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Lumber Yields—Constraints and Opportunities

by GILBERT L. COMSTOCK

The wood products industry for many years had the luxury of having a low cost, seemingly endless supply of raw material. Because of this there was little incentive to make better use of the forest through higher yields or use of low grade logs. Emphasis was aimed at maximizing productivity and minimizing production costs without much regard to how well the raw material was utilized.

This luxury no longer exists. Within the last decade the cost of the raw material entering a sawmill or plywood plant has become the major part of the cost of the finished product. Raw material costs account for well over 50% of the cost of most wood products. This, coupled with an ever shrinking land area for timber production and the threat of a diminishing supply of raw material, is bringing about a new era in the forest products industries.

Maximizing profits is no longer synonymous with maximizing productivity and minimizing production costs. It is more nearly synonymous with maximizing yield or more particularly maximizing value recovery from the raw material.

At present lumber and plywood are the major structural products produced from wood and probably represent the highest and best current use of wood in large quantities. Uses are primarily in residential construction and secondarily in industrial construction and for other industrial uses. Lumber and plywood manufacturing consume the majority of the high value raw material contained in the merchantable bole of harvested timber. However, the conversion to finished product is not very efficient in either process. Some improvements have been made in processing to increase yields, but the improvements made to date are small compared to the potential gains.

As presently practiced, particleboard and the pulp chip market reap the benefits of inefficiencies in the manufacture of lumber and plywood. These inefficiencies result in large amounts of residue which end up as pulp chips or wood particles at a relatively low value.

Although the prices of most forest products fluctuate wildly with supply and demand shifts, a fairly typical price structure is about $100/bdt* for lumber and plywood, $25/bdt for pulp chips, and $10/bdt for other wood residuals. It's fairly obvious from this price structure that the driving economic incentive is to maximize the yield of the primary products. If yields could be significantly increased, the value recovered from our forest resource would be increased and the price of chips would be forced up by a reduction in the supply of chips as by products. This in turn would lead to greater use of all forest residuals and provide some of the economic impetus needed for complete tree utilization.

There are some real opportunities for increasing lumber yields, but there are also some constraints that limit the yields attainable with existing lumber manufacturing technology. Understanding the opportunities and constraints is important to anyone involved either in the growing or processing of timber, since there are opportunities in both ends to make significant gains in the yields of valuable forest products.

Limitations to lumber yields from our forests fall into two broad categories, raw material charac-

* bdt—1 dry ton
teristics and lumber processing capabilities. These will be discussed in turn.

**RAW MATERIAL CHARACTERISTICS**

Lumber manufacturing has some inherent inefficiencies because we are producing rectangular shapes directly from more or less cylindrical segments. In short, we are trying to fit the square peg in a round hole. Add to this the constraints on sizes produced and the variable shape of logs, and you have some severe limitations to lumber yields.

The predominant raw material characteristics which influence lumber yields are log diameter, taper, and sweep. Eccentricity can also be a factor, but it is less important.

**Log Diameter**

Diameter influences both the yield of lumber products attainable from our forest resource and the flexibility in product sizes which can be produced. Diameter is particularly important in small logs which are a predominant raw material now in the south and are becoming a major factor in the west as the last commercial old-growth forests are harvested.

In general, the smaller the diameter of log processed, the lower the potential yield because the opportunities for fitting the desired rectangular shapes to the log are more limited. Figure 1 as an example shows how the theoretical yield of lumber varies with log diameter. The calculated theoretical yields can shift up or down if different assumptions are made on how to cut the logs, but the influence of diameter will always be similar. Potential yield will invariably be less out of small diameter logs.

This has broad implications in forestry practice and should become a part of forestry planning and decision making on what the optimum size and age are for timber harvest. I have some personal concerns that forest management and manufacturing people don’t communicate on this subject to the extent they should to extract maximum value from our forest lands.

**Taper**

Although we all recognize that taper is an inevitable characteristic of trees, there is little recognition of the impact that taper has on limiting the attainable yield of lumber from logs, particularly from small logs.

Assuming a fairly standard taper factor of 1” diameter per 8’ and assuming 8’ long logs, which are about the shortest logs processed, the volume of wood contained in the tapered portion (i.e., the wood out-
side the cylinder projected by the small end diameter) represents 26% of the log volume in a 4" diameter log and 10% in a 10" diameter log. Figure 2 shows how the percentage of volume in the tapered portion of an 8' long log varies with small end diameter. Clearly in small logs taper is an important factor limiting lumber yield, since virtually all the taper in an 8' log will end up as chips or residual.

