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Economic Feasibility of Products From Inland West Small-Diameter Timber

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Abstract

A large part of the forests located in the Rocky Mountain region of the U.S. West (inland West) is characterized by densely packed, small-diameter stands. The purpose of this study was to examine the economic feasibility of using small-diameter material from this resource to manufacture various wood products: oriented strandboard (OSB), stud lumber, random-length dimension lumber, machine-stress-rated random-length lumber, laminated veneer lumber (LVL), and market pulp. The analysis indicated that LVL promises the best ratio of revenue to wood input, followed by market pulp and OSB. Among the lumber alternatives, machine-stress-rated lumber yields the greatest return. In terms of investment risk, the lower-cost lumber alternatives are favored over the capital-intensive OSB, market pulp, and LVL options. The manufacture of OSB would require the most fiber, almost four times the amount required for market pulp.

Keywords: Oriented strandboard, particleboard, medium density fiberboard, LVL

Contents

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Economic Feasibility of Products From Inland West Small-Diameter Timber

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Introduction

The inland West has considerable stands of forests that consist of densely packed, predominantly small-diameter trees. These even-aged stands have resulted from fires, which at one time raged over and cleared large areas. Although some of the resurgent stands have evolved into a varied, multi-storied mix of emergent and successor plants, other stands, particularly those dominated by lodgepole pine, have not differentiated well. One goal of ecosystem management is to create a more varied character in those areas by removing some of the small, suppressed stems to create openings for other plants, improve habitat for animal life, and reduce the fuel loading for potential catastrophic fires.

A problem from thinning such stands is what to do with the mostly small-diameter (4- to 8-in.) stems that would be harvested. (See Table 1 for SI conversion factors.) Generally, material of this size does not have high economic value and consequently was not harvested in the past. However, as the size of logs being processed for products has declined, technology has been developed to process small-diameter logs more economically. The purpose of this study was to examine how much value could be imputed to this small-diameter thinning material if it were converted to products utilizing various processing alternatives.

Table 1—SI conversion factors

English unit	Conversion factor	SI unit
acre	4.046×10^3	square meter (m^2)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
cubic foot (ft^3)	2.831×10^{-2}	cubic meter (m^3)
square foot (ft^2)	9.29×10^{-2}	square meter (m^2)
board foot	2.359×10^{-3}	cubic meter (m^3)
degree Fahrenheit (°F)	$(t_F - 32)/1.8$	degree Celsius (°C)
gallon (gal)	3.785×10^{-3}	cubic meter (m^3)
pound (lb)	0.454	kilogram (kg)
ton (short)	9.071×10^2	kilogram (kg)

Oriented Strandboard

Background

One of the most successful technologies developed for small-diameter timber utilization in the past two decades has been that of making structural panels from strands or flakes. Oriented strandboard (OSB) is an engineered, wood-based panel that is used primarily in structural applications where plywood has historically been used. The term “engineered” refers to the fact that the mechanical properties of the product can be controlled by manufacturing process parameters, such as glue content, panel density, and press residence time, and are not wholly dependent on the natural properties of the material.

Oriented strandboard products are made exclusively from roundwood because of the need to control particle size and thickness. Log diameters as small as 4 in. can be utilized. The OSB particles are typically long, slender strands that are at least twice as long as they are wide. The slenderness promotes particle alignment, which increases panel strength in the direction of orientation.

Process

A key variable affecting the market feasibility of OSB is the density of the wood. To bond successfully, strong interparticle contact is necessary during curing of the resin. This is achieved by compressing panels to densities greater than the initial density of the wood. If the density of the species is high, then the panel is proportionately heavier. This is not advantageous, because the market requires boards in the medium density range so that the product can be easily moved by one person. As a result, lower density species have been preferred. The necessary pressure required to achieve good board properties is related to the ratio of board specific gravity (SG) to wood SG. A ratio of 1.3:1.0 provides a rough guide to determine if a species is suitable.

Commodity-grade OSB panels are made in a SG range of 0.61 to 0.64, thus requiring a wood SG not much greater than 0.48. Among the inland species, lodgepole pine (SG 0.41), ponderosa pine (SG 0.40), and white fir (SG 0.39) fall into the suitable range. Douglas-fir (SG 0.48) would be marginal.

The steps in the OSB manufacturing process are log processing; flaking; drying; screening; blending and forming; and pressing, panel sizing, and finishing.

Log Processing

Logs brought in by truck are weighed and unloaded in a storage area. In regions such as Montana, Idaho, and eastern Washington, logs often arrive frozen. Heating is necessary to aid debarking and reduce loss resulting from the generation of too many undersize particles during flaking. The logs are conditioned for 4 to 6 h in hot water vats.

Flaking

Logs are reduced to flakes of required lengths and thicknesses. Most OSB plants use a disk-type flaker (vertical rotating disk into which bolts are pushed). Large-capacity mills have been installing ring-type flakers (circular row of knives that push into the stationary wood) capable of handling random-length bolts. Typical throughput rates range between 3.4 and 13.5 ton/h, depending on flaker model size and flake thickness.

Drying

The main types of dryers used in the manufacture of OSB are triple-pass and single-pass rotary dryers. Triple-pass rotary dryers are the most widespread, but this type of dryer places a limit on flake length because long flakes tend to plug the inside of the dryer. Long flakes improve board strength and where such flakes are needed, single-pass rotary dryers are used. The dwell time is approximately 10 min. Wood-fired burners supply much of the necessary heat; bark, dried reject particles (fines), and pulverized panel trim are used for fuel. Although both triple-pass and single-pass dryers are effective, they generate many volatile organic compounds (VOCs) because of the high temperatures required, which create an environmental risk, pose a fire hazard, and degrade particles as a result of breakage. A new type of dryer, called a conveyor dryer, has been developed and installed in at least one facility. The drying temperatures are lower, resulting in higher quality flakes with reduced VOC emissions and wood loss.

Screening

The dried flakes are transported by a conveyer belt to a multi-deck screening system, where particles are separated according to size. Oversize material, removed from the top deck, is usually reprocessed. Large flakes are used for the face layers and coarse flakes for the core. Small, fine particles are burned for fuel.

