards strategic goals; ensuring measurability and easy access to required information; and avoiding metrics that promote undesirable behavior, such as local minimization or maximization that is not aligned with overall SC goals. Beamon (1999) argues that performance metrics should cover *resources*, *outputs* (products and deliveries to customers) and *flexibility* (for handling uncertainty).

SC activities have also been categorized for performance evaluation purposes, by grouping those related to: strategic supplier partnerships; customer relationships; information sharing; information quality; lean practices, and postponement (Li, 2002).

Espinoza (2010) noted that despite research on SCM in the wood products industry, little attention has been paid to development of performance measurement systems in wood products SCs. He also suggested a framework for developing wood SCs, focusing on *product quality* and *time performance* measurements linking the performance of different business units in the SC. The framework is based on suggestions by Lambert and Pohlen (2001), and consists of five steps: 1) mapping the value stream of a single product component from lumber manufacture to final delivery; 2) defining critical performance areas where the SC has to perform particularly well to create customer value; 3)

identifying relevant SC entities for key performance-related variables; 4) defining and calculating the required SC metrics; and 5) assessing the robustness and sensitivity of the system and making appropriate changes.

There have also been several attempts to construct multi-objective performance models, covering SCs wholly or partially. Notably, Sabri and Beamon (2000) developed an integrated multi-objective SC model for use in simultaneous strategic and operational SC planning. The model incorporates production, delivery, and demand uncertainty, and provides a multi-objective performance vector for SC networks, in order to aid the design of efficient, effective, and flexible SC systems and evaluation of competing SC networks. In addition, efforts to create a common tool for SC management resulted in the Supply Chain Operations Reference (SCOR) Model, a reference process model and management tool endorsed by the Supply Chain Council (SCC; http://www.supply-chain.org). It is based on three "pillars". The first pillar is process modelling, where supply chains are modelled using building blocks and a common set of definitions. The second comprises performance measurements, via (potentially) more than 150 key indicators of the efficiency of SC operations with various levels of aggregation. The third is a "best-practice pillar", involving comparison of current SC performance with "best practice" benchmarks derived from experience of SCC members. SCOR is based on the plan-source-make-deliver sequence of SCM processes (Stewart, 1995; Gunasekaran, 2001) and has been adapted to forestry in the Flexwood project (Westlund and Furness-Lindén, 2010).

Another well-known performance management tool, or system, is the Balanced Score Card (BSC), designed to help managers track the execution of activities and monitor their consequences. A BSC records measurements of a mixture of financial and non-financial metrics, each compared to a target value. The selected metrics should be those that are most important for efficiency and relevant to the organization's vision, mission, goals and strategy (Kaplan and Norton, 2001). Four steps are required to design a BSC: translating the vision into operational goals; communicating the vision and linking it to individual goals; business planning/index setting; and finally feedback and learning. According to the original concept (Norton and Kaplan, 1992) a BSC should include four elements or groups of metrics, related to: financial status, customers (satisfaction and relations); internal business processes, and learning and growth. BSCs can be presented, for example, on an executive "dashboard", focusing on important aspects of performance.

## Synthesis of the reviewed literature

To summarize the review, PIs may be related to strategic, tactical or operational levels, and associated time horizons. As illustrated in Table 1, they may be financial (largely related to strategic goals) or non-financial (largely related to operational performance and the behavior of actors). Hence, six groups of PIs are included in the table. Group A and B (strategic, tactical and financial) includes key performance measurements derived from the focal organization's (or SC's) Balance sheets and Profit and Loss statements. These metrics are often calculated and summarized either on annual basis or for part of the year, often quarterly. Group C (operational and financial) includes short-term financial measurements, e.g. cost per unit produced. Groups D, E and F (strategic, tactical or operational and non-financial) include parameters that are often difficult to define and measure, unlike financial parameters, since they have strong behavioral elements with high degrees of subjectivism and uncertainty. The level or degree of strategic fit should be included here, and the quality of communication in the supply chain (which is challenging to measure). Lead times, fill rates and customer-perceived values are other examples.