Sweep (crook)

A third characteristic which is extremely important in limiting lumber yields is the amount of sweep or crook in the logs. The amount of sweep depends on the species and probably several other factors. Casual observation on my part indicates this is probably a much more important factor in the southern pines than in most other softwood species.

The lack of straightness in logs is far more important in limiting lumber yields than is generally recognized. Like taper, the impact of sweep on yield is more pronounced on small logs. On a fairly typical 8-10" log, 1 inch of sweep will result in a reduction in yield of about 15% compared to a straight log of that size. The reduction in yield increases in direct proportion to the amount of sweep, i.e., with 2" of sweep the yield reduction would be 30% etc. A typical graph of the effect of sweep on yield is shown in Figure 3.

In summary the important raw material characteristics influencing lumber yields, particularly as we look to the forest of the future, are log diameter, taper and straightness of the logs. The larger, straighter and more cylindrical the logs, the higher the potential yields will be and the more valuable the forest will be.

LUMBER PROCESSING

From the previous discussion, it's clear that a number of raw material characteristics influence the potential yield of lumber from logs. The manufacturing process can also have a great influence on the actual yields attained. Because of the broad range of raw materials, processing equipment, and products, it's impossible to generalize on where we stand now compared to the theoretical maximum yields. Figure 4 shows a fiber balance with a fairly typical range of values for a softwood small log mill producing dry-surfaced dimension lumber. Of the actual cubic volume of logs entering a sawmill, 45-55% will end up as rough green lumber, 35-40% as chips and 5-15% of other residuals, mostly sawdust. Through drying and surfacing, another 10-15% of the original volume is lost to shrinkage, planer shavings and trim leaving roughly 30-45% of the initial log volume as finished dry product. Individual mills can be cited that fall outside that range, but most will be within it.

The lumber manufacturing process involves a series of sawing machine centers. Although the flow varies from mill to mill, a typical sequence is bucking, primary breakdown, edging, resawing and trimming. The processing step at each machine center involves making a decision about what to do with the raw material being processed through it followed by the actual sawing or execution of the decision. Losses from potential yield occur as a result of incorrect decisions as well as inability to accurately execute the decisions. There are lumber yield improvement opportunities through better decision making and better sawing.

Decision Making

Most sawmills rely on machine operators to make the decisions about how to process each piece of raw material. Since the product of a machine in the front of the sawmill becomes raw material for a downstream machine and several machine centers are typically involved in the sequence of producing lumber, it is apparent that a number of operators are involved in making decisions that influence the yield and quality of product produced. The machine center operators in a sawmill therefore can have a tremendous impact on the performance of that mill.

One way of minimizing the number of mistakes is to have well trained, highly motivated operators who understand the market requirements and capabilities of their machine center. However, even a well trained, highly motivated operator is not capable of always making the correct decisions. Obtaining

Figure 3: Typical data showing the influence of the amount of sweep on lumber yield for 6" and 10" logs 8' and 16' long.
maximum yield from small logs requires the ability
to measure diameter to within 0.1 inch and adjust the
cutting pattern accordingly. Clearly, no one can
consistently judge log diameters that accurately.

This brings me to a key point. Correct decision
making in a sawmill requires the ability to accurately
measure the size and shape of the raw material being
processed. This includes logs, cants, slabs, and
boards. The capability to measure those pieces ac-
curately will make it possible to fully automate most
processing steps by applying minicomputers to
analyze the data and make the best decisions. Some
very significant strides have been made in the last
few years in scanning logs for diameter and shape
and in the application of minicomputers for process
control on small log headrigs. Yield improvements of
10% compared to manual control are not uncommon
for this one step in automation. Relatively little has
been done downstream of the headrig to replace the
man in the decision making process, primarily
because the scanning involves different requirements
and the measuring systems are not yet fully
developed. Although the gains may not be quite as
spectacular as that obtained by headrig control,
significant contributions to improved lumber yields
should be possible. Major advance in process control
at edgers and trimmers should occur within the next 2
or 3 years.

Figure 4: Typical fiber balance for a softwood small log
sawmill.

