

**Benchmarking Performance Measurement and the
Implementation of Lean Manufacturing in the Secondary
Wood Processing Rough Mill**

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Executive Summary

It is hypothesized that, while other components of the secondary wood products value stream; e.g., moulding, turning, sanding, etc, are being integrated and “leaned up” so to speak, the rough mill represents a real or perceived barrier to full implementation of lean manufacturing tools, techniques and concepts. 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. Data were collected from a nationwide survey of secondary wood processing facilities. The following are highlights of the study.

- The average secondary wood products manufacturer holds a combined total of greater than 500 MBF in dry lumber and ripped-chopped parts inventory.
- On average, one third of ripped-chopped parts inventory is classified as “low demand”, “off fall” or “not needed to meet an immediate demand”.
- The average order-to-delivery lead time was calculated at 23 days.
- A statistically significant difference of approximately ten 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).
- Of those companies involved in lean manufacturing, 85 percent had not implemented it in their rough mill
- Yield was the most common metric used to measure rough mill performance
- Rough mill barriers to lean manufacturing implementation included: performance measurement, machinery constraints and inability to control “off fall” production.

Background

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. In this context, manufacturing flexibility relates to the manufacturer's ability to effectively supply a fluctuating customer demand, which includes adequate product quality, on-time-error-free-complete shipments and acceptable lead time.

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 florescent markers to be detected by scanners controlling crosscut saws, or directly to an automatic defect scanner/crosscut process. In both processes, manual and automatic, scanners are used to identify defects and provide data, which is 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 typically manually offloaded and stacked for further downstream processing. Figure 1 shows a simple schematic comparing the two common types of optimized rough mill systems.

