# Benchmarking performance measurement and lean manufacturing in the rough mill

Dan Cumbo*
D. Earl Kline*
Matthew S. Bumgardner*

## Abstract

Lean manufacturing represents a set of tools and a stepwise strategy for achieving smooth, predictable product flow, maximum product flexibility, and minimum system waste. While lean manufacturing principles have been successfully applied to some components of the secondary wood products value stream (e.g., moulding, turning, assembly, and finishing), the rough mill is perceived as a barrier to such an application. This study investigated the implementation of lean manufacturing in the rough mill as well as performance measurement and metrics at both the rough mill and overall business level. Key manufacturing as well as overall business-related metrics were benchmarked. Data were collected from a nationwide survey of secondary wood processing facilities. Notable findings of this study include: 1) the average secondary wood products manufacturer holds a combined total of greater than 500,000 board feet in dry lumber and ripped-chopped parts inventory; 2) the average order-to-delivery lead time was calculated at 23 days; 3) a statistically significant difference of approximately 10 days was detected when comparing mean lead times between companies involved in lean manufacturing (19 days) and those not involved in lean manufacturing (28 days); and 4) rough mill related barriers to lean manufacturing implementation included performance measurement, machinery constraints, and inability to control "off spec" production. Lean manufacturing concepts appear to be taking hold in the secondary industry and study results reveal that companies involved in lean manufacturing are shortening order-to-delivery lead times. However, not unlike other industries, there is evidence of a variety of barriers to full implementation in the secondary wood products industry.

The rough mill represents the first step in the lumber breakdown process in secondary wood products manufacturing, which includes products such as wood furniture, cabinets, flooring, turnings, mouldings, and millwork. In the typical rough mill, kiln-dried lumber is planed and then sawn (ripped and chopped/crosscut) into parts of varying sizes to be used in the manufacture of more complex products farther down the value stream. Perhaps more importantly, the rough mill is a shared resource and, therefore, the effects caused by changes in demand are felt quite strongly there. As a result, manufacturing flexibility is an important issue in the rough mill, particularly as demand becomes increasingly variable amid customer requests for shorter order-to-delivery lead times.

Modern rough mills typically follow an optimized "scan-rip-scan-crosscut" configuration in which planed and dried lumber is first scanned with lasers to determine the lumber width. The width of the lumber and preprogrammed part width priorities are then used to determine the location along the width of the multiple-blade saw arbor where the lumber should be input to obtain the highest yield in ripped parts. Ripped parts are then conveyed to either a manual defect marking station, where humans mark the location of defects with fluorescent markers to be detected by scanners controlling crosscut saws, or directly to an automatic defect scanner/crosscut process. In both processes, manual and automatic, a system is used to identify defects and provide data, which are then used in conjunction with part length priorities to control crosscut locations. Parts of various widths and lengths are then distributed to separate conveyors where they are typi-

The authors are, respectively, Research Associate and Professor, Sloan Foundation Forest Industries Center, Virginia Tech, Blacksburg, VA (dcumbo@vt.edu; kline@vt.edu); and Research Forest Products Technologist, USDA Northeastern Res. Sta., Princeton, WV (mbumgardner@fs.fed.us). This work was supported by the USDA Forest Serv. Northeastern Res. Sta. in Princeton, WV. This paper was received for publication in April 2005. Article No. 10039.
*Forest Products Society Member.

Forest Prod. J. 56(6):25-30.

cally manually offloaded and stacked for further downstream processing.

Past research dedicated to improving rough mill operations has focused primarily on optimizing rough mill yield based on lumber grade and cutting requirements.[1,2,3,4] However, much of this work, while helpful in improving rough mill efficiency, does not consider the dynamic nature of downstream demand for parts produced in the rough mill and the impact of that changing demand on the rough mill. In other words, it is possible to achieve an overall high part yield, while the parts produced may or may not supply any real or immediate demand, which negatively affects manufacturing flexibility downstream.

Lean manufacturing offers a set of tools and techniques as well as a systematic approach for eliminating manufacturing waste and increasing manufacturing flexibility, while creating a continuous improvement-based organizational culture. In this context, waste reduction considers not only material related waste, but all manufacturing waste as defined by Rother and Shook.[5] These wastes include: overproduction, defects, excess inventory, waiting, excessive transportation, wasted motion, and inappropriate processing. Full implementation of lean manufacturing involves changes in approach to human resource management, performance measurement, information flow, and cost accounting procedures, all of which can influence strategic decision making.