Table 1. Performance indicators grouped according to operational level and nature (financial or non-financial)

| | Strategic | Tactical | Operational |
|---|---|---|---|
| Financial | A | B | C |
| Non-financial | D | E | F |

It is important to harmonize short-term and long-term metrics. For example, if only operational costs are measured, but a higher degree of responsibility (customer orientation) is desired, there is an obvious risk of missing targets. This is a well-known problem that is frequently described in textbooks, for example Chopra & Meindl (2013, p 33) state that: "A company may fail either because of a lack of strategic fit or because its overall supply chain design, processes, and resources do not provide the capabilities to support the desired strategic fit."

Frameworks for SC performance measurement recognize sequence of actions, e.g. "plan-source-make-deliver", for which relevant PIs must be identified, and can be summarized or calculated and presented in tables.

Methodologies for developing PIs includes: mapping the focal SC, defining key performance aspects and indicators; defining appropriate metrics, measures and calculations; simulating and assessing performance using the defined metrics; validating the PIs; and finally applying the results to enhance SC performance. Figure 1 shows a generic methodology, adopted from Lambert & Pohlen and Espinoza.

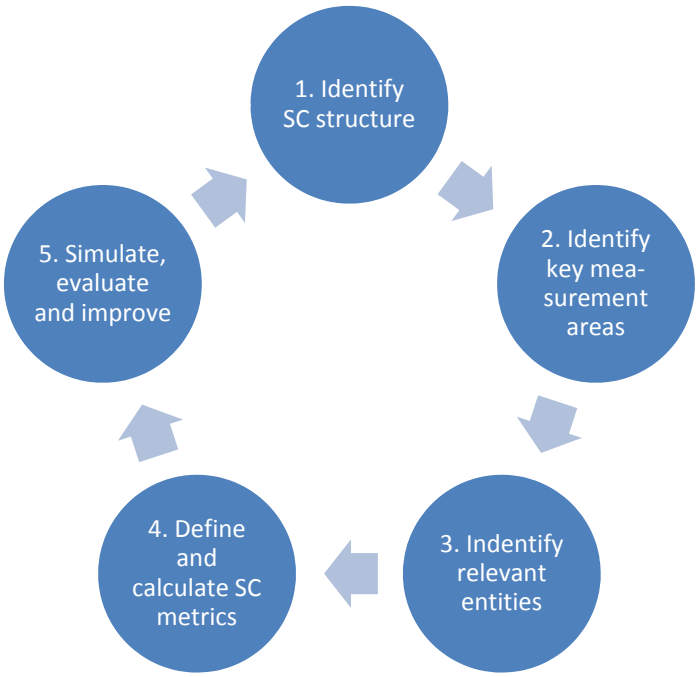


Figure 1. Sequence of steps in the development of SC performance measures (from Espinosa, 2010)

Several systems or tools have been developed for measuring performance, for example the Balanced Score Card, SCOR and the multi-objective SC model for use in simultaneous strategic and operational planning presented by Sabri and Beamon (2000).

**Case study**

The studied SC is part of a vertically integrated forest product organization. It consists of a forest company, a saw mill company that has four saw mills and a sales organization, a pulp and paper

producing company, and several other production and transporting units. Sales are executed through internal sales organizations (UK, France and Nordic countries) or by external retailers. The production of sawn wood has quadrupled during the last 20 years and its importance has increased. In this study, the SC of one of the saw mills is investigated.

The forest company is the first link of the studied SC and responsible for supplying the saw mill with timber. The procurement is divided in two sub-links: regional departments are responsible for harvesting, bucking and producing timber at road side, and a timber procurement department is responsible for transporting and delivering raw material to the saw mills (or other industrial processing sites).

The saw mills are considered to be modern (following recent investments), well managed and efficient. They produce both value added and standard wood products (*inter alia*, furniture material, paneling, decking and building/construction timber) for either domestic use or export. The mills' customers are mainly wood industries and building materials merchants, mainly located in Europe, especially the Nordic countries, UK and France.