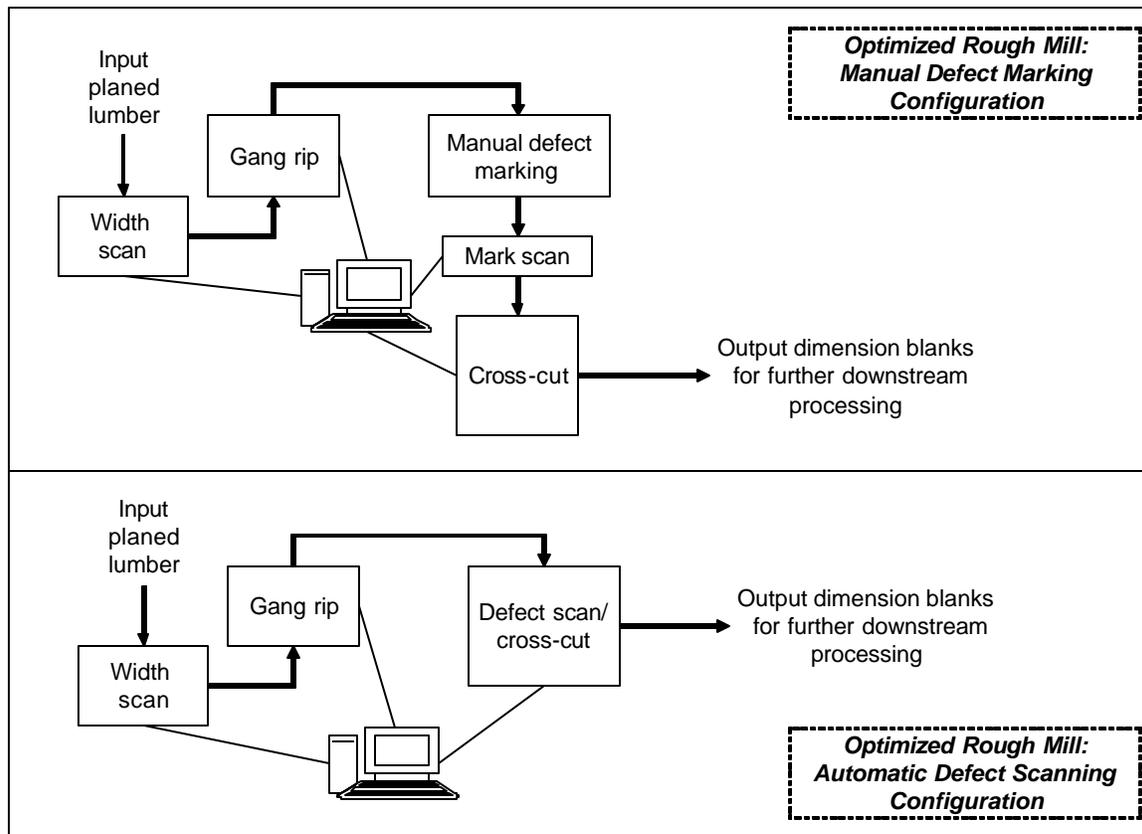


Figure 1: Common rough mill configurations

Depending on the use of a manual defect marking system or an automatic scanning system prior to the crosscut step, the rough mill might be considered either a semi-continuous or true continuous flow process. For example, a large quantity of strip inventory can accumulate on the conveyor between the rip and crosscut steps prior to

manual defect marking. While the cycle time of the rip step is typically lower than the crosscut step in both systems, automatic systems tend to minimize the gap between cycle times more effectively than manual systems smoothing the flow of material between processes. However, strip buildup prior to crosscutting in manual defect marking systems can also be reduced by increasing defect marking capacity; i.e., increasing the number of human defect markers.

Designing robust systems with high processing speed capabilities were significant challenges to the development of optimizing rough mill systems early on. Today, processing speeds of over 600 linear feet per minute are commonly advertised. More recent developments include built in databases, which compile lumber characteristic and processing data allowing for future simulations to further optimize cutting solutions. In addition, some systems are equipped to allow offsite diagnosis and repair of software based problems through an internet connection. However, the enhanced capabilities of today's rough mill have not come cheaply. Purchase and installation costs for a typical fully optimized rough mill system can easily exceed \$1,500,000.

Past research dedicated to improving rough mill operations has focused primarily on optimizing rough mill yield based on lumber grade and cutting requirements (Buehlmann et al. 1998, Gatchell et al. 1999, Hamner et al. 2002, Shepley 2002). 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. It becomes increasingly difficult to supply changing downstream demand if resources are occupied producing low demand parts regardless of overall yield measurements.

Lean manufacturing (LM) 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 relates not only to material related waste, but to all manufacturing waste as defined by Rother and Shook (1999). These wastes include: overproduction, defects, excess inventory, waiting, excessive transportation, wasted motion and inappropriate processing. Some view lean manufacturing as largely a production improvement initiative focused on goals at the operational or tactical level in the organization. However, a broader perspective 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 rough mill with respect to implementation of lean manufacturing concepts and techniques. The specific objectives of this work were: 1) to benchmark LM related statistics including: order to delivery lead time, inventory levels and demand variability, and 2) to assess the industry's perspective on manufacturing waste and performance measurement.

Results and Discussion

A nationwide mail survey of secondary wood products manufacturers was conducted in March 2004 to collect data related to objectives 1 and 2 above. The sample frame, constructed from a list of subscribers to Wood & Wood Products Magazine, included manufacturers of wood furniture, cabinets, flooring, dimension & component products, and moulding & millwork. Sample selection was limited to manufacturing facilities employing 50 or more people within the five industry sectors listed above. After two mailings, a total of 258 questionnaires were returned. Of those, 145 contained usable responses. The respondent breakdown by sector is as follows: cabinets (41), furniture (upholstered and non-upholstered) (39), mouldings & 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.

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.

Except for the flooring industry, the lowest at just three percent of responding companies, responses were somewhat evenly dispersed among industry sectors (Figure 2).