It is hypothesized that the modern rough mill is inflexible with respect to today's variable customer demand. Moreover, this inflexibility is believed to be evidenced by a lack of integration of innovative concepts in the rough mill such as those offered by lean manufacturing. Factors affecting rough mill flexibility could include misalignment between organizational goals and performance measurement in the rough mill and misallocation of functions with respect to people and technology. More information is needed regarding key performance measures and the rate of implementation of lean manufacturing concepts in the rough mill and secondary wood products industry.

## Objectives

The goal of this study was to determine the current state of the typical rough mill with respect to implementation of lean manufacturing concepts and techniques. The specific objectives of this work were to: 1) benchmark lean manufacturing related statistics including order-to-delivery lead time, inventory levels, and demand variability; and 2) assess the industry's perspective on manufacturing waste and performance measurement.

## Methods

A nationwide mail survey of secondary wood products manufacturers was conducted in March 2004 to collect data related to objectives 1 and 2. The sample frame, constructed from a master list of approximately 5,500 subscribers to *Wood & Wood Products Magazine*, included a variety of secondary wood products manufacturing companies. Sample selection was limited to manufacturing facilities employing 50 or more people and those listed as producers of furniture, cabinets, flooring, dimension/component products, and moulding/millwork. After 2 mailings, a total of 258 of 2,500 questionnaires were returned, resulting in a response rate of 10.3 percent. Of those, 145 contained usable responses. The remaining 113 responding facilities performed operations not relevant to the study. The respondent breakdown by sector is as follows: cabinets (41), furniture (upholstered and non-upholstered) (39), moulding/millwork (34), dimension/components (26), and flooring (5).

Due to the small flooring sample size, a degree of caution should be used when making inferences about the flooring industry based on these data. However, due to the relative small number of flooring manufacturers in comparison to the other sectors of interest, the flooring industry's contribution to the overall sample might be considered in proportion with the other sectors studied. That is, a relatively smaller industry sector might be expected to contribute fewer responses with respect to the overall secondary manufacturing industry.

The survey questionnaire was developed with help from faculty members at Virginia Tech and USDA Forest Service personnel. In addition, a pre-test of the questionnaire was conducted with six secondary wood products producing firms (one from each segment of interest) ranging from operations possessing little to no formal knowledge of lean manufacturing to one firm entering its fifth year of lean implementation. Final adjustments were made primarily to question wording prior to mailing.

Respondent job titles reflected, in general, senior to mid-level management. Responses were split roughly equally between the following job titles: chief executive officer, president, vice president of manufacturing/operations, general manager, chief operations officer, production/plant manager, and industrial/production/process engineer. Other less frequently listed job titles included: continuous improvement coordinator, kaizen leader, and Six Sigma black belt.

## Results and discussion

Responses were split roughly 50/50 between companies identifying themselves as a single-facility operation and those indicating that their plants were part of a multiple-facility company. Mean annual sales were calculated at $40 million for the sample (**Fig. 1**).

The average responding facility employed 258 people (**Fig. 2**), produced 2,119 individual stock-keeping-units (SKU) in the rough mill (**Fig. 3**), and required 22 people per shift to operate the rough mill.

The average respondent held 286 thousand board feet (MBF) of dried lumber in inventory for processing in the rough mill and 225 MBF in ripped-chopped parts (**Fig. 4**).

From **Figure 4**, moulding/millwork producers reported holding the highest total inventory (nearly 1 million board feet

[1] Buehlmann, U., J.K. Wiedenbeck, and D.E. Kline. 1998. Character-marked furniture: Potential for lumber yield increase in rip-first rough mills. Forest Prod. J. 48(4):43-50.

[2] Gatchell, C.J., R.E. Thomas, and E.S. Walker. 1999. Effects of preprocessing 1 Common and 2A Common red oak lumber on gang-rip-first rough mill dimension part yields. Forest Prod. J. 49(3):53-60.

[3] Hamner, P.C., B.H. Bond, and J.K. Wiedenbeck. 2002. The effects of lumber length on part yields in gang-rip-first rough mills. Forest Prod. J. 52(5):71-76.

[4] Shepley, B. 2002. Simulating optimal part yield from No. 3A Common grade lumber. MS thesis. Virginia Tech, Dept. of Wood Sci. and Forest Products, Blacksburg, VA.

[5] Rother, M. and J. Shook. 1999. Learning to See: Value Stream Mapping to Create Value and Eliminate Muda. Lean Enterprise Inst., Inc., Brookline, MA.