Blending and Forming

Binders used in the North American OSB industry include powdered and liquid phenolics and diphenyl methane di-isocyanates. Resin and wax are sprayed onto rotating flakes inside a rotary blender. Typical resin dosage for powdered phenolics is 2 percent, for liquid phenolics 3.2 percent, and for diphenyl methane di-isocyanates about 2.5 percent. The resin-treated flakes are fed through a series of rotating disks that align and deposit them on a conveyor in layers, forming a mat. The mat is segmented by a cutoff saw and transported onto loading trays for conveyance into a multi-opening batch press.

Pressing, Sizing, and Finishing

After the mats are loaded, the press is closed until the target panel thickness is reached. The dwell time for standard 7/16-in.-thick panels is normally less than 4 min, including loading and unloading time. An unloading elevator discharges the panels individually onto a belt conveyor that directs them first through edge-trim saws and then secondary trim and cross-cut saws, which reduce the pressed panels to the finished size, usually 4 by 8 ft. Panels are then sent through a detector to identify below-grade boards. Additionally, flooring-grade panels are sanded.

Plant Size and Fiber Requirements

The first OSB plants ranged from about 100 to 160 $\times 10^6$ ft^2/year (3/8 in. basis). The size of current economical mills has increased, ranging from 300×10^6 ft^2 to more than 400×10^6 ft^2. For a mill in the inland region, a size at the lower end of the range is assumed.

With a normal mix of log sizes, averaging 7 in. in diameter, such a plant would require about 16.8×10^3 ft^2 of fiber. However, the amount of fiber is influenced by the amount of undersized particles (fines) generated in the process. The amount of fines should be as low as possible to minimize resin consumption. The economy of the process is such that it is better to screen out fines and burn them for heat rather than use them in the board. This translates to varying wood requirements because fines generation varies according to such factors as knife speed, log condition, species, and log size. Fines generation rises exponentially with knife speed beyond a certain level; frozen logs are more brittle and break more easily than warm logs; softwoods and ring-porous hardwoods are more prone to pulverization than are ring-diffuse hardwoods; and small logs result in more fines than do large logs. In particular, the most generation of fines occurs when individual bolts moving into the flaker are so reduced in size that they become loose in the stack. The smaller the log, the greater the proportion of the wedge to the entire log. A batch consisting entirely of 4-in.-diameter blocks would require approximately 5 percent more total fiber than a batch consisting of 7-in. blocks (Table 2). Assuming an average diameter of 7 in., 16.8×10^6 ft^3 of fiber translates to 210×10^3 cords, or 220×10^3 ovendried tons. (See materials balance sheet in Appendix.) At approximately 50 ton/acre, this is equivalent to 4,400 acres/year.

Table 2—Fiber required for various sizes of OSB blocks

Block diameter (in.)	Total fiber required ($\times 10^6$ ft^3)	($\times 10^3$ cord)
4	17.6	220
5	17.2	214
6	17.0	212
7	16.8	210
8	16.7	209
12	16.5	207

Table 3—Estimated costs for OSB plant

	($\times 10^3$ \$)
Land	250
Engineering and permits	4,000
Site preparation	1,000
Buildings	6,000
Equipment	
Processing	35,000
Mobile	1,500
Office	250
Freight cost	4,000
Installation	13,000
Working capital	5,000
Total	70,000

Table 4—OSB manufacturing costs

	Amount	Cost ($\times 10^6$ \$)	Cost (\$/10^3 ft^2)
Resin (\$0.65/lb)	11.4×10^6 lb	7.4	24.7
Wax (\$0.30/lb)	4.2×10^6 lb	1.3	4.2
Electricity (\$0.06/kWh)	51×10^6 kWh	3.1	10.2
Diesel and propane fuel	—	0.2	0.7
Heat energy (from residues)	—	0.0	0.0
Administrative labor	17 persons	0.7	2.3
Maintenance labor	14 persons	0.6	1.9
Processing labor	101 persons	3.6	12.1
Operating supplies	—	3.5	11.7
Maintenance supplies	—	2.3	7.7
Taxes	—	0.5	1.7
Insurance	—	0.3	1.0
Depreciation	—	5.6	18.7
Total	—	29.0	96.9

Table 5—Economic returns for various OSB blocks

Block diameter (in.)	Return to wood (\$/ft^3) Low price	High price
4	1.20	2.16
5	1.23	2.22
6	1.24	2.24
7	1.25	2.26
8	1.26	2.27
12	1.27	2.29

Costs and Revenue

Operating and manufacturing costs for OSB plants are shown in Tables 3 and 4, respectively. The ratio of revenue (sales less manufacturing costs) to wood input (hereafter called the return to wood) under low and high price scenarios is shown in Table 5.

Costs

Estimated operating costs for OSB plants are based on a variety of engineering studies conducted for the Forest Products Laboratory over the years and brought up to current levels on the basis of recent published aggregate plant costs (Table 3). Manufacturing costs are based on 38 lb of resin and 170 kWh/10^3 ft^2 of OSB (Table 4). Labor requirements are typical of industry staffing levels. Wood costs are not included. (See section on revenue.)

Revenue

Prices for OSB have ranged between \$100 and \$300/10^3 ft^2 (3/8 in. basis) during the past two decades. During the summer of 1995, prices slumped as a result of weak housing activity and the addition of a large increment of new capacity.

The price of OSB was quoted at about \$170/10^3 ft^2 in mid-1995; output at 300×10^6 ft^2 would yield total revenue of about \$50 million. By the fall of 1995, however, prices had recovered somewhat to about \$220/10^3 ft^2, which would yield a revenue of \$66 million. The cost and revenue streams yield a surplus of approximately \$21 to \$38 million, corresponding to return to the wood of \$1.20 to \$1.27/ft^3 under a low price scenario and \$2.16–\$2.29/ft^3 under a high price scenario (Table 5).

Stud Lumber

Background

Studs are nominal 2- by 4-in. and 2- by 6-in. pieces of lumber[1] used primarily for framing walls in light construction. Studs are usually cut to a standard length of 8 ft. Many species are used to make studs, but since even studs made from relatively weak species are stronger and stiffer than necessary to meet normal loads in repetitive framing, species are often used interchangeably as a basic commodity.

