# Plywood manufacturing and the pursuit of improvement: Does lean manufacturing fit in?

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WOOD 493

A Report Submitted in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Wood Products Processing

In

The Faculty of Forestry

April 23, 2012

## Executive Summary

Due to a personal interest in softwood plywood manufacturing and an appreciation of the general manufacturing trend towards continuous improvement, a discussion of the two topics together seemed natural. Among existing improvement philosophies, the concepts of lean manufacturing have received much attention and some secondary producers within the wood products industry have applied the concepts successfully. Primary producers, on the other hand, are often suspicious of the suitability of lean ideas to their industry. Therefore, the question of whether aspects of lean manufacturing can fit in with plywood manufacturing improvement strategies is an interesting one. To explore the concept, this paper provides some background on lean manufacturing and discusses the limitations of applying it to a primary wood products industry. In light of these limitations, some plywood manufacturers claim to have implemented certain lean techniques and a review of these accounts is given.

The lean concepts of focusing on value-creating activities and identifying manufacturing waste are then used to construct a value framework for the four main stages of plywood manufacture: the green end, the dryers, the layup and press, and the finishing end. Certain types of waste are then discussed at each stage and discussion from personal experience is given on either how plywood plants currently approach the identified waste or on how they could approach it, given the structure and confines of the industry. This exploration leads to the general conclusion that areas for improvement in plywood manufacturing can be recognized by searching for certain wastes defined by lean manufacturing. In this way, waste identification can answer the question of where improvement can be pursued. However, it is difficult for plywood operations to aspire to full leanness, and so the operations are typically bound to making improvements in the identified areas by focusing on cost savings or on other techniques that are not necessarily lean techniques.

**Key Words:** softwood plywood, plywood manufacturing, lean manufacturing, manufacturing improvement

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## Introduction

The motivation for writing this paper came after working in a softwood plywood plant. When discussing improvement strategies, the topic of lean manufacturing came up and most personnel were skeptical on whether the tools of lean manufacturing were truly applicable in a plywood setting. The discussion at the time was purely philosophical but it stoked a personal interest on the subject of how the lean paradigm related to the plywood business. Was it true that it did not relate to plywood manufacture at all? Or were there aspects that could be applied? It therefore seemed worthwhile to write a paper on the topic of plywood manufacturing and improvement and whether lean thinking could be part of the improvement package.

Definitely improvement is a hot topic in manufacturing settings and lean manufacturing in particular is well known as an improvement technique thanks to its relative success in the automotive industry. Compared to the automotive and other industries, the wood products industry has been slower to experiment with and adopt modern improvement approaches. Nevertheless, sectors of the wood products industry have received attention in the last ten to 20 years as the industry becomes more competitive. In particular, many North American secondary wood products manufacturers found they could not compete with low cost international competition; as a result, these companies altered their manufacturing processes out of necessity, with many companies implementing lean techniques. It is less clear, however, how improvement techniques such as lean can be applied to primary wood producers such as plywood manufacturers.

Undoubtedly there is no lack of need for improvement in the softwood plywood industry. The industry is maturing, as noted by the fact that the number of softwood plywood mills in North America has almost decreased by half from 1995 to 2012, with capacity decreasing from 23.4 billion square feet on a three-eighths basis to about 13.0 billion (Fuller, 2011). In the wood paneling industry in general, Moldvay (2011) anticipated a trend towards increasing competition and plywood will definitely continue to face stiff competition from oriented strand board (OSB) in many structural applications. Any improvements in plywood manufacturing are helpful in face of such issues.

This paper tackles the topic of improvement and the applicability of lean principles in the softwood plywood industry by first giving a background on the structure of the industry. Next, a background overview of manufacturing improvement philosophies is given, with an emphasis on the tools of lean manufacturing. The ensuing section notes some of the difficulties in applying lean principles to the primary wood products industry. Despite these difficulties, some softwood plywood producers claim to have had moderate success with lean techniques and a review of the few documented cases is given. Finally, the lean concepts of focusing on value-creating activities and identifying manufacturing waste are then used to construct a value framework for the four main stages of plywood manufacture: the green end, the dryers, the layup and press, and the finishing end. Areas of improvement as identified by the framework are discussed and the extent to which improvements can be pursued is mentioned. In conclusion, the paper finds that waste identification as a lean technique can find areas for improvement in plywood manufacturing, but often the improvements cannot be made to full lean standards. Instead, improvements are made by focusing more on cost-savings than on full lean aspiration.

## Background

### *Structure of softwood plywood manufacturing industry*

The industry of interest in this paper is the North American softwood veneer and plywood manufacturing industry. This industry has North American Industry Classification System (NAICS) code 321212. From now on in this paper, any reference to plywood is a reference to softwood plywood unless noted. Softwood plywood is separate from the hardwood veneer and plywood manufacturing industry (NAICS code 321211) in both a product and manufacturing sense. From a product sense, hardwood plywood is typically sold for use in value-added applications such as furniture and cabinets. Although some softwood plywood is also sold for a variety of value-added applications, the majority of it is produced as a commodity product for use in construction. Typical construction applications include roof sheathing, wall sheathing, and floor underlayment.

From a manufacturing perspective, hardwood plywood often involves separate entities for veneer production and for panel production. The veneer producing entity slices veneer from hardwood trees and sells the veneer to the panel producer, who laminates the veneer onto a core material. This core material may often be softwood plywood. In softwood plywood manufacturing, the veneer producing and panel producing functions are usually performed by the same company and often on the same site. Veneer for softwood plywood is rotary peeled and clipped into veneer sheets; three or more sheets are then glued together into an entire panel, with the faces of the panel having the same grain orientation and the core layers having grain orientations alternating at 90 degrees.

As of 2012, there were 61 softwood plywood mills in North America with a combined capacity of just over 13 billion square feet on a three-eighths basis (Fuller, 2011). A typical softwood plywood mill sells the majority of its products to construction wholesalers or distributors, with any value-added products potentially travelling through more specialized channels. For supply of logs, many companies are vertically integrated and so operate their own woodlands division. A representative schematic of a softwood plywood manufacturing operation is shown in Figure 1 on page 5.

From the demand side in Figure 1, a wholesaler or other customer orders products from a sales office based on the range of products that a mill produces. The sales office communicates the upcoming month's orders (usually by making them available electronically) to production control at the mill. Based on the orders, production control establishes an approximate schedule for each week outlining the products to be processed at each manufacturing stage. Supervisors are responsible for implementing the schedule on the plant floor but may make changes to it each day as necessary. The question of how they fill each order relates to the supply side.