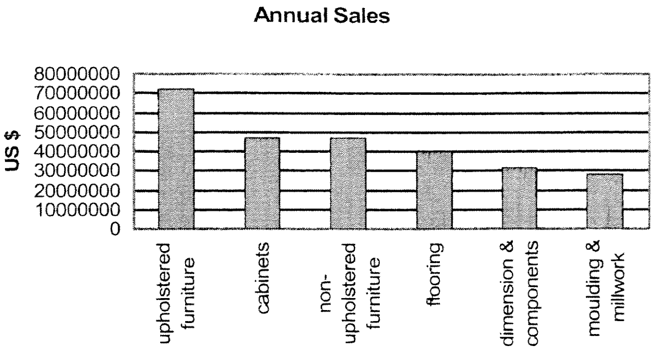


*Figure 1. — Mean annual sales by industry sector (n = 129).*

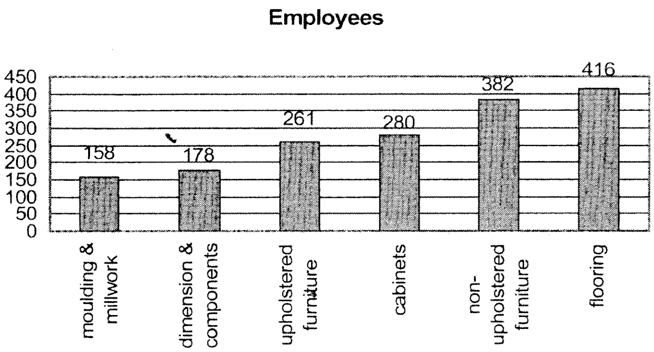


*Figure 2. — Mean employment by industry sector (n = 144).*

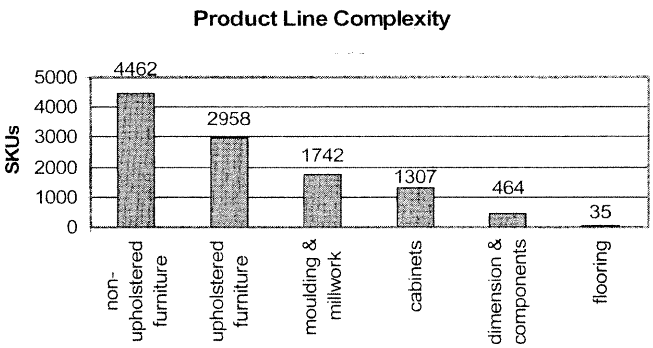


*Figure 3. — Mean number of rough mill SKUs by industry sector (n = 86).*

in lumber and parts), while upholstered furniture and cabinet producers held the least total inventory of the sample at roughly 110 MBF and 195 MBF, respectively. Study results suggest that the cabinet and upholstered furniture industries are implementing lean manufacturing at perhaps a higher rate than other sectors of the secondary industry. The moulding/millwork sector and the flooring sector both reported holding more volume in ripped-chopped parts than in dry lumber. This could be an indication of outsourced cut stock in those sectors or the presence of specific bottlenecks downstream from the rough mill.

When asked what percentage of their ripped-chopped part inventory could be classified as "high demand" or "products representing a majority of customer demand," the average respondent reported a value of 66 percent. Responses to this question ranged from a low mean of 30 percent in the flooring sector to a high of 71 percent in the moulding/millwork sector. Mean percentages for the remaining industry sectors were: 59

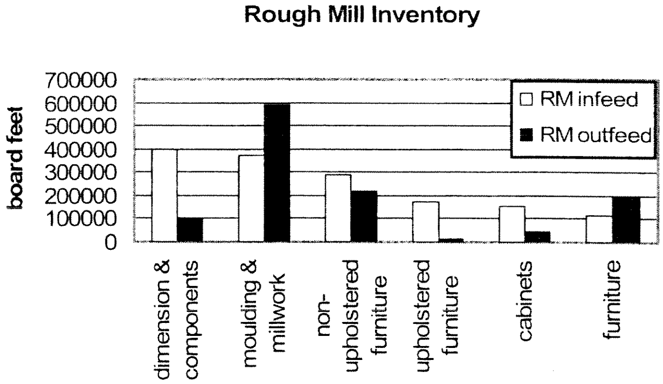


*Figure 4. — Dry lumber and ripped-chopped parts inventories by industry sector.*

percent (upholstered furniture), 66 percent (cabinets), 66 percent (non-upholstered furniture), and 67 percent (dimension/components) representing "high demand" parts.