Process

Studs can be made from relatively low grade, small-diameter trees. The low value placed on the product has usually required the generation of a high volume of material per unit of time, even if the high volume has been at the expense of product recovery per unit of log. The main processing steps are log processing, breakdown, edge trimming, kiln drying, and planing.

Log Processing

Tree-length logs are fed individually from an in-feed deck onto a moving chain. To obtain clean residues suitable for pulp and to extend the service life of saws, the logs are debarked. Rotating knives rub against the stem, separating the bark from the cambium. After debarking, the stems are scanned and cut to sawlog lengths by slashing saws. The sawlogs are placed on a storage deck ahead of the headrig.

Breakdown

The primary breakdown system consists of an in-feed chain (feedworks) and a primary breakdown center (saw). The role of the feedworks is to move the log through the saw in a straight line while holding it firmly. In most stud mills, the feedworks consist of sharp chains on which the logs are impaled or lugged chains that push the logs through the system. Such feedworks are capable of high throughput but they do not hold the logs firmly, causing some looseness during cutting that necessitates higher target sizes, reducing recovery. End-dogging feedworks, in which a log is securely held at both ends during the cut, provide much better control and hence greater recovery, but at the cost of reduced throughput.

Many breakdown systems are used to saw studs. For the smallest log diameters, a simple system of a single-pass chipper and saw combination suffices: a set of knives first removes the out-of-square portions of a log, and the saws then cut the remaining cant. For larger logs, more complex systems are used that involve resawing of a center cant and the side pieces. These systems include the twin-band or double-circular saw, quad-band or chipper canter/quad/edger, chipper canter/band resaw/edger, and profiler chipper canter.

[1] Hereafter called 2 by 4 and 2 by 6.
Nominal 2- by 4-in. = standard 38- by 89-mm.
Nominal 2- by 6-in. = standard 38- by 140-mm.

Twin-band or double-circular saw—Mills with either twin-band or double-circular saw headrigs have similar flow designs. As the log goes through the system, two cuts are made, producing two slabs and a center cant. The cant is taken to a cant saw and the slabs to an edger. Two kinds of equipment are used to edge the slabs, depending on slab size. Small slabs are directed to a resaw to remove the outer circumference before edging. The equipment for large slabs consists of a chipping unit with three heads that square the slab for possible further resawing by a cant saw. Systems that use a double-circular saw (also called a two-saw scrag) process logs faster than systems that use a twin-band saw because they position the logs more quickly (Table 6). The twin-band saw, on the other hand, produces higher lumber recovery factors (LRFs) because the sawkerf is thinner.

Quad-band saw, four-circular saw, or chipper canter/quad/edger—The quad-band or four-circular saw (four-saw scrag) is used for processing larger logs. In all setups, up to four cuts are made, generating a center cant and up to four side pieces. In one setup (the chipper canter/quad/edger), the log sides are first chipped away, thereby generating only flitches. (A flitch has two parallel faces, a slab only one cut face.) In the other basic variant (quad band or four-saw scrag), two slabs and two flitches are produced. If the logs are extra large, the two slabs generated from the outermost part of the log are resawed at separate machine centers. The three types of saws operate very much the same. There is little difference in LRF between the chipper canter/quad/edger and quad band saw (Table 7). The scrag system, however, has lower LRFs, which is mainly attributable to the large differences in lumber sizes and saw kerf.

Chipper canter/band resaw/edger—In all cases, this configuration generates a single cant, with two or four sides chipped flat, followed by twin- or quad-band resaw or circular gang edger. A circular gang edger is adequate for small logs (4 to 12 in.) For large logs, a band resaw breaks down the cant; the design usually includes a "merry-go-round" to resaw large cants that cannot be handled in one pass. Pieces with wane are sent to an edger. The LRFs of various chipper canter systems are shown in Table 8.

Profiler chipper canter—The profiler chipper canter is also known as a Chip-N-Saw. The board pattern is first profiled from a log, and the profiled cant is then sawn in a close-coupled circular gang edger. The headrig type is unique—a given cutterhead set combination determines the number and size of the boards and their location in the log. The profiler chipper canter is designed to process logs within certain log diameter ranges. Various models cut different centers from the log; LRFs are shown in Table 9.

Edge Trimming, Kiln Drying, and Planing

The sawn boards are end-trimmed to precise lengths and sorted according to size. If the mill sells green lumber, no further processing is done. Some species, however, must be dried to avoid warp. Studs are stacked on rolling beds and fed through heated kilns. To reduce stud degrade, the stacks

Table 6—Lumber recovery factors for processing small logs into studs

Machine type	Throughput per 8-h shift (no. of logs)	LRF (7 in. diameter)
Twin-band saw	1,500	7.5
Two-saw scrag	1,980	6.7

Table 7—Lumber recovery factors for processing large logs into studs

Machine type	Throughput per 8-h shift (no. of logs)	LRF (7 in. diameter)
Quad-band saw	1,380	7.8
Four-saw scrag	1,640	6.2
Chipper canter/quad/edger	1,720	8.4

Table 8—Lumber recovery factors for chipper canters

Chipper canter	Throughput per 8-h shift (no. of logs)	LRF (7 in. diameter)
Two-side cant/edger	2,010	7.5
Four-side cant/edger	2,840	6.3
Four-side cant/band saw	2,210	7.6

Table 9—Lumber recovery factors for profiler chippers

Canter type	Throughput per 8-h shift (no. of logs)	LRF (7 in. diameter)
4-in. center	1,470	8.4
6/4-in. center	2,960	6.9
8/6/4-in. center	2,080	6.9
12/10/8/6/4-in. center	1,690	6.2

are restrained during drying. The dried lumber is fed through a planer to take care of drying defects and produce smooth, properly dimensioned lumber.

Plant Size and Fiber Requirements

The size assumed for a stud mill is 100×10^6 board feet per year, a large size for a studmill. For a plant of this size, fiber requirements would range from 12 to 16×10^6 ft^3, depending on recovery. (See materials balance sheet in Appendix.)