From the supply side, logs arrive from woodlands at the green end. Production control at the mill is usually aware of what types of logs will be arriving based on forecasts from woodlands. However, a large log inventory is maintained so production control is not necessarily relying on daily log shipments. Logs from the inventory that will satisfy upcoming orders are processed through the green end and the output (green veneer) is pushed on to the veneer dryers. The dried veneer is then pushed on to the layup line, where panels are laid up and pressed. Pressed panels are pushed to the finishing end. Along the way, any material that cannot be pushed immediately to the next stage (for example, it is a grade that is not needed to fill upcoming orders) is stored in work-in-progress inventory. After the finishing end, all finished panels are staged in finished inventory. Those panels that satisfy upcoming orders are shipped out relatively quickly (within a few days), while any extra panels made along the way will be stored for future shipments. In a very basic way, this flow illustrates the approximate structure of the softwood plywood manufacturing industry. The next section provides background on lean manufacturing and manufacturing improvement techniques in general.

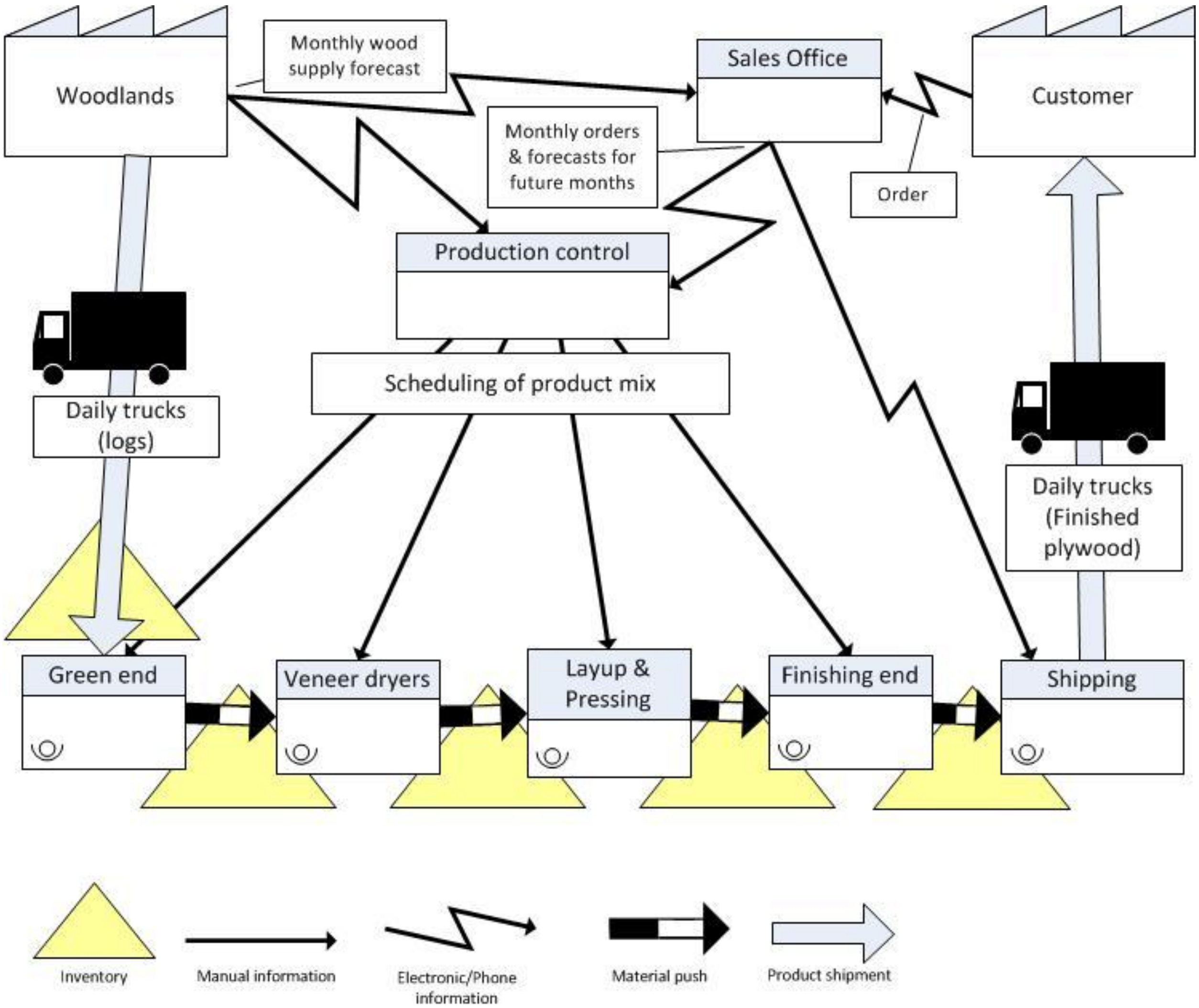


Figure 1 Representative material and information flow in the softwood plywood manufacturing process

### *Lean manufacturing and manufacturing improvement techniques*

Many manufacturing improvement techniques have been proposed. Each technique focuses on its own area of improvement, with the prevailing goal to somehow reduce costs or otherwise make a company more profitable. Often, the corresponding cost savings relate to manufacturing aspects, such as reduced labour requirements or reduced downtime. Total productive maintenance (TPM) strategies, for example, seek to prevent the unexpected failure of equipment and machinery. However, broadly speaking, cost savings can also be achieved in areas such as quality and customer satisfaction.

For example, Six Sigma strategies focus on defects, with the goal of achieving only 3.4 defective products per million. Lower defect rates do save money on certain manufacturing aspects, such as material costs and rework time, but they also affect customer satisfaction. Fewer defective parts mean fewer disappointed customers. In general, it costs companies less to satisfy and keep customers than it does to continuously find new customers.

Lean manufacturing approaches the issue of cost savings in a very all-encompassing way. The principles and tools that are a part of lean thinking aim to eliminate unnecessary waste. Here, waste is considered anything in physical production that does not add value for the final customer. Rooney and Rooney (2005, p. 42) listed eight wastes that lean manufacturing tries to avoid as:

1. Unnecessary transport of materials.
2. Inventories more than the absolute minimum.
3. Unnecessary movement by employees during the course of their work.
4. Waiting for the next process, worker, material, or equipment.
5. Over-processing of parts due to poor tool and product design.
6. Overproduction ahead of demand.
7. Production of defective parts.
8. Not fully utilizing employees’ brainpower, skills, experience, and talents.

The first seven wastes are the most well-known and are the ones originally listed by Taiichi Ohno of Toyota; the eighth waste is one of many wastes that have been suggested as later additions. For the wood products industry, Ray et al. (2006) suggested unnecessary energy consumption might also be considered a waste to avoid. The first seven wastes are often referred to by the acronym TIM WOOD (standing for unnecessary Transport, Inventory, Motion, Waiting, Over-processing, Overproduction, and Defects). Although originally developed for physical production, the objective of eliminating unnecessary TIM WOOD is not limited to such settings. Lean thinking, in fact, can be used successfully in office functions and service industries such as healthcare (Lean Enterprise Institute, 2012).