## Methodology for the case study

The performance and coordination of actors in the focal saw mill's SC were qualitatively studied, using open interviews. This was made by inviting actors involved in various parts of the chain to state their views regarding current performance and to suggest actions that could enhance the SC's competiveness and profitability. Notes taken during the interviews and transcriptions were presented to the respondents for approval or comments. Finally, adjustments were made according to their comments.
The interviewees included 21 members of staff from the following components of the SC.

- Forest company (roundwood supplier): managers and supervisors of roundwood production, procurement and logistics
- Saw mill company (mills division): managing director, saw mill manager, marketing manager, supervisors
- Saw mill company (UK sales organization): managing director
- Saw mill company (Nordic sales organization): managing director
- Retail company (customer): owner/manager, supply manager

## Results

As shown in Table 2, responses of interviewees representing companies in three consecutive links of the mill's SC — the forest company (supplier), saw mill (manufacturer) and retailers (sales organizations/customers) —were summarized. Of the 21 interviewees, 11, six and four were representatives of the forest company, saw mill and retailers (two internal sales organizations and one external customer of the business group), respectively.

Table 2. Main findings from interviews with actors in the case study

| | Main performance characteristics | Most important performance measurements used | Perceived aspects that could be enhanced |
|---|---|---|---|
| Retailers | - Customer orientation<br>- Defining and creating | - Fill rates<br>- Delivery precision | - Forecasting and prognoses from suppliers (saw mill – |

| | | | |
|---|---|---|---|
| | businesses and markets<br>- Development of new markets<br>- Fulfillment of agreements | - JIT deliveries | forestry)<br>- SC communication<br>- Alignment of goals within the SC<br>- Delivery precision from mills |
| Saw mill | - Production efficiency and customer orientation | - Production efficiency measurements<br>- Fill rates (from supplier)<br>- *On time* and *In full* deliveries (to customers) | - Handling uncertainty and variation<br>- Forecasting and prognosis from supplier |
| Forest company | - Efficiency in all actions<br>- Deliveries of timber volumes to industry | - Cost per cubic meter<br>- Delivery of volume of raw material<br>- Fill rates (numbers of logs in diameter and length classes) | - SC coordination<br>and cooperation<br>- Alignment of goals and incentives<br>- Market/customer (end user) orientation<br>- Delivery precision (saw mill)<br>- Calculation aids |

Goals, incentives and follow-ups are mainly focused on the performance of the individual actor (retailer, saw mill, forest company). Furthermore, there seems to be a clear negative correlation between customer orientation and distance from the market, i.e. a high degree of 'responsiveness' at the retailer end and concentration on efficiency at the supplier end of the SC.'

At the saw mill, sales organizations and retailer the focus is on customer relations and fulfillment of orders and expectations, while the over-riding priorities of the supplier are to meet timber volume and delivery expectations while keeping costs low. Agreements are negotiated and fill rates (delivered numbers of logs in diameter and length classes) are monitored in the interface between the forest company and saw mill. Respondents from both forest company and saw mill stated that delivery of sufficient volumes is over-riding quality agreements (fill rates).

All respondents clearly expressed a desire for better coordination, cooperation and alignment in the SC, and recognition of a need for common tools and models for calculating benefits of investments for the entire SC, e.g. they stated that better prognosis of timber deliveries (length and diameter) would improve both production costs in the saw mill and customer relations.

They also stated that efficiency (in simple terms of minimizing local costs) is a major concern, and numerous metrics are used to measure it, in all steps and links of the SC. In contrast, quality measurements radically differ. In the retailer/sales links and saw mill they are largely related to customer-related issues. In contrast, in the forest company quality covers diverse elements, including (*inter alia*) silvicultural actions, environmental aspects of managing the forests and fill rates. Furthermore, current performance measurements mainly concern internal activities and are rarely

shared by multiple actors in the SC except fill rate measurements, which are shared by the saw mill and forest company, and the retailer and saw mill respectively. These are also the most important supplier-related metrics from the mill's perspective, while the most important metrics for the forest company are related to the efficiency of producing timber (harvesting and hauling) and transporting it to industrial processing sites.

Respondents reported that, occasionally, significant volumes can be moved from one destination (mill) to another to meet sudden shortfalls in supply. These volumes might not suit the bucketing requirements (length and diameter classes) of the new destination, and thus meet 'volume delivery' goals, but at higher costs of transporting and handling timber with deviant properties in the mill. These costs are rarely, if ever, calculated.