Respondents were asked to indicate their average order-to-delivery lead time in days. An overall mean of 23 days was calculated for the sample (**Fig. 5**). Study participants were asked to indicate the status of outsourcing products/production in their facilities over the past 5-year period. A majority of respondents reported either an increase or no change in outsourcing. Of those respondents reporting an increase in outsourcing over the previous 5 years, the average rate of increase was calculated at 50 percent. Comparatively, those reporting a decrease in outsourcing, on average, saw outsourcing decrease by 15 percent in their facilities.

## Lean manufacturing

Study participants were asked whether their facility was involved in implementing lean manufacturing at the time of the study. Overall, a majority of companies (55%) indicated that they were implementing lean manufacturing at the time of the study. The industry sectors indicating a majority of companies "involved" in lean manufacturing were: cabinets (56%) and upholstered furniture (71%). The remaining sectors, moulding/millwork, non-upholstered furniture, dimension/components, and flooring reported 63, 53, 53, and 50 percent of companies, respectively, "not involved" in lean manufacturing at the time of the study. The average responding company currently involved in lean manufacturing had begun their lean transformation roughly 30 months prior to the time of study.

Interestingly, of those respondents involved in lean implementation, a majority (83%) characterized their rough mill as "not lean." When asked what was preventing the implementation of lean manufacturing in the rough mill, respondents cited several constraints:

- inflexible machinery,
- forecasting paradigm,
- too much focus on yield and not enough on demand,
- performance measurement constraints,
- long changeover times,
- inability to control production "off fall" or residues,
- variability of demand.

Responses were varied when asked, "What would you cite as your main motivation for beginning implementation of lean

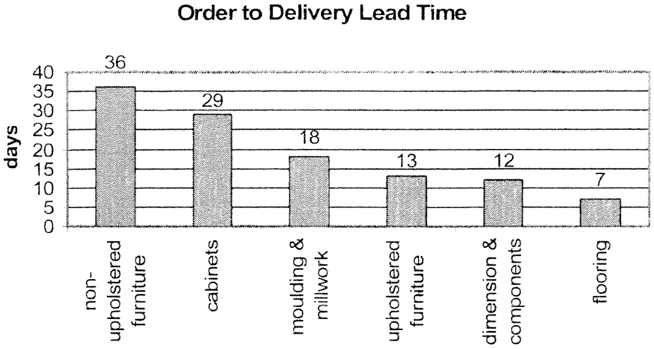


*Figure 5. — Lead time (days) by industry sector (n = 127).*

manufacturing in this facility?" However, a plurality of respondents noted "cost reduction" as a significant motivator. Other responses included: "necessary to remain competitive, customer dictated, changes in customer demand, needed to achieve shorter lead times, and increased flexibility.".

Study participants were then asked to indicate, from their perspectives, the key accomplishments/milestones that must be reached to signify a "truly lean" operation. Again, responses were varied; however, a plurality of respondents cited "100% buy-in throughout the organization" as key to becoming "truly lean." Other responses included both quantitative and qualitative metrics such as:

- reduced inventory levels,
- shortened lead times, minimized set-up/changeover times,
- the ability to produce what is needed when it is needed,
- 100% on-time shipments,
- continuous flow,
- use of lean-based performance measurements
- "culture change."

## Mean comparisons

A major goal of lean manufacturing is to reduce lead time, in many cases through inventory reduction. To test for significant differences in mean lead time between companies involved in lean manufacturing and those not involved in lean manufacturing, an analysis of variance (ANOVA) was conducted at the 95 percent confidence level (**Table 1**). A significant difference was detected between "lean" and "non-lean" companies, with a mean lead time difference of roughly 10 days.

·Similarly, an ANOVA was used to test for differences in mean dry lumber as well as ripped-chopped parts inventories. Both tests were conducted at the 95 percent confidence level (**Table 1**). No significant differences were detected between groups with respect to inventory levels either at the infeed or outfeed of the rough mill. Therefore, shortened lead times resulting from inventory reductions among "lean" companies appear unrelated to the rough mill, i.e., inventory reduction is taking place elsewhere in the value stream.

Interestingly, while not statistically different, contrary to expectations, companies involved in lean implementation reported higher mean inventory levels in both categories: lumber and parts. However, it should be noted that standard deviation values were high for these measures.