While identifying the wastes listed above, consideration must be given to three categories of activities. As explained by Reeb and Leavengood (2010, p.4), these categories are: "steps that create value, . . . steps that create no value but are necessary because of the current state of the system, . . . and steps that create no value and can be immediately eliminated." Often these categories are considered during the creation of a value stream map. A value stream map shows both material and information flow between activities in a work setting and it typically highlights measures such as lead times, processing times, and machine uptimes. A value stream map of the current work setting highlights areas for improvement. Those non-value-creating steps that can be immediately eliminated are done away with and subsequent efforts focus on minimizing as much as possible the non-value-creating but necessary steps. The end goal is to change the system so that only value-creating steps remain. To aspire to that goal, companies move through a five-phase lean approach, as listed in the lean glossary by Rooney and Rooney (2005, p. 42). The approach involves decreasing initial waste as much as possible, moving to a continuous one-piece flow system, synchronizing operations with customer requirements, creating a pull system of demand, and then leveling production in line with the pull.

Authors such as Testa (2003) have noted that the broad nature of lean concepts makes them ideal for initiating improvement programs. Other techniques, such as Six Sigma and TPM, can be used later on to fine-tune processes. However, to be truly successful in implementing lean manufacturing, the principles of lean manufacturing must be followed (Lihra, 2004). In their study of secondary wood products manufacturers, Pirraglia, Saloni, and Van Dyk. (2009) found that many companies were definitely trying to improve, but were not necessarily implementing lean manufacturing. Instead, they were pursuing simple cost savings. A critical point can be interpreted from this observation: manufacturing improvement techniques aim to reduce costs or increase profit, but they each have a certain framework and it is possible to chase cost savings without utilizing the framework of a particular technique.

## Limitations of lean principles in the primary wood products industry

Now that the concepts of lean manufacturing have been reviewed, the next step is to discuss their limitations in the primary wood products industry. Oddly enough, this discussion will start with some points on the application of lean thinking within the secondary wood products industry.

Secondary wood products manufacturers have had some success in implementing lean concepts. Mainly they have used the concepts to move away from batch production and reorganize their plants into self-contained manufacturing cells in which work piece flow is more continuous. After introducing lean programs, companies such as Woodland Furniture and Merrilat Industries Door and Panel have even won the Shingo Prize for operational excellence (The Shingo Prize, 2011). In their survey of secondary wood products producers, Pirraglia et al. (2009) found that lean success stories within the industry were a strong motivator for more companies to jump on the lean bandwagon. At the same time, the authors found there is some disagreement over exactly how the lean model can fit the secondary wood industry. Of the companies surveyed, about 67.5% agreed that lean techniques can help the competitiveness of the industry, while 15% believed that lean techniques on their own were not sufficient to help the competitiveness of the industry.

The results of a similar survey for the primary wood products industry would likely reveal interesting results. Ray et al. (2006) developed their own "lean index" for measuring the leanness of a wood products company[1], and, based on this index, they actually found primary wood products operations to be "inherently leaner" than secondary ones. However, this result does not mean that primary producers can benefit and become even leaner and more competitive from the application of lean manufacturing techniques. Indeed, Ray et al. (2006, p. 240) also noted in their article that "it has been demonstrated that differential realization of benefits occurs when lean production techniques are implemented in (different) industries because every industry has its own economic situation and system of operations." So regardless of whether secondary wood product manufacturers are currently more or less lean than their primary

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[1] The authors considered variables such as productivity, energy consumption, and inventory size.

counterparts, it is possible that the lean paradigm simply suits their industry better and they have recognized the opportunity to use that model to improve.

One of the difficulties in applying lean concepts to the primary industry relates to the commodity nature of the products. Overall lean thinking does not always apply that well to commodity markets. For example, Lihra (2004) noted that fluctuating market demand makes the implementation of lean concepts very difficult. Unfortunately, primary producers such as plywood plants face fluctuating demand throughout the year. These market fluctuations can make it worthwhile to tolerate finished inventory at times of low demand and low price and only sell when the price rises again. Hence some extra storage capacity is required to support high inventories at certain times of the year and allow production to continue. This strategy does contradict the lean goal of avoiding overproduction ahead of demand in order to keep finished inventories low.

In addition to market fluctuations, plywood producers face fluctuations in raw material supply and grade yields. For example, the amount of Select grade face veneer that will be obtained from a supply of logs is only fully known once the logs are peeled. For this reason, it is again useful to have inventories (such as veneer inventories) above the absolute minimum in order to provide a buffer against low grade outturns. In addition, one-piece flow becomes almost impossible when peeling a variety of veneer grades from a log. Not all veneer grades will be needed right away for laying up panels and therefore some will have to be stored. Storage typically results in transport of the veneers to and from a designated area; plywood plants often have many forklifts to accomplish such transport. According to lean concepts, this constant transport of materials by forklift into and out of storage areas would be viewed as a non-value adding activity. However, the reality, as noted by Ray et al. (2006) is that it is not always practical or profitable to hold small inventories in wood products plants and primary producers are often not comfortable operating in a lean inventory mode.

Despite the obvious challenges in fitting the lean model to primary production, a few plywood producers claim to have successfully utilized concepts behind lean thinking. The next section discusses these cases.

## Review of softwood plywood companies claiming use of lean principles

A review of the literature on lean manufacturing use in softwood plywood plants returned few results. The notable cases are discussed here. First up is Hardel Mutual Plywood Corporation of Chehalis, Washington. As documented by Testa (2003), Hardel identified that the cleaning process for its veneer dryers needed to be improved. The whole cleaning process took ten hours and required that workers go to and from the maintenance shop in order to retrieve jet tubes for the dryers. Hardel recognized the wasted time and motion inherent in the process and eliminated the waste by planning for the jet tubes to be by the dryers when required. This planning cut half an hour from the cleaning time. Further organization reduced the cleaning time to only four hours.

Another plywood manufacturer recognized by Testa (2003) for improvement techniques was Swanson Group. Swanson was concerned about wasting valuable press time on products that did not have high profit margins for its mill. Consequently, the company used time and motion studies to determine the most profitable product mixes (and quantities) for its mill. Lean techniques such as the identification and elimination of unnecessary physical movement were also utilized. In this way, Swanson tried to minimize excessive production of products that were not suited to its mill and this was part of its larger competitive plan to become a lower-cost producer.

A third plywood manufacturer recognized for utilization of lean techniques for improvement is Roseburg Forest Products (RFP). Massey (2011) did not list specific details on lean implementation at RFP, but did mention that RFP focused on using kaizen events, a lean technique for achieving continuous improvement, to better utilize its existing technology. In particular, it realized productivity increases in its veneer dryers.

The three plants mentioned above are all softwood plywood plants. Although the manufacture of softwood plywood is the focus of this report, it is still of interest here to divert briefly and explore an example of how a hardwood plywood producer has implemented lean principles. As documented by the EPA (2011), Apollo Hardwoods utilized lean principles right from the time of its launch as a company. Mainly Apollo sought to avoid the purchase of high-production, capital-intensive machinery. Instead, it invested only in equipment needed for current demand and organized the equipment into the one-piece flow cells typical of lean manufacturing. The idea was that more work cells could easily be added if demand increased. The fact that Apollo was able to implement lean principles in this way is partly a reflection of differences in the scale of production sought by softwood and hardwood plywood producers.