Table 10—Estimated costs for stud plant

Item	Cost ($\times 10^3$ $)
Land	150
Site preparation	1,500
Buildings	3,500
Equipment	
Processing	9,100
Mobile	1,000
Office	250
Freight cost	1,500
Installation	3,500
Working capital	1,500
Total	22,000

Costs and Revenue

Costs

Estimates of stud plant costs are based on a variety of engineering studies conducted for the Forest Products Laboratory and brought up to current levels on the basis of recent published plant costs (Table 10). These data represent average costs for stud mills rather than costs associated with any particular design. The estimated total is $22 million. Manufacturing costs are shown in Table 11.

Revenue

Sales of lumber and residues provide revenues. In the past decade, stud prices have varied from $160 to $390/$10^3$ board feet for kiln-dried, 2 by 4 western species. Prices have been quoted at about $250/$10^3$ board feet for mid-1995 and $280/$10^3$ board feet for the fall of 1995. Output of 100×10^6 board feet would yield revenue of about $25 to $28 million (Table 12). Pulp chip prices were about $100/bone-dry unit (bdu) (200 ft^3) in the past 2 years. For 100×10^6 board feet of lumber, approximately 6.3 to 4.6×10^6 ft^3 of pulp chips would be produced, equivalent to 31 to 23×10^3 bdu and yielding between $3.1 and $2.3 million. Additional revenues from the sale of shavings and sawdust would generate between $300 and $400 thousand. The LRF varies between 6.4 and 7.3, depending on bolt diameter.

The cost and revenue streams for studs yield surpluses of between $19.6 and $15.7 million or $1.06 to $1.36/$ft^3$ (Table 12). Note that the LRFs upon which these estimates were made are to some extent high because only round, straight, and sound logs were used in the studies. Average mill-run logs would reduce these return-to-wood values.

Table 11—Stud manufacturing costs, excluding wood

	Amount	Cost ($\times 10^6$ \$)	Cost (\$/10^3 board feet)
Electricity (\$0.06/kWh)	23.3×10^6 kWh	1.40	14.0
Diesel and propane fuel	—	0.10	1.0
Heat energy (from residues)	—	0.00	0.0
Administrative labor	15 persons	0.60	6.0
Maintenance labor	16 persons	0.58	5.8
Processing labor	114 persons	3.88	38.8
Operating supplies	—	1.00	10.0
Maintenance supplies	—	2.00	20.0
Taxes	—	0.45	4.5
Insurance	—	0.25	2.5
Depreciation	—	1.76	17.6
Total	—	12.02	120.2

Table 12—Output, revenue, and return to wood for studs of various bolt sizes

Avg. bolt	Output						Revenue ($\times 10^6$ \$)		Return to wood	
diameter (in.)	Wood (ft^3)	LRF	Lumber ($\times 10^6$ board feet)	Chips (ft^3)	Shavings (ft^3)	Sawdust (ft^3)	High	Low	High	Low
4	15.7	6.4	100	6.3	1.5	0.9	31.6	28.6	1.24	1.06
5	15.0	6.7	100	5.7	1.4	0.9	31.3	28.3	1.28	1.08
6	14.6	6.8	100	5.4	1.4	0.9	31.1	28.1	1.31	1.10
7	14.4	7.0	100	5.2	1.3	0.9	31.0	28.0	1.32	1.11
8	14.2	7.1	100	5.1	1.3	0.9	30.9	27.9	1.33	1.12
12	13.7	7.3	100	4.6	1.2	0.8	30.7	27.7	1.36	1.14

Random-Length Dimension Lumber

Background

For the most part, a mill for processing small logs into random-length dimension lumber is patterned on the same lines as a stud mill. The log and lumber handling and conveyor systems are more complex since a greater variety of log lengths are processed. Also, since a significant portion of the log input is expected to be 9 in. and greater, the headrig may be geared more for grade or volume recovery, with orienting capability and greater positioning control.

Plant Size and Fiber Requirements

The size assumed for the random-length dimension lumber mill is 100×10^6 board feet per year, the same as that for the stud mill. For a plant of this size, fiber requirements range from 12 to 16×10^6 ft^3, depending on recovery. (See materials balance sheet in Appendix.)

Costs and Revenue

Estimated plant and manufacturing costs are shown in Tables 13 and 14, respectively. From April 1994 to August 1995, prices for random-length 2 by 4 lumber were on average \$7 higher than those for stud-grade lumber. For the exercise here, such a premium is assumed. (However, a premium is not a certainty. In the fall of 1995, for example, random-length 2 by 4 lumber sold at a \$20 discount to studs.) The net incomes generated under these scenarios yield returns to wood of \$1.06 to \$1.38 (Table 15), essentially the same as returns for studs priced at a \$7 discount.

Table 13—Estimated costs for random-length dimension lumber plant

	Cost ($\times 10^3$ \$)
Land	150
Site preparation	1,700
Buildings	5,500
Equipment	
Processing	13,300
Mobile	1,000
Office	250
Freight cost	1,600
Installation	4,000
Working capital	2,000
Total	29,500

Table 14—Random-length dimension lumber manufacturing costs, excluding wood

	Amount	Cost ($\times 10^6$ \$)	Cost (\$/10^3 board feet)
Electricity (\$0.06/kWh)	23.3×10^6 kWh	1.40	14.0
Diesel and propane fuel	—	0.10	1.0
Heat energy (from residues)	—	0.00	0.0
Administrative labor	15 persons	0.60	6.0
Maintenance labor	16 persons	0.58	5.8
Processing labor	114 persons	3.88	38.8
Operating supplies	—	1.00	10.0
Maintenance supplies	—	2.00	20.0
Taxes	—	0.50	5.0
Insurance	—	0.30	3.0
Depreciation	—	2.36	23.6
Total	—	12.72	127.2

Table 15—Output, revenue, and return to wood for random-length lumber of various bolt sizes

Avg. bolt diameter (in.)	Wood (ft^3)	LRF	Output: Lumber ($\times 10^6$ board feet)	Output: Chips (ft^3)	Output: Shavings (ft^3)	Output: Sawdust (ft^3)	Revenue ($\times 10^6$ \$): High	Revenue ($\times 10^6$ \$): Low	Return to wood: High	Return to wood: Low
4	15.5	6.5	100	6.0	1.5	0.9	32.1	29.2	1.26	1.06
5	14.8	6.8	100	5.5	1.4	0.9	31.9	28.9	1.29	1.09
6	14.4	6.9	100	5.2	1.4	0.9	31.7	28.7	1.32	1.11
7	14.2	7.1	100	5.0	1.3	0.9	31.6	28.6	1.33	1.12
8	14.0	7.2	100	4.9	1.3	0.9	31.5	28.5	1.35	1.13
12	13.5	7.4	100	4.6	1.2	0.8	31.4	28.4	1.38	1.16

MSR Random-Length Lumber

Background

Traditionally, lumber has been graded according to visual criteria. The actual strength of any given piece, however, can vary widely with that of another piece of the same appearance and species. Such variation must be allowed for in the design of structures, with the consequence that load ratings of visually graded lumber in building codes are drastically reduced in comparison with the actual strength of most individual pieces.