Sawing

The best possible decisions are not worth a whole
lot if the machines in the mill don't have the
capability to accurately execute the decision. The
ultimate goal is to cut the wood precisely in the right
place with a high degree of accuracy and a minimum
amount of sawdust or other residual. Most existing
sawmill machinery leaves something to be desired in
one or several aspects related to carrying out the
optimum decisions.

The essential elements of each sawmill machine
center are positioning the raw material onto the
transport, setting the saws accurately relative to the
raw material, transporting the raw material ac-
curately past the saw(s) in a stright line, and sawing
with a minimum kerf and maximum accuracy. To
achieve maximum benefits of improved decision
making requires the ability to perform each of these
four elements. Of course, some significant gains can
be made independent of the decision making aspect
by more accurate sawing with less wood waste.

Major advances have been made in some areas in
recent years. For example, the precision ball screw
networks has improved precision to within a few
thousands of an inch and the high strain bandmill has
resulted in markedly better sawing accuracy and
reduced kerf as has the use of thin kerf carbide tipped
round saws in many areas.

Kerfs of 1/8 inch are not uncommon for 6” and 8”
deep cuts. However, some major room for im-
provement still exists in improving sawing accuracy.

Saw preparation is an area that has benefited
relatively little by the application of science and
engineering to the lumber business. Saw filers are
using procedures that haven’t changed much for
many years, and the success of a lumber processing
operation is contingent on the skill of the saw filer.
With the tools available to them, saw filers do a
remarkable job of keeping the sawmills operating.
However, there are real opportunities to improve the
art of filing by the application of science and
engineering principles and the use of more accurate
measuring equipment to help the filer do his job even
better. This will require a concentrated effort on the
part of technical people working in cooperation with
the filers to push back the frontiers of knowledge and
bring saw preparation more into the realm of a
quantitative science.

Figure 5 shows roughly the amount of waste
typical of most current softwood sawmills and the
opportunity for improvement. To produce a finished
dry thickness of 1.500 inches requires about 1.875
inches thick of raw material including allowance for
kerf, sawing variation, roughness, planing, and
shrinkage. This represents about 25% waste. With the
development and application of new technology to the
sawing of wood, it should be possible to reduce this
waste factor to only 15% and produce a corresponding
10% increase in lumber yields.

AMES FORESTER
Drying and Surfacing

Although the direct impact on yield is less than in the sawmill itself, drying and surfacing can be very significant factors in overall yield and grade recovery. We are just getting into the plantation grown trees in this country, but there is some evidence from here and abroad that this type of timber gives much greater problems in drying, largely due to greater tendency to warp. Although this can be controlled to some extent, there appears to be significant opportunity for further improvement. These improvements could come either through research and development of improved drying techniques or research on forest quality aimed at producing trees with little or no reaction wood and a minimum of juvenile wood and spiral grain.

Moisture content is also a significant factor in drying. The end use normally requires a certain maximum moisture content, for example, 19% for dry dimension lumber. To meet this requirement there is a tendency to over-dry much of the lumber, which causes excessive shrinkage and warp and loss in both grade and yield. This can be controlled to a considerable extent by better kiln design, moisture content measuring instruments for in-kiln measurement and recycling of wets through the kiln.

Surfacing is probably more a factor in grade than in yield, but it can affect yield. As technology develops for precise size control in the sawmills, surfacing will become more a matter of touching up the lumber to achieve the final size.

At present, surfacing in part involves hogging off excessive quantities of wood from thick pieces to achieve the final size. Likewise drying suffers from thick and thin pieces which cause drying problems and contribute to moisture content variations in the final product. Better size control in the sawmill will definitely have a positive impact on both drying and surfacing.

Glued Products

From the foregoing discussion, it should be clear that there are significant opportunities to increase lumber yields well beyond where we are now, but it is also clear that there are some yield limitations and in particular, there will be product size limitations from small logs without the use of some gluing processes. Yields of prime sizes can be increased markedly by the use of gluing technology already developed or now emerging. Development of process control for gluing and proof testing technology should result in much broader use of gluing on structural lumber products.

SUMMARY

The economic incentive is very great for better use of our forest resources through improvements in yield. In lumber manufacturing there are some limitations to yield resulting from raw material characteristics and processing capabilities. Yields decrease with decreasing log diameter and with increasing amounts of sweep and taper. Major improvements in yield can be made through better decision making in the sawmill and better sawing technology. Improvements can also be made in both yield and grade through better drying and surfacing.

![Figure 5: Waste generated due to sawing wood today and where we might be with improvements in technology of sawing.](image-url)