Overall, the purpose of this section was to review how softwood plywood companies claim to have used lean principles. The previous section on the limitations of lean principles in the primary wood products industry highlighted difficulties associated with reducing inventories and achieving one-piece flow. Definitely none of the softwood plywood producers mentioned above claimed to have substantially reduced inventory or achieved one-piece flow. Rather, much of the focus was on improving productivity by reducing wasted time (whether at the press or the dryers). Any subsequent productivity increases or waste reductions achieved were the basis for claiming implementation of lean. Whether this represents a full commitment to lean principles is arguable, but it does suggest that the lean concepts of identifying areas of value and waste can be applied within a plywood setting. Using this idea, the next section proposes a value framework for the stages of plywood manufacture and then uses it to discuss areas for improvement.

## Applying a value framework to the manufacture of softwood plywood

In this section, the lean concepts of focusing on value-creating activities and identifying manufacturing waste are used to construct a value framework for the four main stages of plywood manufacture: the green end, the dryers, the layup and press, and the finishing end. The intent is to clarify where waste (as defined by lean manufacturing) can be identified in the manufacture of plywood and what steps (if any) can be taken to improve areas that do not necessarily add value for the end customer. Personal experience together with some referenced material is used to explore the issues of how improvement of the identified wastes in plywood manufacturing is currently pursued and the extent to which it can be pursued. This discussion of improvement is very general, as there are unique improvements possible for any individual mill that would require thorough study by plant personnel or by outside consultants.

To create the value framework, consideration is given to the three categories of activities used in lean thinking. As mentioned in the background section, Reeb and Leavengood (2010, p.4) described these categories as: "steps that create value, . . . steps that create no value but are necessary because of the current state of the system, . . . and steps that create no value and can be immediately eliminated." For the value framework adopted here, however, a slight adjustment will be made to the presentation of the three categories. The first category, value-creating steps, will be maintained. The second category, non-value-creating but necessary steps, will include items such as inventory that have already been described as limiting factors in the ability of plywood manufacturers to achieve full lean status. The third category, non-value-creating steps to immediately eliminate, will be modified to highlight areas of waste that have not already been mentioned and that plywood producers may want to eliminate, even if it is difficult to so. In this way, the third category will be renamed "non-value-creating steps as targets for elimination or significant reduction."

Table 1 through Table 4 in the following sections sort the major processing steps in each of the four plywood manufacturing stages according to the three categories of activities. Approximate times are given for each step. Discussion of wastes in the third category is often given priority, but discussion on reducing those wastes in the second category is also provided when of interest.

***Green end***

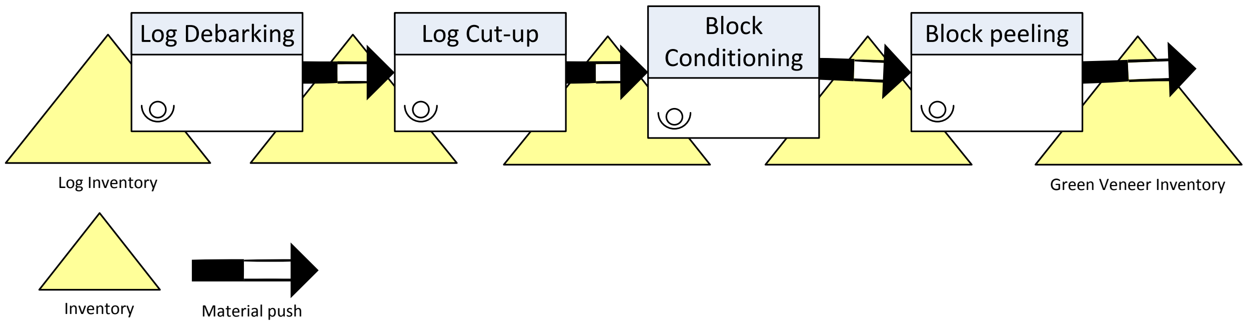


Figure 2 Outline of material flow for the green end

The green end includes log storage, log debarking, log cut-up (into blocks), block conditioning, and block peeling (Figure 2). The value-creating steps listed in Table 1 on page 17 include the time a log spends being debarked and cut into blocks, the time a block spends being conditioned, and the time a block spends being peeled into veneer and clipped to size. The non-value-creating steps that could be significantly reduced or eliminated are relatively minor. Among these steps, the first one involves debarked logs waiting for the cut-off saw; such logs typically travel onto a deck and must wait for a few minutes before being processed by the cut-off saw. Admittedly some waiting time here is necessary because the operator of the cut-off saw needs some time to visually inspect incoming logs. The other steps flagged as undesirable are the waiting of blocks for conditioning and the waiting of blocks for the lathe. The general extent of improvement is to keep the waiting times as low as possible since the green end on its own is meant to operate approximately as a continuous-flow line. There is no desire to keep work-in-progress inventory until the end of the line, when loads of green veneer are inventoried to satisfy the dryers.

Those waiting steps aside, an interesting and important feature of the green end that will influence improvement directives is the type of block conditioning utilized. Two common conditioning systems are drive-in steam chambers and hot water vats. The drive-in chambers involve a batch process in which a block loader[2] steadily moves cut blocks into a chamber until the chamber is full. The chamber door is then shut and the steaming process begins. Usually

[2] A four-wheeled piece of heavy equipment with front forks designed for picking up and carrying large loads.

several chambers are required so that some are being steamed, some are being loaded, and some are being unloaded. Unloaded blocks are taken by the block loader to a staging area to wait for the lathe.

From a lean perspective, there are several wastes that can be associated with drive-in chambers. In this case, the main problems occur with the block loader and the loading and unloading functions. Block loader operators cannot just drive into a chamber and quickly drop a load of blocks; instead, they have to carefully drop the load and fiddle with the existing pile to make the blocks stack nicely. If even one block comes astray, it may take the operator several minutes to reposition the block in the confines of the chamber. This effort in piling blocks is wasted motion by the loader and operator. In addition, transport time is wasted more on some blocks than on others. In this case, extra transport time is required when the block loader must travel right to the back of the chamber (either to place the first blocks into a chamber being loaded or to remove the last blocks from a chamber being unloaded). A final waste problem relates to the difficulty in fully utilizing the block loader. Throughout the day, the operator may have to wait for several minutes at a time if he or she is ahead of both the lathe and the cut-off saws (in such a case, the operator would have filled the staging area for the lathe with conditioned blocks and be waiting for cut blocks to load into a chamber). To eliminate wasteful waiting during the operation of a drive-in chamber, the speed of the cut-off saw line can be adjusted as best as possible, but ultimately the process nature of the drive-in chamber makes full lean application difficult.

If hot water vats are utilized for block conditioning, the problem of the block loader goes away. Hot water vats involve a continuous process in which blocks are dropped into hot water immediately after the cut-off saw. Chains or other conveying devices transport blocks from one end of the vat to the other, at which point the blocks are staged up for the lathe. From a lean perspective this system is less wasteful in terms of the loading and unloading functions. A dedicated operator is not even required for these functions. However, the hot water vat system is more capital-intensive than the drive-in chambers (Steinhagen, 2005, p. 51). Also, care must be taken with either conditioning system to get the right benefits.