Mechanical grading allows each piece of lumber to be tested physically by a machine for its mechanical properties to more accurately estimate its actual strength. For the producer, this results in increased yield of higher value grades. For the user, this assures that the strength values of the material lie within more precisely defined and narrower bands.

However, the mass market for lumber remains primarily with the traditional visual grades. To date, the use of stress-graded lumber has been mainly limited to truss, laminating, and fabricated joist applications where engineering considerations play a larger role. Machine-stress-rated (MSR) lumber is normally sold directly to these users and little, if any, appears at the normal distribution outlets where most lumber is marketed. Accordingly, MSR lumber production would provide the most benefit where a species mix is handicapped by the visual grading rules and would otherwise be excluded from those specialty markets. This could be the case with the material envisioned here, which would fall predominantly into the "western woods" commercial grade, a category whose low design values remove it from consideration for most engineered applications. The principal reason for the lower values assigned to this group is the low specific gravity of some of its components, like lodgepole pine.

Process

A practical method for measuring the strength of a piece of lumber without testing it to failure is to measure the lumber's stiffness, or its modulus of elasticity (MOE). Mechanical grading relies on the high correlation between the MOE and modulus of rupture (MOR) of a material. The most common machine used for this purpose is the continuous lumber tester (CLT). The CLT is a fast machine capable of speeds of up to 1,200 ft/min, sufficient to be close-coupled to a lumber planer. Other designs involve a bypass in which a grader directs only the most likely pieces to the testing machine. In either case, the lumber to be evaluated passes through a series of rollers that deflect it up and down by a fixed amount every 4 ft of its length. The force required to achieve those deflections is measured and averaged. The average MOE together with the lowest MOE measurement are used to assign potential grades to each piece. The lumber is then visually graded for defects such as checks, splits, warp, and excessively large knots, which can result in the downgrading of a piece. All MSR grades have to meet either the visual rules applicable for No. 2 or Standard grades or an agency-approved qualification procedure. Thus, there is potential for upgrading the No. 2 or Standard visual grades of western wood species that collectively carry 70 percent or less of the bending strength assigned to the main commercial species, such as Spruce–Pine–Fir, Douglas Fir, and Southern Pine.

Plant Size and Fiber Requirements

The plant size and fiber requirements assumed for a MSR random-length lumber mill are the same as those for a random-length dimension lumber mill. For a mill of this size, fiber requirements range from 13 to 16×10^6 ft^3, depending on recovery. It is assumed that an offset stress-rating machine and pull chain sorters are used in an otherwise standard planer mill.

Costs and Revenue

Costs

In addition to the capital costs of a random-length dimension lumber mill, the costs listed in Table 16 would be incurred to install the tester in a MSR random-length lumber mill. The incremental costs (excluding the cost of wood) of running a MSR line inside a random-length lumber mill are shown in Table 17.

Revenue

Product output carries the following assumptions:

- Only 2 by 4 lumber in 10- to 20-ft lengths is MSR graded.
- Sawn 2 by 4 lumber in these length categories is assumed to account for 50 percent of mill output.
- Two grades of MSR lumber are sold: 1650f-1.5E and 2100f-1.8E.
- The yield of these two grades of the eligible pool of 2 by 4 lumber is 25 and 5 percent, respectively.

From April 1994 to August 1995, the average price premium for 2100f-1.8E grade of Douglas Fir–Larch relative to Standard and Better Douglas Fir–Larch was $98. The premium of 1650f-1.5E is assumed to be two-thirds of that value ($65). The additional revenues generated from such a mix and the prices, assuming no decrease in the value of the residual lumber, are shown in Table 18. The total incremental revenue is $1.87 million. The additional revenues, less cost, would boost the return to wood by \$0.12/ft^3 to \$0.14/ft^3 (Table 19).

Table 16—Estimated costs for MSR random-length lumber mill

	Cost ($\times 10^3$ \$)
Site preparation	6
Engineering	38
Buildings	70
Processing equipment	460
Office equipment	12
Freight cost	24
Installation	22
Contingency	66
Miscellaneous	40
Total	738

Table 17—MSR random-length lumber manufacturing costs

	Amount	Cost ($\times 10^6$ \$)
Electricity (\$0.06/kWh)	0.297×10^6 kWh	0.018
Processing labor	1 person (2 shifts)	0.081
Additional marketing expense	—	0.037
Operating supplies	—	0.002
Maintenance supplies	—	0.003
Depreciation	—	0.059
Total	—	0.200

Table 18—Additional revenues generated from mixes of MSR lumber

Lumber grade	Volume ($\times 10^6$ board feet)	Price (\$/10^3 board feet)	Revenue increment ($\times 10^6$ \$)
2100f-1.8E MSR	2.5	98	0.245
1650f-1.5E MSR	25.0	65	1.625
Total	—	—	1.870

Table 19—Economic returns for MSR random-length lumber of various sizes

Average bolt diameter (in.)	Wood (ft^3)	Additional revenue ($\times 10^6$ \$)	Return to wood /ft^3
4	15.5	1.87	0.12
5	14.8	1.87	0.12
6	14.4	1.87	0.13
7	14.2	1.87	0.13
8	14.0	1.87	0.13
12	13.5	1.87	0.14

Laminated Veneer Lumber

Background

The manufacture of laminated veneer lumber (LVL) is one way to convert sawlogs of moderate size and quality into a high strength, dimension lumber-like product. Laminated veneer lumber is used as a structural material for applications such as beams and headers or where long spans are needed.