*Table 1. — ANOVA lead time comparison, ANOVA dried lumber inventory comparison, ANOVA ripped-chopped part inventory comparison.*

| Is your company involved in lean manufacturing? | $n$ | Mean | Significance |
|---|---|---|---|
| | | Lead time (days) | |
| No | 55 | 28.0 | 0.033 |
| Yes | 70 | 18.9 | |
| | | Dry lumber (BF) | |
| No | 43 | 202,302 | 0.172 |
| Yes | 52 | 358,370 | |
| | | R/C parts (BF) | |
| No | 38 | 50,763 | 0.201 |
| Yes | 52 | 356,143 | |

To determine whether companies involved in lean manufacturing tended to be larger or smaller companies/facilities, ANOVA was used to test for differences in number of employees (a measure of company/facility size) between companies involved in lean manufacturing and those not involved in lean manufacturing. No difference was detected in employee size between "lean" and "non-lean" companies at the 95 percent confidence level.

## Benchmarking and performance measurement

Study participants were asked to list the three to six most important performance metrics/measures/indicators by which performance is gauged in the rough mill. While a variety of responses were received, the most common (ordered according to frequency) were: 1) yield; 2) production output (tally/quota); 3) throughput (BF/labor hour); 4) labor cost (labor hours used); and 5) quality (measured in various ways). Of somewhat lesser importance were: 1) downstream demand supply rate; 2) safety-related metrics; 3) overall equipment effectiveness (OEE or uptime); and 4) monetary value of parts produced.

Similarly, respondents were asked to list the three to six most important performance or success areas for their operations. This question differed from the previous one in that it asked for broader areas of performance relative to the overall business, whereas the previous question asked for specific metrics related to the rough mill. Again, a variety of responses were received; however, respondents overwhelmingly cited the "financial" aspect of the business as well as "customer satisfaction" as key to overall success. Of lesser importance were employee quality of work life, employee satisfaction, and continuous process improvement.

Study participants were asked to select, from a list, all metrics for which they compared their operation's performance to either benchmarked performance levels in their industry or in other industries (**Fig. 6**). Customer satisfaction, lead time, profit margins, on-time shipment rate, and sales volume are all benchmarked with relative frequency compared to others listed. Three of the top five benchmarked metrics are customer service related, two are specifically time related, and two are focused on financial metrics. By contrast, metrics related to employee satisfaction were benchmarked relatively infrequently. Also of interest, neither "yield," which was cited as a top rough mill performance metric, nor "error-free shipment rate," which relates to quality, were frequently benchmarked.

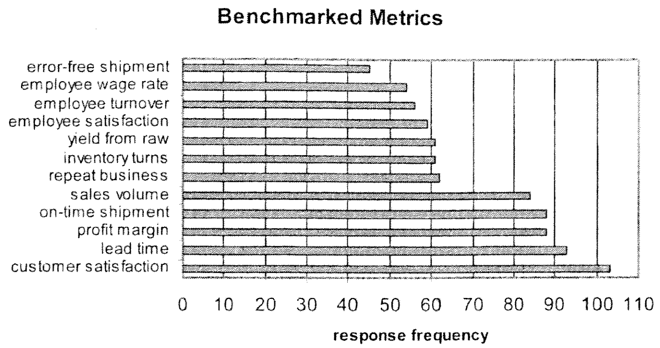


*Figure 6. — Benchmarked performance metrics (frequencies).*

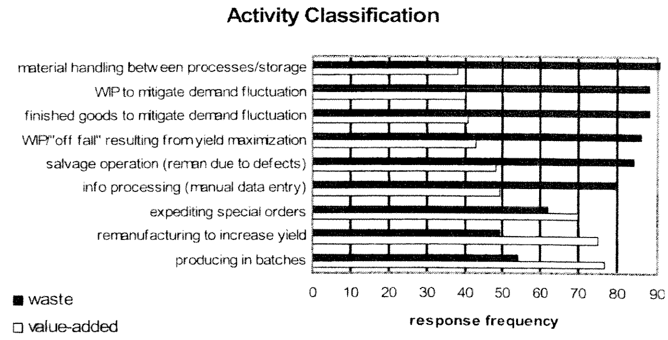


*Figure 7. — Perceptions of value-added vs. wasteful activities (frequencies).*

In an effort to better understand respondents' perceptions of performance and understanding of key lean manufacturing concepts, participants were provided a list of activities and asked to indicate whether each activity would be considered value-added or waste in their facilities (**Fig. 7**).