As mentioned, Table 1 considers conditioning as value-added time. Definitely conditioning has several reported benefits for production, including increased volume recovery of veneer and reduced power requirements for peeling (Steinhagen, 2005, p. 50). However, it also helps increase the quality of recovered veneer by causing fewer splits and providing a smoother peel. This last reason is the main argument for including conditioning as value-added time. In this case, conditioning can be considered responsible for changing the blocks in such a way that the final product is more appealing to the end customer. As such, conditioning is perhaps the longest value-creating step in plywood production; it lasts several hours, although exact time requirements depend on a number of variables, including species, outside temperature, and log diameter.

Given the time and heat requirements involved in conditioning, mill managers must monitor energy use closely. Ray et al. (2006) noted the importance of reducing energy consumption in moving towards lean production in the wood products industry; unnecessary energy consumption is seen to be a waste just as much as the other TIM WOOD variables. In the case of conditioning, a balanced schedule must be pursued with respect to the amount of time blocks are conditioned. Steinhagen (2005, p. 49) noted that "underheating . . . blocks by a given amount of time appeared more costly than overheating them" because the benefits of conditioning were not fully realized. Therefore, the pursuit of improved scheduling for conditioning systems must balance energy use against the conditioning benefits realized. All in all, a big issue at the green end is conditioning and controlling the cost of conditioning, and the opportunity to become more lean (given existing technology) is limited to reducing a few waiting times.

Table 1 Value classification of manufacturing steps for the green end

| | Value classification of step | | | | | |
|---|---|---|---|---|---|---|
| **Step No.** | **Value-creating steps** | **Approx Time** | **Non-value-creating but necessary steps** | **Approx Time** | **Non-value-creating steps as targets for elimination or significant reduction** | **Approx Time** |
| 1 | | | Log sits in log yard | 1 week per log | | |
| 2 | | | Log loaded into debarker | 1 min per log | | |
| 3 | Log debarked | 10 s per log | | | | |
| 4 | | | | | Log waits for cut-off saw | 3 min per log |
| 5 | Log cut into blocks by cut-off saw | 10 s per log | | | | |
| 6 | | | | | Block waits for conditioning | 5 min per block |
| 7 | | | Block loaded into conditioning unit | 5 min per block | | |
| 8 | Block conditioned | 10 hr per block | | | | |
| 9 | | | Block unloaded from conditioning unit | 5 min per block | | |
| 10 | | | | | Block waits for lathe | 15 min per block |
| 11 | Block peeled and veneer clipped | 10 s per block | | | | |
| 12 | | | Veneer from blocks scanned and stacked into loads | 5 min per load | | |
| 13 | | | Load of veneer moved by forklift to green inventory | 2 min per load | | |
| 14 | | | Load of veneer waits for dryers in green inventory | 0.5 day per load | | |

***Dryers***

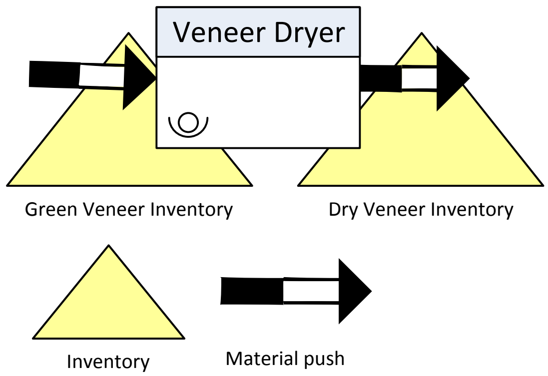


Figure 3 Outline of material flow for the dryers

Plywood plants may have several veneer drying lines. Each drying line (Figure 3) consists of an infeed, a continuous dryer, and an outfeed and stacker. The drying time itself is considered value-adding time in Table 2 on page 20 and so is the grading of dried veneer, as separation of grades is desired by the customer. Table 2 targets the step of having a worker attend to the dryer infeed as a non-value-creating step to eliminate. The dryer feeding step is listed in this way to draw attention to a characteristic limitation in the plywood manufacturing process that has not yet been discussed. In this case, although equipment and technology are good enough to do the bulk of the work, they cannot be trusted to respond appropriately to all situations. This uncertainty therefore requires workers to monitor the equipment. Under the lean framework, this setup could be classified under the eighth waste listed in the background section: not fully utilizing employees' brainpower, skills, experience, and talents. The dryer feeding situation is a perfect example of this waste.

At a typical dryer infeed, suction heads pick up individual veneer sheets and feed on them onto the dryer conveying rolls. The suction heads work autonomously as long as the green veneer is relatively flat and there is no debris (broken pieces of veneer) in the load. If there is a piece of debris or if a veneer sheet is folded over or askew, the suction heads may either fail to pick up the veneer sheet or they may pick it up and cause a plug up in the dryer. For this reason, a worker is required to watch the suction heads and to remove debris or veneer sheets that may cause problems. This arrangement creates a bit of an unusual situation in the plywood plant.

Obviously personnel in the plant want the green end to produce high quality veneer and to stack that veneer exceptionally well. However, as the quality of the veneer and the stacking gets better, the worker at the dryer infeed becomes more and more of a dead weight (when the veneer is running smoothly into the dryers, this worker literally stands there and watches the veneer go in). Even if the quality of veneer became superb, it would be extremely difficult to guarantee that the dryer infeed would not stall or plug up. Therefore, pending significant improvements in feeding technology, it is difficult to get rid of this worker or to increase his or her responsibilities (he or she must watch the infeed continuously to be effective). Ideally, managers would love to use the skills of workers in more meaningful ways, but for now this waste of underutilized talent is decidedly difficult to eliminate.

Another interesting area in drying to analyze from a waste perspective is energy use. The energy demands of dryers are great. Although somewhat dated, the FAO (1990, section 1.3.3) reported that veneer drying "accounts for some 70% of the thermal energy consumed in plywood production and approximately 60% of the mill's total energy requirement." The amount of energy consumed is typically affected by controlling operating parameters such as the temperature and humidity within the dryers. These operating parameters are modified throughout the day to achieve a target distribution of moisture content for veneer out of the dryer. The unavoidable tails of the moisture content distribution include some over-dry veneer and some under-dry veneer. From a waste perspective, plants do not want to put in too much energy and overcook too much veneer, as overcooked veneer does not glue well. In addition, they do not want to put in too little energy and undercook too much veneer, as undercooked veneer will have to be sent through the dryers again, effectively increasing energy costs (note that this can be thought of as over-processing from the TIM WOOD wastes). Most plants are highly aware of these issues and spend a great deal of time trying to achieve the most economical moisture content distributions out of the dryers.

In summary, the dryers include some labor positions that should be eliminated under a lean model, but are very difficult to eliminate in practice. In addition, the issues of over-dry and under-dry veneer are wastes and managers try to balance them from a cost perspective.