Process

The process for manufacturing LVL is primarily the same as that for manufacturing plywood. The main difference is that the veneers are oriented parallel to each other rather than at right angles. The process consists of heating the bolts; peeling, drying, and scarfing the veneer; and pressing the veneer into panels.

Heating of Bolts

Because veneer is most readily peeled when wood is in the temperature range of 60°F to 140°F, most mills condition peeler bolts by immersion in hot water to attain a wood temperature within this favorable range—usually a core temperature of about 100°F.

Peeling, Drying, and Scarfing of Veneer

The bolt is clamped, rotated, and advanced into a stationary knife. Just above the knife, a bar slightly compresses the wood to reduce splitting as it is peeled. The peeling thickness is normally 1/8, 1/6 or 1/10 in. The cut sheets of veneer are dried to about 4 percent moisture content. To produce long, continuous sheets, the veneers are cut at an angle by a scarfing saw, where the wedge ratio (length of vertical side to length of cut) varies from 1:10 to 1:6, based on the veneer thickness. Glue is spread on the scarfed surface and the ends of adjacent veneers are positioned over each other and pressed. The veneer sheets are then placed on a flexible caul by side shifter forks and sprayed with glue.

Pressing

A prepress is used to prevent premature drying of the glue. After prepressing, the assembled panel is placed in a press feeder. A 10-opening 4- by 64-ft press line is assumed here. When done, pulling bars remove the LVL billets and simultaneously pull the material from the in-feed into the empty press. The pressed LVL billets are cut and sawn to the dimensions required by the customer and packaged.

Plant Size and Fiber Requirements

The capacity of the LVL plant is calculated at about 5.6×10^6 ft^3 of LVL per year. The product recovery factors (Table 20) are based on a 2-in. core diameter. The fiber requirements of such a plant would range from 21×10^6 ft^3 if only small 4-in. logs were used to 10.4×10^6 ft^3 for 12-in. logs. An average log size of 8-in. would require 11.6×10^6 ft^3, corresponding to about 66.26×10^6 board feet (Scribner scale).

Table 20—Volume recovery during LVL manufacture

	Volume recovery (percent) for various log diameters					
	4 in.	5 in.	6 in.	7 in.	8 in.	12 in.
Logs at debarker	100.0	100.0	100.0	100.0	100.0	100.0
Log trim loss	—	—	—	3.5	—	—
Spur waste (spindleless)	—	—	—	0.0	—	—
Spin-out waste	—	—	—	0.0	—	—
Round-up waste	16.0	13.0	11.0	10.0	9.0	6.5
Core waste	21.0	15.0	11.0	8.0	6.2	3.5
Clipping waste	—	—	—	16.0	—	
Gross green veneer recovery	43.5	52.5	58.5	62.5	65.3	70.5
Shrinkage in drying	—	—	—	4.5	—	—
Compression loss	—	—	—	3.3	—	—
Scarfing loss	—	—	—	1.3	—	—
Composing loss	—	—	—	1.3	—	—
Process loss (including blows)	—	—	—	0.7	—	—
Billet edge trim	—	—	—	2.9	—	—
Additional trim loss	—	—	—	2.9	—	—
Final product recovery	26.6	35.6	41.6	45.6	48.4	53.6
Wood fiber requirements (ft^3)	21.0	15.7	13.5	12.3	11.6	10.4

Table 21—Estimated costs for LVL plant[a]

	Cost ($\times 10^3$ \$)
Land	250
Engineering and permits	4,000
Site preparation	1,000
Buildings	6,000
Equipment	
Processing	30,000
Mobile	1,500
Office	250
Freight cost	4,000
Installation	13,000
Working capital	5,000
Total	65,000

[a]Costs supplied by Durand Raute Industries, Ltd., New Westminster, British Columbia.

Table 22—LVL manufacturing costs, excluding wood

	Amount	Cost ($\times 10^6$ \$)	Cost (\$/10^3 ft^3)	Cost (\$/10^3 ft^2) (3/8 in. basis)
Resins (\$0.65/lb)	8.1×10^6 lb	5.27	940	29.4
Fillers (\$0.12/lb)	3.1×10^6 lb	0.37	66	2.1
Soda ash (\$0.08/lb)	0.6×10^6 lb	0.05	9	0.3
Electricity (\$0.06/kWh)	28.7×10^6 kWh	1.72	307	9.6
Diesel and propane fuel	—	0.20	36	1.1
Heat energy (from residues)	—	0.00	0	0.0
Administrative labor	15 persons	0.60	107	3.3
Maintenance labor	16 persons	0.58	104	3.2
Processing labor	124 persons	4.47	798	24.9
Operating supplies	—	3.00	536	16.7
Maintenance supplies	—	2.00	357	11.2
Taxes	—	0.50	89	2.8
Insurance	—	0.30	54	1.7
Depreciation	—	5.20	929	29.0
Total	—	24.26	4,332	135.3

Costs and Revenue

Estimated plant and operating costs for an LVL plant are showed in Tables 21 and 22, respectively. Prices for 1.8E grade stock of LVL were quoted at about \$13.5/ft^3 in mid-1993. Output at 5.6×10^6 ft^3 would yield a total revenue of about \$75.6 million. At a lower price of \$10/ft^3 (\$320/10^3 ft^2), total revenue would be about \$56 million.

These cost and revenue streams yield a surplus of approximately \$51.34 million under the high price scenario and \$31.74 million under the low price scenario. These figures yield return-to-wood estimates ranging from \$1.51 to \$3.05 under low prices and \$2.44 to \$4.94 under high prices.

Market Pulp

Background

Paper encompasses a broad spectrum of products for written or printed communication and information storage (printing and writing paper grades and newsprint), sanitary and absorbent applications (tissue and sanitary paper products), packaging (paperboard for corrugated containers, boxboard, and packaging paper grades), and miscellaneous commercial, industrial, and structural uses.