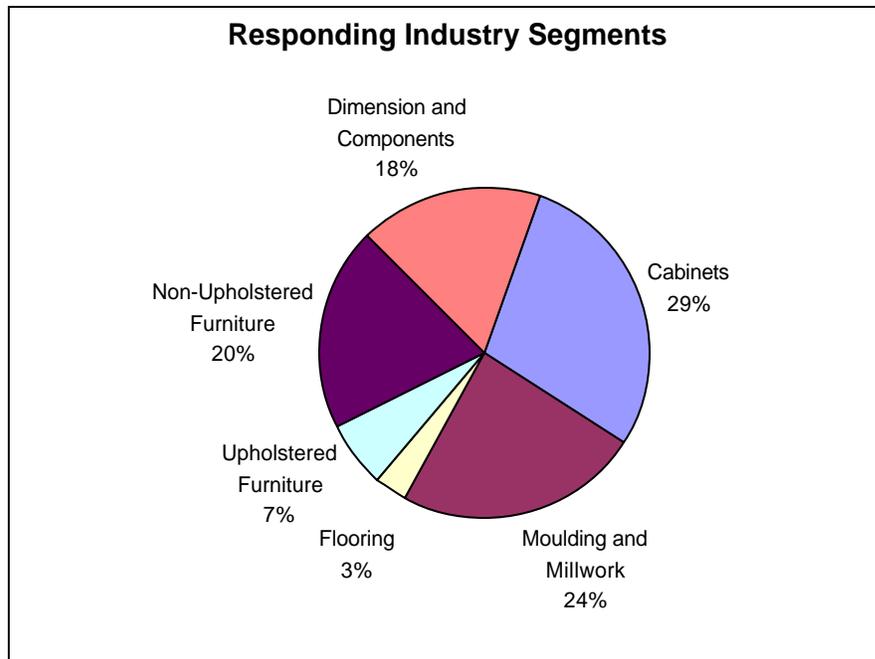


Figure 2: Survey response breakdown

Sample Descriptive Statistics

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 (Figure 3).

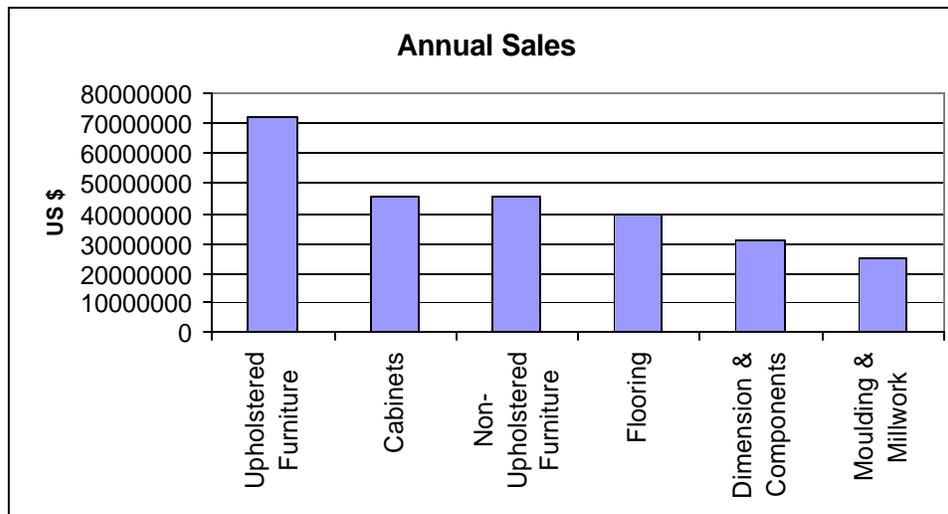


Figure 3: Mean annual sales by industry sector (N=129)

The average responding facility employed 258 people (Figure 4), produced 2,119 individual stock-keeping-units (SKU) in the rough mill (Figure 5) and required 22 people per shift to operate the rough mill.

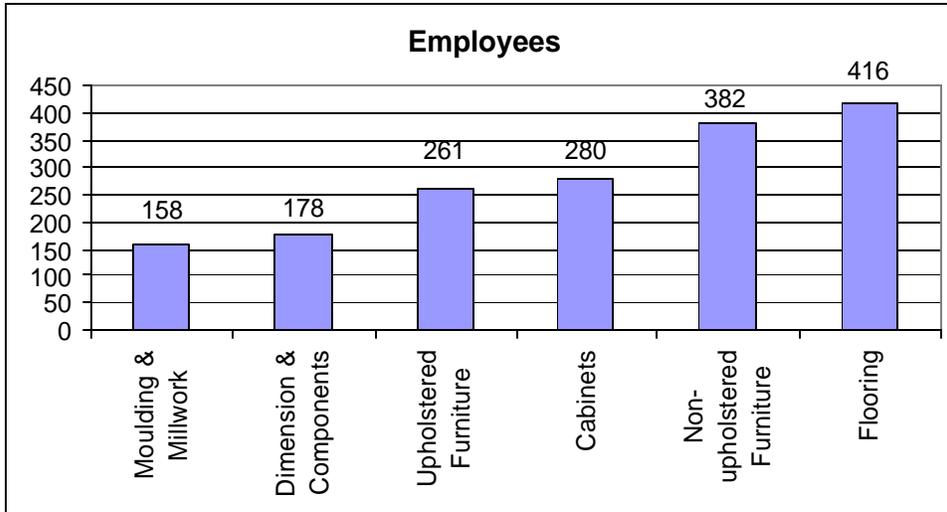


Figure 4: Mean employment by industry sector (N=144)