Table 2 Value classification of manufacturing steps for the dryers

| Step No. | Value-creating steps | Approx Time | Non-value-creating but necessary steps | Approx Time | Non-value-creating steps as targets for elimination or significant reduction | Approx Time |
|---|---|---|---|---|---|---|
| | **Value classification of step** | | | | | |
| 1 | | | Load of veneer moved by forklift to dryer infeed | 2 min per load | | |
| 2 | | | | | Load of veneer fed into dryer with worker attending | 6 min per load |
| 3 | Veneer dried and graded | 10 min per sheet | | | | |
| 4 | | | Veneer scanned and stacked into a new load | 10 min per load | | |
| 5 | | | Load of veneer moved by forklift to dry inventory | 2 min per load | | |
| 6 | | | Load of veneer waits for layup line in dry inventory | 2 days per load | | |

***Layup and press***

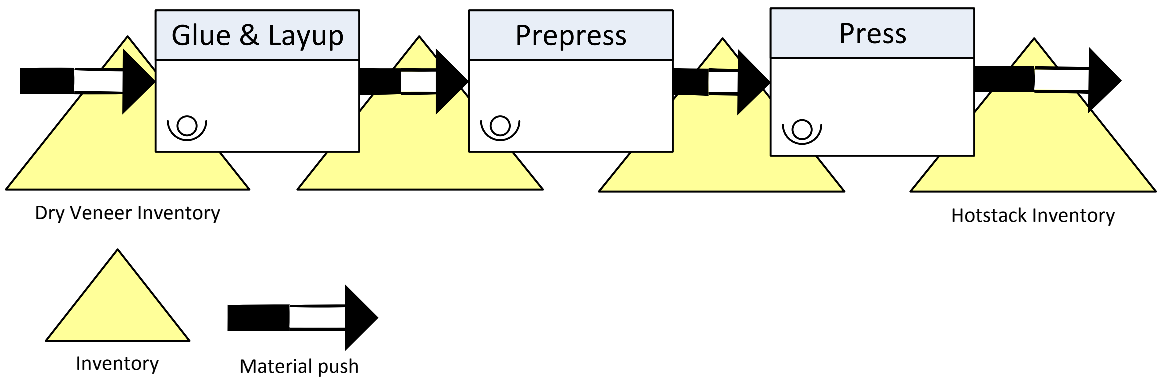


Figure 4 Outline of material flow for the layup and press

The layup line consists of devices that apply glue to veneer sheets and devices that accumulate glued sheets into a panel. The press line consists of a prepress and a main press (Figure 4 outlines entire layup and press line). The value-creating steps listed in Table 3 on page 23 include the time spent applying glue and arranging veneer sheets into a panel, and the time the laid up panel spends in the press. Any excessive waiting time before the prepress is listed as a non-value-creating step that should be targeted for elimination. Such waiting relates to one of the major challenges at this stage of plywood manufacture: balancing the pace at which panels are laid up against the pace of the press.

If panels are laid up faster than the press can process them there will be an excess of laid-up panels behind the prepress (assuming the prepress takes just one load of panels at a time and feeds immediately into the press). This situation is dangerous because glue will start to dry out and lose its tackiness if left out in the open for too long. If the glue does dry out, then portions of the panel will delaminate after pressing and the panels will be defective. This threat of defects is why Table 3 lists waiting time for the prepress as an activity to eliminate or reduce as much as possible. A major goal of the layup and press line then must be to keep the amount of time between glue application and press entry within certain limits in order to avoid producing unnecessary defects.

To achieve this goal, principles of lean manufacturing can actually be applied since much of lean manufacturing involves balancing the flow of products based on demand. In particular, the concept of takt time could be employed here. Under lean principles, takt time is the production time available per unit demanded by the customer. In this case, the customer can be considered the press. If the press demands 30 panels per 5 minutes production time, than the layup line should aim to lay up about one panel every 10 seconds (5 minutes divided by 30 panels). Of course, these times should have been accurately taken into account when the equipment lines were first installed in a plant. For example, conveying speeds may have been pre-set to achieve approximately one panel every 10 seconds. Nevertheless, different product mixes[3] may require slightly different takt times and this creates the need for a flexible work force that is able to adjust its output.

One way to introduce flexibility into the layup line is to put up monitors beside workstations that let each worker know whether they are ahead of or behind the press. Such monitors are an example of a visual control. Reeb and Leavengood (2010, p.5) described a visual control as something that displays the status of an activity "so every employee can see, make the appropriate conclusions, and, together with their team, take appropriate action." The appropriate action for workers on the layup line may be to wait if they start to get ahead of the press. Although unnecessary waiting is considered waste under lean principles, it can be argued that the waiting here is not entirely waste. Instead, the waiting here can be deemed necessary as it helps avoid the more unfavorable waste of producing defective panels.

In summary, the application of lean thinking to the layup line has potential as there is a desire to synchronize activities here carefully based on the demand of the press.

[3] Here, a product mix may refer to products of different thicknesses and/or different number of plies.

Table 3 Value classification of manufacturing steps for the layup and press

| | Value classification of step | | | | | |
|---|---|---|---|---|---|---|
| **Step No.** | **Value-creating steps** | **Approx Time** | **Non-value-creating but necessary steps** | **Approx Time** | **Non-value-creating steps as targets for elimination or significant reduction** | **Approx Time** |
| 1 | | | Load of veneer moved by forklift to layup line | 2 min per load | | |
| 2 | Sheets of veneer covered with glue and laid up into a panel | 1 min per panel | | | | |
| 3 | | | | | Load of laid up panels wait for prepress | <20min per load |
| 4 | | | Load of laid up panels wait for press in prepress | 5 min per load | | |
| 5 | Load of laid up panels pressed | 5 min per load | | | | |
| 6 | | | Load of pressed panels stacked into load of hotstack | 2 min per load | | |
| 7 | | | Load of pressed panels wait for gradeline in hotstack inventory | 0.5 day per load | | |