In North America, newsprint accounts for 16 percent of total paper and paperboard production, printing and writing papers for 28 percent, tissue and sanitary products for 6 percent, packaging paper and paperboard grades for 48 percent (paperboard for corrugated containers for 28 percent), and all other products for only 2 percent.

Paper and paperboard products consist mostly of plant fibers, chiefly wood. More than 99.5 percent of fiber used in papermaking in North America is wood, derived from pulpwood. Although many other plant fibers can and have been used in papermaking, wood is the most abundant and economical source of fiber. Worldwide, more than 90 percent of fiber used in papermaking is wood fiber. Coatings, fillers, and pigments are used in some paper products (clay coatings in some coated printing and writing papers can be 30 percent or more of the product weight), and small quantities of other materials such as synthetic fibers are added to other products, but virtually all paper products produced in North America consist primarily of wood fiber.

The conversion of plant material, such as pulpwood, into a fibrous raw material suitable for papermaking is known as pulping. Most wood pulp produced in North America is used for production of paper or paperboard, although a small and declining fraction has been used for other applications (presently around 1 to 2 percent, chiefly dissolving pulp used for production of synthetic rayon fibers). Various pulping processes are used to convert pulpwood into wood pulp suitable for papermaking.

The paper and allied products industry is one of the largest elements of the manufacturing sector in the U.S. economy, with an annual value of industry shipments currently in excess of $160 billion. In most cases, the primary paper or paperboard products are made in so-called integrated pulping and papermaking facilities—mills that produce pulp and use the pulp to produce paper or paperboard at the same site. However, a fraction of wood pulp production (roughly 15 percent or around 10×10^6 tonnes of production in the United States) is known as "market pulp," which generally refers to pulp that is sold on the open market and used at production facilities that are remote from pulp mills or at mills that have greater need for pulp than can be satisfied internally. As the industry has evolved in the United States, virtually all paper-grade market pulp has been used for production of printing and writing paper products, newsprint, and tissue products. These are essentially the only product grades in which there is a deficit in pulp capacity or other special need for purchase of market pulp. Furthermore, the type of market pulp that is required in those cases is almost exclusively high-quality bleached (white) pulp. Thus, around 90 percent of market pulp produced in the United States is bleached chemical market pulp, mostly kraft (sulfate) pulp and a small amount of bleached sulfite pulp. The remaining 10 percent of market pulp is primarily white market pulp made from recycled fiber (so-called recycled market pulp, which has grown rapidly in recent years from around 1 percent of market share 10 years ago). In addition, bleached mechanical market pulp (chiefly bleached chemithermomechanical pulp, or BCTMP) has entered the North American market in recent years.

Technically, the two primary market pulp alternatives for commercial utilization of small-diameter timber are bleached softwood kraft (sulfate) pulp and BCTMP. A third possibility is bleached sulfite pulp, but sulfite is an old technology that has a small and gradually declining market share and has largely been supplanted by bleached kraft. However, because of the significant economies of scale in the processing of bleached kraft market pulp (economical facilities must be built at the scale of at least 500 tonnes per day), the very large capital costs of such facilities ($500 million or more), and the very significant difficulties that would be encountered with siting and permits for such facilities in the intermountain West, it is appropriate to first consider the feasibility of the smaller scale and less capital intensive BCTMP technology.

Process

For market pulp (BCTMP and bleached kraft), some important physical variables of wood fiber determined by wood species influence commercial and economic potential. Those variables include fiber length, fiber flexibility, surface characteristics of wood fibers, and density of wood. Lodgepole pine (*Pinus contorta*) is among the "long fiber," low density, softwood pulpwood species, which have generally been preferred for pulping and papermaking. The relatively longer and more flexible fibers of such species contribute better to sheet strength and conformability in papermaking. Indeed, lodgepole pine has been utilized commercially for production of market pulp and various paper and paperboard products in North America. Western lodgepole pine is similar genetically and morphologically to jack pine (*Pinus banksiana*), an eastern North American softwood species that has been used extensively for pulping in Canada and the United States for many years. Bleached chemithermomechanical pulp is somewhat more restricted in the range of species that have proven commercially successful than is kraft pulp, with current production based for the most part on aspen (*populus* sp.) in Canada. However, other low-density species have been shown to be suitable for pulping via BCTMP technology. Thus, in purely physical terms, small-diameter western softwood species, such as lodgepole pine, are suitable for production of market pulp using BCTMP technology.

However, apart from sharing a suitability for use of softwood species such as lodgepole pine, the bleached kraft and BCTMP processes differ substantially in ways that are quite relevant to determining their relative suitability for commercial exploitation of small-diameter timber in the West. Kraft pulping is the dominant pulping process employed in North America. It is a so-called chemical pulping process, in which chemical agents are primarily responsible for dissolving the lignin matrix that holds fibers together in wood. This is accomplished by exposing wood chips for several hours to a solution of heated and concentrated alkaline chemicals (chiefly sodium hydroxide, along with sulfide compounds that serve as alkaline buffers or caustic donors to replenish the sodium hydroxide consumed in the process). This is the so-called alkaline cook or kraft cooking that occurs in a large digester vessel. Subsequently, the individual fibers of the softened and digested wood material are easily separated by mechanical means, and the chemical residue is reprocessed by combustion and reduction (burning off the organic residues of lignin in the spent pulping liquors, leaving sodium sulfide and sodium carbonate), followed by slaking and causticizing (firing of sodium carbonate with lime to yield caustic sodium hydroxide) to rejuvenate more caustic chemicals for further pulping. The pulp fibers are then bleached, traditionally using chlorine compounds. Essentially, kraft pulping is an elaborate chemical process.

In contrast, BCTMP technology relies primarily (although not exclusively) on mechanical means to convert wood into a fibrous raw material or pulp. In the BCTMP process, wood chips are first briefly exposed to steam heat and a relatively mild chemical solution (usually sodium sulfite). The exposure to chemicals and heat is usually only for a matter of minutes as opposed to hours in the case of kraft pulping. Instead of completely digesting the wood chips into pulp, the brief exposure to heat and chemicals in the BCTMP process simply softens the wood chips. The chips are then fed into large pressurized refiners, which are large mechanical devices for reducing chips into fibrous raw material powered by very large electric motors (10,000-hp refiners are common in the industry). Mechanical action of rotating metal blades in the refiners is responsible for reducing the softened wood chips to fibrous raw material or pulp. Subsequently, the pulp is bleached, typically using hydrogen peroxide or oxygen.