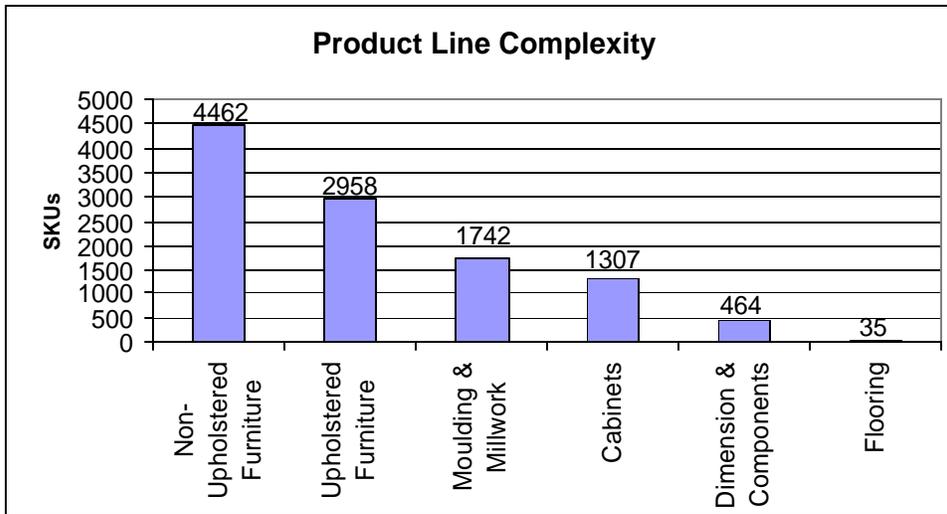


Figure 5: Mean number of rough mill SKUs by industry sector (N=86)

When comparing sales per employee (a productivity measure) across industry sectors, the upholstered furniture industry leads with approximately \$275,000 in annual sales per employee. Calculated values for the flooring and non-upholstered furniture industries are

substantially lower, while values for dimension & components, cabinets and moulding & millwork are similar (Figure 6).

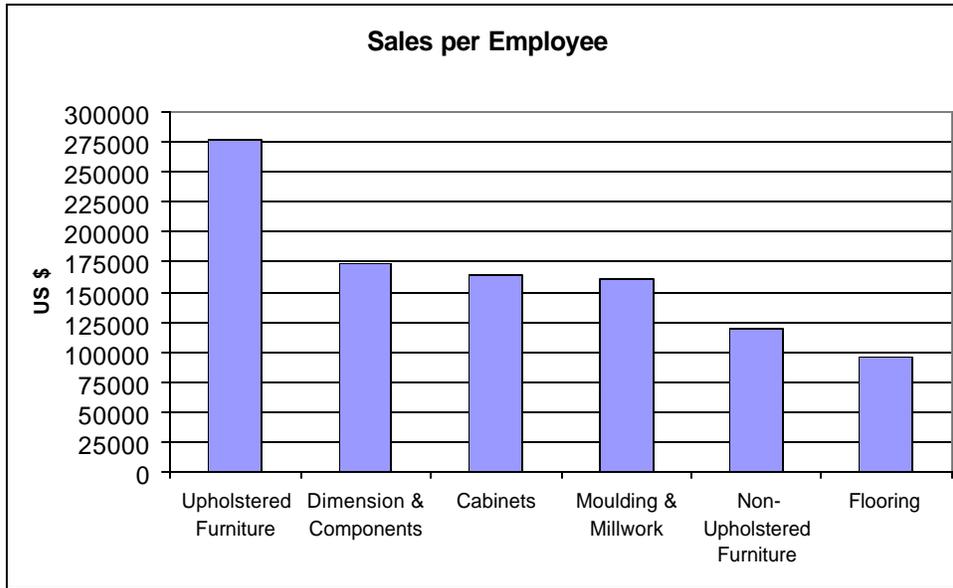


Figure 6: Productivity (defined by sales per employee) by industry sector

The average respondent held roughly 286 MBF of dried lumber in inventory for processing in the rough mill and roughly 225 MBF in ripped-chopped parts (Figure 7).