***Finishing end***

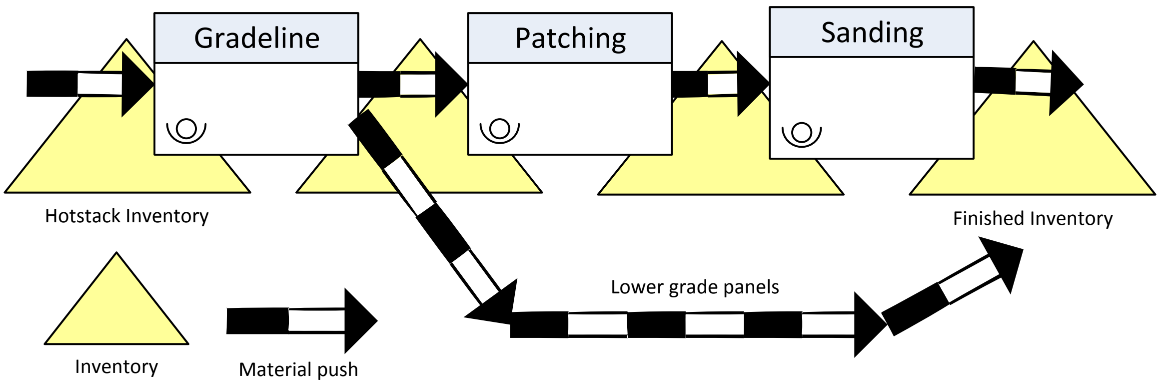


Figure 5 Outline of material flow for the finishing end

The finishing end (Figure 5) starts with a gradeline in which pressed panels are cut to size and graded. Lower grade panels are strapped up immediately for finished inventory, while higher grade panels are sent on to patching[4] and sanding operations before being strapped up themselves. The value-creating steps listed in Table 4 on page 27 include the cutting and grading time, the patching time, the sanding time, and the time spent strapping a load (with the view that the straps are part of the final product that customers are willing to pay for). Several non-value-creating but necessary steps are listed that relate to the movement of material between stations and the corresponding work-in-progress inventories. Although the table does not specifically highlight any non-value-creating steps to eliminate or severely reduce, there are some interesting sources of potential waste in the finishing end that can be discussed.

First of all, there is the issue of panels being sent to the patching and sanding operations and then being subsequently downgraded. Panels are sent to these operations from the gradeline if they are judged (by a human grader, scanning system, or combination of the two) to be of sufficiently high quality that, after patching and sanding, they will make a premium grade. Typically, a grader at the sander outfeed makes a final call on the grade of each panel; in this case, not all panels that go through patching and sanding make their intended premium grade. For example, if all the knot holes in a panel face were not patched by the patchers at the patching operation,

[4] At a patching operation, panels pass by on a conveyor belt as workers fill knot holes or other openings in the panel face with a type of putty or filler.

the sander grader will downgrade the associated panel. Another common reason for downgrade is excessive roughness (the panel did not sand down as well as expected).

It is obviously unwelcome if the panel gets downgraded to a less-than-premium grade. In hindsight such a panel should never have been patched or sanded; it should have just been sent to a less-than-premium grade immediately out of the gradeline. The panel is not defective (it can still be sold), but its manufacturing cost is high due to unnecessary transport by forklift, unnecessary motion and effort by patchers, and unnecessary processing by the sander. In addition, the panel took up space in work-in-progress inventory that could have been better utilized.

Due to the wide ranging reasons for downgrade, the approaches to minimize it are quite varied. For an issue such as unpatched knot holes, Kofoed (2012) noted the importance of balancing costs and revenue when sending panels to the patching operation. In this case, if the gradeline only sends those panels with very few holes to the patching operation, then grade outturns will be high as the patchers are able to patch all holes. However, there are only a limited number of panels with few holes, so revenues are lower because fewer premium panels are produced. As panels with more and more holes are sent to the patching operation, the potential for greater revenue due to the greater number of panels increases, but so does the potential for downgrading due to unpatched holes. The trick is to find the level of panels to send to the patching operation that maximizes profit by considering revenue, standard manufacturing cost, and downgrade cost.

In addition to the issue of downgrading, another worthwhile source of waste to consider in the finishing end involves the finished inventory. As mentioned already several times, plywood plants have reasons to keep larger inventories than classical lean thinking would allow. Problems do occur though if the finished inventory becomes so large that it becomes hard to keep track of. This scenario can cause a headache for the shipper if he or she has to constantly waste motion by counting and recounting inventory. An interesting solution is to implement a barcode system in which a barcode tag is affixed to all finished loads. The barcode is scanned when a load is placed in inventory and scanned again when the load is shipped. Such inventory tracking systems are common in other industries, but are not yet widespread in the plywood business.

In summary, there is a strong focus at the finishing end on controlling the costs of producing value-added panels and keeping track of finished panels.

Table 4 Value classification of manufacturing steps for the finishing end

| | Value classification of step | | | | | |
|---|---|---|---|---|---|---|
| **Step No.** | **Value-creating steps** | **Approx Time** | **Non-value-creating but necessary steps** | **Approx Time** | **Non-value-creating steps as targets for elimination or significant reduction** | **Approx Time** |
| 1 | | | Load of pressed panels moved by forklift to gradeline | 2 min per load | | |
| 2 | Pressed panels cut to size and graded | 10 s per panel | | | | |
| 3 | | | Graded panels stacked into a new load | 5 min per load | | |
| 4 | If no patching needed, load of graded panels strapped into load | 2 min per load | If patching needed, load of graded panels moved by forklift to patching inventory | 2 min per load | | |
| 5 | | | Load of graded panels wait for patching in patching inventory | 3 days per load | | |
| 6 | | | Load of graded panels moved by forklift to patching | 2 min per load | | |
| 7 | Graded panels patched | 15 s per panel | | | | |
| 8 | | | Patched panels stacked into a new load | 15 min per load | | |
| 9 | | | Load of patched panels moved by forklift to sander inventory | 2 min per load | | |
| 10 | | | Load of patched panels wait for sander in sander inventory | 3 days per load | | |
| 11 | | | Load of patched panels moved by forklift to sander | 2 min per load | | |
| 12 | Patched panels sanded and graded | 6 s per panel | | | | |
| 13 | | | Sanded panels stacked into a new load | 6 min per load | | |
| 14 | Load of sanded panels strapped in load | 2 min per load | | | | |
| 15 | | | All strapped loads wait to be shipped in finished inventory | 8 days per load | | |

***Discussion of the value framework***

In summary for this section, the four stages of plywood manufacture (green end, dryers, layup and press, and finishing end) were discussed in terms of the value-creating nature of their steps. The idea was to borrow the principle from lean manufacturing that only those steps that add value for the end customer should be maintained and other steps should be eliminated or minimized as much as possible. Clearly, it is impractical to maintain only the value-creating steps in plywood. In such an ideal case (created by looking at only the value-creating steps in Table 1 to Table 4), a log would be debarked, cut, conditioned, and peeled into veneer with no unnecessary transport or waiting in between. Individual sheets of green veneer would not be stacked into loads but would instead go directly into the dryers. Once dry, veneer would immediately be laid up into a panel and pressed. Pressed panels would move on through the gradeline, and, if needed, would move continuously through the patching and sanding operations. Only at the end of the process would stacking occur for the finished load.

Given the impracticality of achieving such a manufacturing line, this section provided some discussion on a proposed context of non-value-creating but necessary steps in plywood manufacture and non-value-creating steps to target for significant reduction or elimination. Admittedly, the line drawn here between necessary and eliminable steps was somewhat indistinct. Activities such as forklift transport, machine loading, and inventory accumulation were considered necessary because of the structure of the plywood industry. Other activities could also be considered necessary, but were flagged here as desirable targets for elimination or significant reduction in order to draw attention to the step. For example, having a worker watch over the dryer infeed could be considered necessary because of the state of technology in the plywood industry, but it was considered here as a desirable target for elimination for the sake of discussion. Ultimately, any non-value-creating step should be minimized as much as possible and the point of attempting to classify the value-creating nature of the steps was to provide an example of how waste identification can be applied to a plywood manufacturing setting.