As the size of the mill has grown, so has its catchment-area for procurement. This has led to greater variation in properties of the timber reaching the mill. Variations in quality sometimes affect the quality of the mill's final products, hence some respondents expressed a belief that better prognosis and knowledge of the inbound timber's quality would help to meet end customer expectations.

The turnover time of raw material in the saw mill's wood yard is about a week, while replenishment takes at least one week, often more than two. Thus, when there are new bucking specifications there is delay of at least 1-2 weeks before timber with the ordered properties reaches the mill. Inventories are maintained at several points of the SC, but the data they contain are reportedly not uniform and it is difficult to acquire a summary or *snap-shot* of the properties of the timber in the flow.

Respondents from the forest company also expressed a view that demands from the saw mill are sometimes "unreasonable", i.e. incompatible with the condition of their stands. For example, logs of specified lengths and quality may be difficult (or impossible) to produce from the available raw material. Furthermore, their harvesting fleet currently includes some relatively expensive combi-machines to handle variations in supply and demand. Thus, these respondents believe that better communication and cooperation between the forest company and the saw mill would reduce harvesting costs, by increasing use of specialized harvesting machines for either thinning or final felling. If the variation were known or (better) minimized or eliminated, it would help scheduling and the use of combi-machines could be reduced.

Many respondents also stated that there are frequent deviations, mostly handled with a high degree of commitment and effort. However, problem-solving is highly dependent on previous experience. There is no (known) following-up or measurement of the costs of handling such deviations. Hence, variation is nearly always handled more reactively than proactively.Several respondents also gave examples of sudden changes in conditions that required substantial adjustment of procedures, and thus incurred significant costs, e.g. changes in deliveries or specifications, or shortfalls of raw material at the mill. However, they stated that there is no documentation of these occasions or adjustments to their knowledge.

In addition, one respondent expressed a belief that cultural differences among the forestry company, industrial and sales actors, together with a lack of knowledge, are greater hindrances than one may think. Thus, according to this respondent greater knowledge and a stronger focus on common goals would improve SC performance and reduce friction.

Overall, the respondents expressed a need for uniform business information throughout the SC, in order to harmonize the mill's requirements, harvesting plans, inventories of wood yard stocks, processing flows in the mill, further processing streams and deliveries to customers.

## Conclusion

For a long time there has been a strong focus on making each link in the SC efficient and streamlined, i.e. minimizing local costs while meeting delivery and quality criteria. Historically, this has been

appropriate and it is still important to keep costs low in order to maintain competitiveness. However, following the change in business strategy from producing standard ("bulk") products to more value added products adjustments of the strategy for monitoring and optimizing efficiency are also required to improve the 'strategic fit'. This could be done by adopting a more holistic perspective, i.e. maximizing the efficiency of the whole SC, while maintaining quality and sufficient responsiveness to requirements of other links in the chain (and end customers), especially for the value added products.

The case study reveals a clear negative correlation between customer orientation and distance from the market, i.e. a high degree of 'responsiveness' at the retailer end and concentration on efficiency at the supplier end of the SC, which creates tension among the actors. However, all of the interviewees appeared to share an equally clear, and strong, interest in enhancing communication. Efforts to improve cooperation and coordination between links have started, and all of the interviewees expressed a desire to contribute to overall SC profitability, but no appropriate measurement or decision support systems are available to them. Thus, there is a need to develop and implement such systems in order to enhance alignment of the SC actors. "We know exactly what everything costs, but we can't calculate the benefits of an investment for either the next link or the whole chain", as one respondent said. Appropriate performance measurements and incentives would help to integrate the SC more closely and thus meet this objective.

A suggestion for further studies is to apply the model presented by Espinoza; mapping and modeling the supply chain (organizations, processes, product flows, lead times etc.), identifying key performance areas, and developing performance indicators and measurements for the benefit of the whole saw mill SC. Key steps would include developing, testing and validating performance indicators and metrics for use as holistic decision support tools.

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