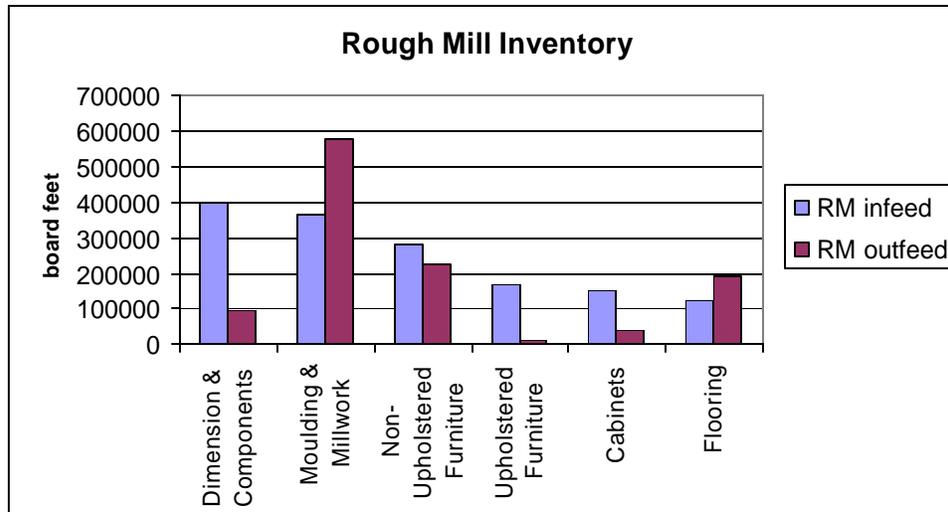


Figure 7: Dry lumber and ripped-chopped parts inventories by industry sector

From Figure 7, moulding & millwork producers reported holding the highest total inventory (lumber and parts), while upholstered furniture and cabinet producers held the least total inventory of the sample. Anecdotal evidence suggests that the cabinet industry is implementing lean manufacturing at, perhaps, a higher rate than other sectors of the secondary industry, while the upholstered sector consumes a comparatively small amount of lumber. Interestingly, 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 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 (Figure 8). Study participants were also asked to rate their lead time on a five-point scale (1 = “relatively poor”, 3 = “about average”, 5 = “industry leader”). An overall mean sample rating was calculated at 3.8, slightly above average (Figure 9).

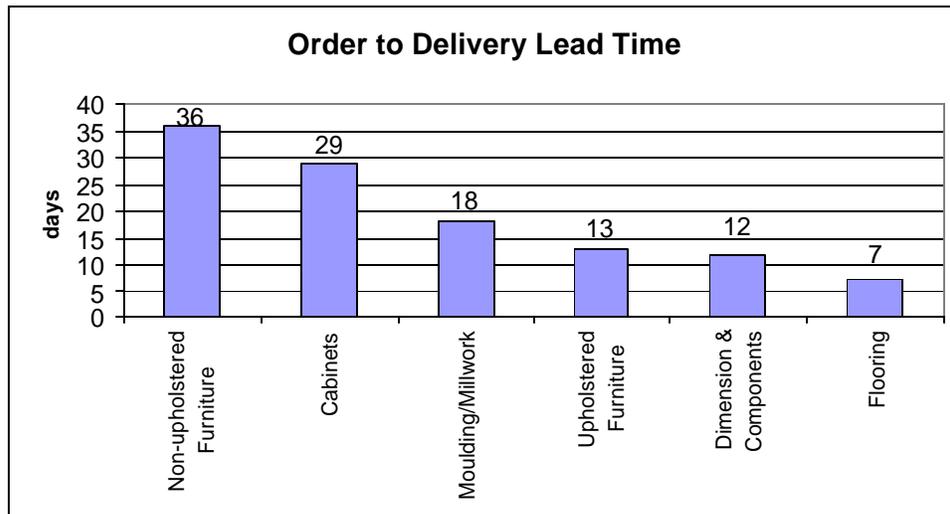


Figure 8: Lead time (days) by industry sector (N=127)