Once a waste has been identified, reduction or elimination of the waste can be pursued. Here the steps and the way of thinking used to tackle the waste in a plywood setting can be unique and do not have to come from the lean manufacturing toolbox. In fact, more often than not, it may be impossible to achieve full lean status (due to current limitations) and therefore there is no temptation to use the lean paradigm (the exception may be the layup line, as the discussion of improving the balance of flow on the layup line does lend itself well to using lean terminology). Instead, a cost saving paradigm is often used. At the green end, the cost of conditioning must be balanced against the benefits realized. At the dryers, the cost of over-dry wood and the cost of under-dry wood must be balanced. At the finishing end, the cost of sending too few panels to the patching operation must be balanced against the cost of sending too many. A major conclusion of this paper then is that the general idea of looking for waste can easily be applied within a plywood setting, but not all wastes can be removed to lean standards and often the best (and probably easiest) way to remedy the waste is through a cost paradigm.

**Conclusion**

This paper was motivated by a personal interest on the degree to which lean manufacturing tools could be applied to the softwood plywood manufacturing process. Definitely the principles of lean have been touted in the automotive industry for many years and some recent articles have tried to connect lean thinking to the wood products industry. In most cases, the secondary wood products industry has been targeted. From personal experience, it was believed that many people in the plywood industry (and in other primary wood products industries) did not view lean as an appropriate technique for their business. This belief inspired an interest on how improvement is pursued and on how it can be pursued in a plywood plant and whether the lean paradigm is compatible with the plywood setting.

The paper started with a brief background on the structure of the North American softwood plywood industry. Then the idea of manufacturing improvement was introduced and focus was given to lean manufacturing and some of the concepts behind this approach. Next the applicability of lean thinking to the primary wood products industry was discussed. Particular reference was made to characteristics of the primary industry that are not compatible with lean thinking. Notably, the need to hold both work-in-progress and finished inventories was discussed. Work-in-progress inventory is often held to hedge against uncertainty in future grade yields and finished inventories may be held to wait out poor market prices.

A literature review on the topic of plywood manufacturing and lean manufacturing returned limited information. Only a handful of plywood companies were found that claimed to have implemented lean techniques with some success, and the basis for the claims mostly related to improving productivity in certain areas with the end goal of becoming a lower cost producer. While it is arguable whether these rationales represent a full commitment to lean principles, the companies did seem motivated by the idea of identifying and trying to eliminate waste (as defined by lean manufacturing).

Given this interest in identifying waste, the idea of classifying activities in terms of whether they create value for the end customer was adopted and a value framework was applied to the four main stages of plywood manufacture: the green end, the dryers, the layup and press, and the finishing end. Each stage was individually explored and the value framework was used to identify where and how waste might be classified at individual steps within the stage. The exploration of each stage also included discussion from personal experience on either how plywood plants currently approach the identified waste or on how they could approach it. Typically, the approaches discussed did not directly involve lean techniques but were motivated instead from a general cost-saving or profit-maximizing mindset. Such cost-savings models are important in areas in plywood manufacture in which complete leanness is impossible. For example, an operation may never eliminate its finished inventory, but it will try to minimize the cost of maintaining it.

Overall, the general conclusion is that the concept of identifying waste can be applied in a plywood setting to get an idea of where improvement can be pursued. It seems that any problem in the manufacture of plywood can be framed from a waste perspective and it is therefore believed that the concept of waste identification has the potential to be applied in finer and finer detail to source more subtle areas for improvement. When it comes time to make the improvement, however, there is no reason to believe that the complete lean toolbox can be applied. The plywood industry looks at ways to reduce costs as much as possible without necessarily achieving full lean status.

**Reference List**

Food and Agriculture Organization (FAO) of the United Nations. (1990). *Energy conservation in the mechanical forest industries* (FAO Forestry Paper). Retrieved 2012 April 6 from http://www.fao.org/docrep/T0269E/t0269e03.htm#TopOfPage

Fuller, B. (2011). *RISI viewpoint: The shakeout in North American panel capacity continues: G-P, a case study*. Retrieved 2012 April 5 from http://www.woodbiomass.com/ woodbiomass/news/North-America/wood_products/RISI-VIEWPOINT-The-shakeout-in-North-American-panel-capacity-continues-G-P-a-case-study.html

Kofoed, M. (2012). *How reducing the allowable number of face openings in panels sent to Select would affect costs and profits relative to sending panels to Sheathing* (University of British Columbia Wood Products Processing Co-op Report).

Lean Enterprise Institute (LEI), Inc. (2012). (Homepage). Retrieved from www.lean.org

Lihra, T. (Ed.). (2004). *Lean manufacturing for the wood processing industry* (Technology Profile TP-04-04E). Retrieved 2012 March 25 from Solutions for Wood website: http://www.solutionsforwood.ca/industry_info/technology_profiles.html

Massey, R. (2011). Roseburg Forest Products' journey to success. *Wood Based Panels International, 31*(2), 46. Retrieved from http://www.wbpionline.com

Moldvay, C. (2011). *Wood paneling manufacturing in the US* (IBISWorld Industry Report 32121). Retrieved from http://clients.ibisworld.com

Pirraglia, A., Saloni, D., & Van Dyk, H. (2009). Status of lean manufacturing implementation on secondary wood industries including residential, cabinet, millwork, and panel markets. *BioResources, 4*(4), 1341-1358. Retrieved from http://www.ncsu.edu/bioresources/

Ray, C. D., Zuo, X., Michael, J. H., & Wiedenbeck, J. K. (2006). The Lean Index: Operational "lean" metrics for the wood products industry. *Wood and Fiber Science, 38*(2), 238-255. Retrieved from www.metapress.com

Reeb, J. E. & Leavengood, S. (2010). Introduction to lean manufacturing. Extension Service EC 1636, Oregon State University. Retrieved 2012 April 6 from http://extension.oregonstate.edu/lincoln/forestry/publications

Rooney, S. A. & Rooney, J. J. (2005). Lean glossary. *Quality Progress, 38*(6), 41-47. Retrieved from http://asq.org/qualityprogress/index.html

Shingo Prize, The. (2011). *The Shingo Prize for operational excellence*. Retrieved from www.shingoprize.org

Steinhagen, H. P. (2005). Veneer block conditioning manual for veneer and plywood production. *Maderas: Ciencia y tecnologia, 7*(1), 49-56. Retrieved 2012 April 6 from http://www.scielo.cl/scielo.php?pid=S0718-221X2005000100006&script=sci_arttext

Testa, B. M. (2003). *Lean manufacturing: Processing buzzword or operational lifesaver?* Retrieved 2012 March 25 from http://www.apawood.org/EWTA/TechForum/LEAN%20MANUFACTURING.pdf

United States Environmental Protection Agency (EPA). (2011). *Apollo Hardwoods Company* (Case study). Retrieved 2012 March 25 from http://www.epa.gov/lean/environment/studies/ apollo.htm

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EPA – See United States Environmental Protection Agency

FAO – See Food and Agriculture Organization