In analyzing respondents' perceptions of value-added vs. waste in **Figure 7**, there appears to be some consensus on most listed activities. To clarify, according to the frequencies reported, respondents seemed to agree that a majority of the listed activities were wasteful. However, some ambiguity is evident regarding expediting special orders, remanufacturing to increase yield, and batch production. Also of interest, there appears to be some contradiction in the general perception that remanufacturing to increase yield is a value-added activity, which by its nature may generate more low-demand parts that tend to increase work in process (WIP), while WIP inventory accumulation as a result of maximizing yield is perceived as wasteful.

## Summary and concluding discussion

The need for lean manufacturing and similar approaches designed to closely align production with demand is clear from the study results. Overall lead time in the industry ranged from 1 to 5 weeks and the average respondent reported over 2,000 unique SKUs in the rough mill alone. With this type of demand amid ever shorter lead time requirements, the need for manufacturing flexibility is paramount in satisfying customers.

Moreover, study results suggest that, while lean manufacturing is being implemented to some degree in the secondary industry, lean thinking does not appear to be permeating the rough mill. This is evidenced by several key findings in the study: 1) of those companies involved in lean, nearly 85 percent have not implemented it in the rough mill; 2) while a significant difference in lead time between "lean" and "non-lean" companies was detected, no significant differences were detected in rough mill inventory levels between the two groups, suggesting that lead time reduction is occurring elsewhere in the value stream; and 3) respondents noted several impediments to lean manufacturing in the rough mill, e.g., misaligned performance metrics and machinery constraints.

Considering the time that the industry has been involved in lean manufacturing, 30 months on average, it is unclear as to the depth of understanding of lean manufacturing tools and concepts. It is unlikely that culture change and the work leading up to it would be accomplishable in a period of 30 months, particularly if the change is a considerable departure from the organization's status quo as lean manufacturing might be to some. Therefore, implementation could be constrained by a need for more in-depth training in lean concepts, tools, and techniques, as well as more generic training in organizational change.

Interestingly, there appeared to be some ambiguity with respect to what is waste and what is value-added in wood products manufacturing and on the topic of "yield" there appears to be some contradiction. That is, remanufacturing to increase yield is perceived, by most, as value-added, while the accumulation of WIP or "off fall" resulting from yield maximization is viewed as waste by most. A true understanding of lean manufacturing and its benefits begins with a clear understanding of value-added vs. wasteful activities from the perspective of the customer.

To put the effects of waste in perspective, consider the following. The average respondent reported holding roughly 286 MBF of dried lumber at the rough mill infeed and roughly 225 MBF of ripped-chopped parts at the rough mill outfeed. This equates to roughly the output capacity of 13 50-MBF dry kilns, approximately 6 kiln charges in dried lumber, and 7 kiln charges in parts, assuming a rough mill yield of 60 percent. Respondents reported, on average, that 33 percent of rough mill production was "low demand" parts. Therefore, roughly 75 MBF of those parts, nearly 125 MBF of dried lumber or 2.5 kiln charges considering a 60 percent yield factor, can be classified as wasted capacity both in the rough mill and back upstream in the dry kilns.

From another perspective, assuming an average rough mill output of 30 MBF per shift and an average of 176 labor-hours (LH) (22 people × 8 hr), an average production of 170 BF/LH can be assumed (30 MBF/176 LH). Dividing 75 MBF (33% of parts inventory) by 170 BF/LH equates to 441 wasted labor hours producing "low demand" parts. At $10/LH, the company is investing nearly $4,500 per shift in labor alone to produce parts that are not meeting demand.

From a performance measurement perspective, financial metrics are most important at the business level, while yield and production output appear most important at the rough mill level. The success of lean manufacturing implementation often hinges on decisions made at the senior management level where financial return on investment is a key driver in decision making. Therefore, the benefits of lean manufacturing and similar types of improvement initiatives must be translated into financial terms to achieve upper level buy-in and guide decision making at the organizational level. Perhaps a shift away from efficiency-based performance measures toward more effectiveness-based measures is needed.

In summary, lean manufacturing concepts appear to be taking hold in the secondary industry and study results reveal that companies involved in lean manufacturing are shortening order-to-delivery lead times. However, not unlike other industries, there is evidence of a variety of barriers to full implementation in the secondary wood products industry. These barriers must be identified and action taken to overcome them before the full benefits of lean manufacturing can become reality in the industry.