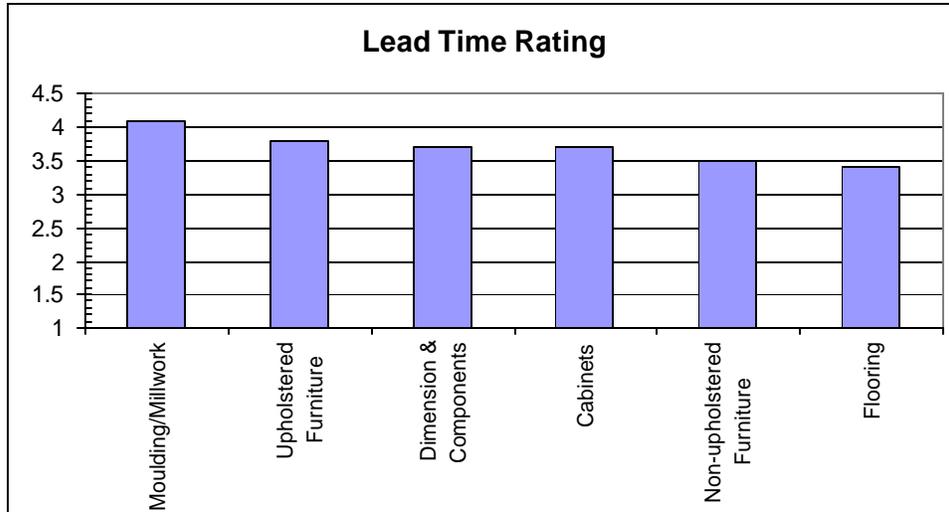


Figure 9: Lead time ratings by industry sector (N=131)

Study participants were asked to indicate the status of outsourcing products/production in their facilities over the past five-year period. A majority of respondents reported either an increase or no change in outsourcing (Figure 10).

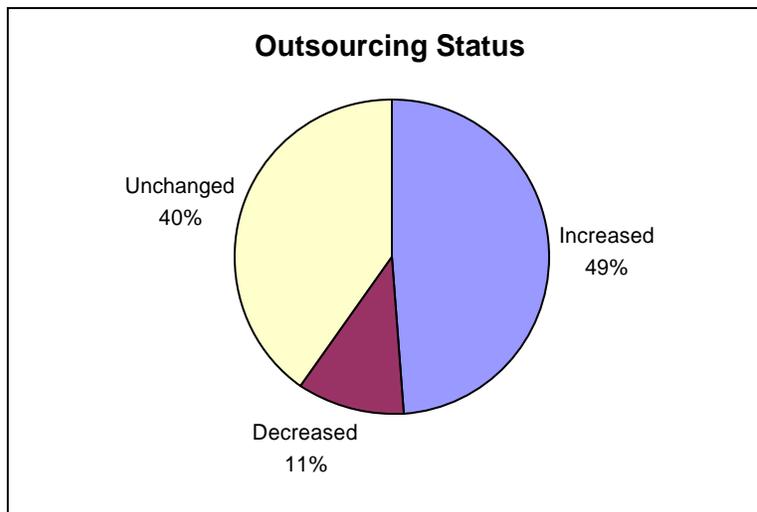


Figure 10: Production outsourcing over the past five-year period (N=137)

Of those respondents reporting an increase in outsourcing over the previous five 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 or not their facility was involved in implementing lean manufacturing at the time of the study. Overall, a small majority of companies (55 percent) indicated that they were implementing lean manufacturing at the time of the study. The industry sectors indicating **involvement** in lean manufacturing were: cabinets (56 percent) and upholstered furniture (71 percent). The remaining sectors, mouldings & 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 a lean implementation, a large majority (83 percent) 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; e.g., “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 and variability of demand” were most notable.

Responses were varied when asked, “What would you cite as your main motivation for beginning implementation of lean 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 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” and simply “culture change”.

Based on their characterization of a “truly lean” operation in the previous question, study participants were asked to rate the overall level of “leanness” of their facility. Again, a five-point scale was used where: (1 = “not at all lean”, 3 = “about average”, 5 = “very lean”). The average respondent gave his/her facility a rating of 2.8, slightly below average.

Study participants were provided a list of twenty two lean manufacturing based tools and asked to indicate which were used in the rough mill. The list was adapted from (Kirby & Green 2003). From Figure 11, cross-training, waste reduction, visual controls and changeover/setup time reduction are receiving attention in the rough mill. Comparatively, some of the fundamental building blocks of lean manufacturing; e.g.,

value stream mapping, kaizen events and total productive maintenance (TPM), are rarely used in the rough mill. Poke Yoke devices and automation were the least frequently used tools listed. However, it was unclear as to whether or not these terms were well understood among study participants.

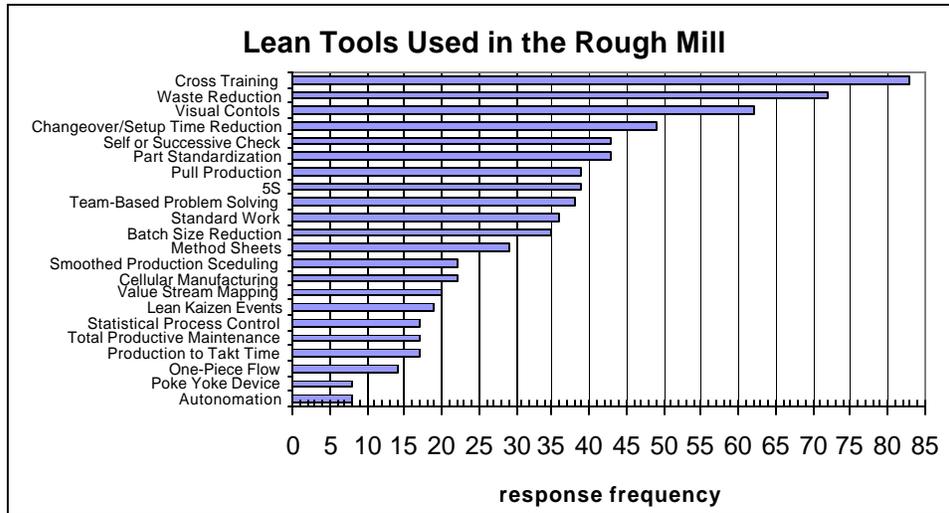


Figure 11: Lean tools used in the rough mill (frequencies)

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).

Table 1: ANOVA, lead time comparison

Is your company involved in lean manufacturing?	N	Mean Lead-time	Significance
No	55	28.0	0.033
Yes	70	18.9	

From Table 1, a significant difference was detected between “lean” and “non-lean” companies, with a mean lead time difference of roughly ten 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 (Tables 2 & 3).

Table 2: ANOVA, dried lumber inventory comparison

Is your company involved in lean manufacturing?	N	Mean Dry Lumber in Queue	Significance
No	43	202302	0.172
Yes	52	358370	

Table 3: ANOVA, ripped-chopped part inventory comparison

Is your company involved in lean manufacturing?	N	Mean R/C Parts in Queue	Significance
No	38	50763	0.201
Yes	52	356143	

No significant differences were detected between groups with respect to inventory levels either at the in feed or out feed 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. Moreover, a high level of variability in part inventories was detected among companies reportedly involved in lean manufacturing. Table 4 lists sample descriptive statistics for lumber and part inventory.

Table 4: Sample descriptive statistics

	Dry Lumber in Queue (bf)	R/C Parts in Queue (bf)
N	95	90
Mean	285773	224928
Median	100000	20000
Mode	100000	10000
Range	3500000	10000000

To determine whether companies involved in lean manufacturing tended to be larger or smaller companies, ANOVA was used to test for differences in number of employees between companies involved in lean manufacturing and those not involved in lean manufacturing. No difference was detected between “lean” and “non-lean” companies at the 95% confidence level.

ANOVA was also used to test for differences in lead time ratings between “lean” and “non-lean” companies. Again, the test was conducted at the 95% confidence level (Table 5).

Table 5: ANOVA, lead time rating comparison

Is your company involved in lean manufacturing?	N	Mean L/T Rating	Significance
No	58	3.67	0.218
Yes	72	3.85	

From Table 5, lead time ratings did not differ between groups. That is, a company's participation in lean manufacturing, or lack thereof, had no effect on respondents' perceptions of their lead time in comparison to others within their sector of the industry. The average respondent perceived their lead time to be slightly above average (3.8 on a 5-point scale).

Benchmarking and Performance Measurement

Study participants were asked to list the 3-6 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)** unit production (board feet/labor hour), **4)** labor cost (hours) and **5)** quality (measured in various ways). Of somewhat lesser importance were: **1)** downstream demand supply rate, **2)** safety metrics, **3)** overall equipment effectiveness (OEE or uptime) and **4)** value of parts produced.

Similarly, respondents were asked to list the 3-6 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. It was unclear if this question was well understood by all respondents because several respondents listed specific metrics instead of broader performance areas.

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 (Figure 12).

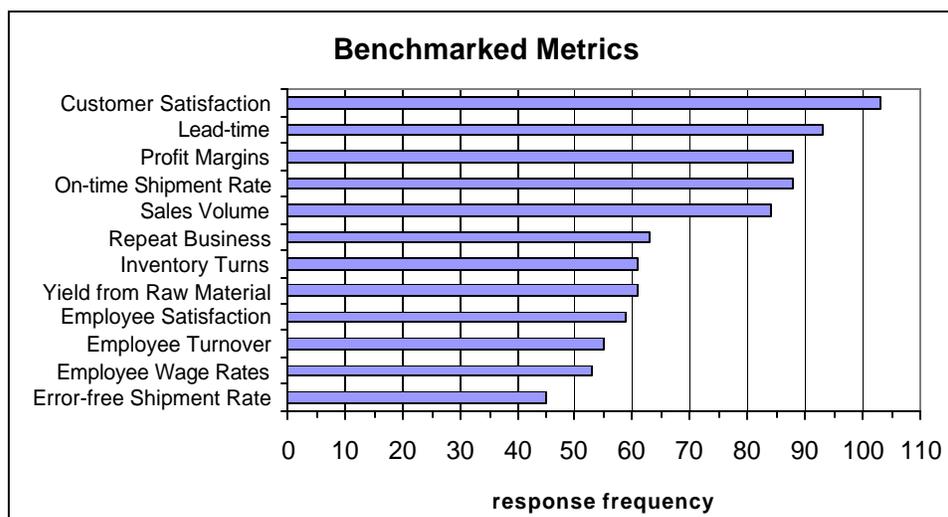


Figure 12: Benchmarked performance metrics (frequencies)

From Figure 12, customer satisfaction, lead time, profit margins, on-time shipment rate and sales volume are all benchmarked with relative frequency compared to others listed. Interestingly, three of the top five benchmarked metrics are customer service related, two are specifically time related and only 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.

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 (Figure 13).

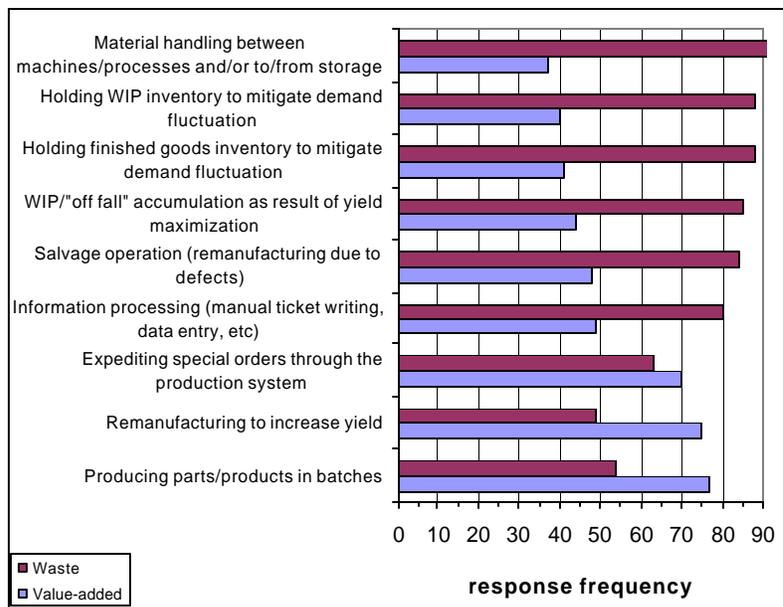


Figure 13: Perceptions of value-added vs. wasteful activities (frequencies)

In analyzing respondents’ perceptions of value-added versus waste in Figure 13, 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, while WIP accumulation as a result of maximizing yield is perceived as wasteful.

Conclusions

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 one to five weeks and the average respondent reported over 2000 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% 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 3) respondents noted several impediments to lean manufacturing in the rough mill; e.g., misaligned performance metrics and machinery constraints and 4) several of the fundamental building blocks of lean manufacturing; e.g., cellular manufacturing, total productive maintenance and kaizen events, are not frequently utilized in the rough mill.

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. Therefore, implementation could be constrained by a need for more in-depth training in lean concepts, tools and techniques. 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 versus 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 in feed and roughly 225 MBF of ripped-chopped parts at the rough mill out feed. This equates to roughly the output capacity of thirteen 50 MBF dry kilns, approximately six kiln charges in dried lumber and seven 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 x 8 hrs), an average production of 170 BF/LH can be assumed (30 MBF/176 LH). Dividing 75 MBF (33 percent 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 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 a 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 type 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.

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