The differences between kraft pulp and BCTMP processes result in big differences in the relative characteristics and quality of the pulps, which have a direct bearing on their marketability and value. The yield of pulp in bleached kraft pulping (expressed as a weight ratio to the quantity of wood input) is typically in the range of 46 to 48 percent, which means that roughly half the weight of the wood input is recovered in the finished product. Most of the lignin constituents of wood, which are responsible for the characteristic brown coloration of wood, are removed in the kraft process, leaving mostly cellulose fibers, which can be bleached to a high degree of whiteness and brightness. The pulp yield for the BCTMP process is much greater than that for kraft pulping, typically in the vicinity of 90 percent based on wood weight, because the process does not dissolve or remove the lignin constituents of wood as does the kraft process. Because most lignin remains in the pulp, it is not possible economically to obtain the same degree of whiteness or brightness that is achieved by bleached kraft pulp. Advances in bleaching technology for BCTMP have resulted in improvements in brightness, but generally BCTMP cannot match the quality of bleached kraft. Also, the lignin present in paper made from BCTMP pulp contributes to a phenomenon known as color reversion, in which the paper gradually loses its whiteness and brightness, a process which is accelerated by exposure of the paper to light (especially ultraviolet light). Thus, BCTMP is not as suitable as kraft pulp in products that demand longevity, such as books, but is more applicable in product grades with short life spans (for example, tissue paper and advertising pamphlets).

Apart from considerations of brightness and whiteness of the pulp, substantial differences in sheet strength also derive from differences in the pulping processes. In kraft pulping, fibers tend to remain intact and are mostly well-separated; the lignin is dissolved by chemicals. In the BCTMP process by contrast, a higher proportion of the fibers tends to be broken or unseparated as a result of the more severe nature of wood defibrillation in mechanical refiners. Since papermaking relies on the length and conformability of individual fibers to achieve strength via a random felting process, the BCTMP process yields a pulp with generally lower strength properties for papermaking than does kraft pulping. However, BCTMP has recently gained in market acceptance, particularly in Europe. Potential exists for further gains in North America.

In summary, substantial differences in the pulping processes result in differences in the physical quality of bleached kraft pulp and BCTMP, as recognized by papermakers, chiefly in terms of relative brightness and strength. The quality advantages of bleached kraft pulp are recognized in the market, where a higher price has always been paid for bleached kraft pulp than for BCTMP. (However, it can be noted, as discussed in the following section, that the price for BCTMP has recently been approaching the price for bleached kraft.) Thus, the processes influence the revenue potential, with bleached kraft pulp generally offering a higher revenue potential per tonne of product than does BCTMP.

In addition to revenue potential, differences between processes also result in substantial differences in costs, chiefly in capital, energy, and labor costs. Overall, BCTMP pulping has lower production costs, lower labor costs, and much lower capital costs per tonne of product than does the kraft process. Kraft pulping technology also has larger economies of scale as a result of its greater complexity and chemical processing aspects. However, the mechanical refiners in a BCTMP process result in a much higher and more costly electrical energy demand than those in kraft pulping; thus, the economics of BCTMP are sensitive to electrical energy costs. The kraft pulping process tends to be more energy self-sufficient as a result of the combustion of spent pulping liquors.

The principal production process steps at a typical BCTMP mill are fiber procurement; wood storage and processing; pulping; heat recovery; screening, cleaning, and thickening; refining of rejects; bleaching; drying; and baling, storage, and shipping.

Fiber Procurement

Planning and scheduling of fiber procurement are needed to ensure adequate and sustained fiber supply. Pulpwood is purchased and delivered to the mill either in the form of roundwood pulpwood or mill residue chips (from sawmills or plywood mills). In some cases, fiber procurement may entail management and scheduling of timber harvest operations.

Wood Storage and Processing

The wood is stored outside in chip or log piles, usually with sufficient inventory for at least 4 to 6 weeks of sustained mill operation. Roundwood material is chipped, and all chips are screened to ensure appropriate sizing and thickness and to eliminate reject fines or oversize material. Pulping efficiency in the subsequent refining stage is sensitive to the geometry of wood chips, so maintaining uniformity in size and shape of chips is critical. A metered flow of chips is loaded continuously onto a conveyor that discharges the chips into a presteaming bin.

Pulping

In the presteaming bin, chips are heated with steam (generally obtained via steam recovery from the refining process). Presteamed chips pass through a chip washer and drainer for cleaning. Clean chips are fed into a final steaming bin, where they are exposed to pressurized steam, and then through a screw compactor into a chip impregnator vessel, where they are bathed in a sodium sulfite solution. The chips are then exposed to additional steam heat and fed into a pressurized primary refiner. Since the primary refiner is the largest and most crucial equipment item in a BCTMP mill, it will generally determine the economical capacity increments of the mill. After refining, the pulp is discharged to cyclones for separation of steam and then diluted with wash water and screened to remove oversize particles. The pulp is washed on a dewatering press to remove dissolved materials. The pulp is then fed to smaller secondary refiners for further processing and discharged again through cyclones for steam recovery. Finally, the pulp is discharged to a retention chest for latency removal (to allow twisted fibers to settle and straighten).

Heat Recovery

Heat recovery is essential for efficient operation of a BCTMP mill. Most mill steam energy requirements can be met by heat recovery from the refiners. Substantial amounts of heat energy are generated by friction in the refiners as the chips are reduced from wood to pulp. The pulp is discharged from the refiners to primary cyclones, which separate energy-laden steam for heat recovery from the pulp. The “refiner steam” is first passed through scrubbers to remove trapped fibers or fines and then through heat exchangers to transfer the heat to clean low-pressure process steam for the mill process. Excess steam is generally condensed and recirculated.

Pulp Screening, Cleaning, and Thickening, and Rejects Refining

The pulp from the retention chest is passed through pressure screens to remove shives (wood particle rejects) and other contaminants. The pulp is then passed through a centrifugal cleaning system, and rejects are processed through additional screening systems. Centrifugal cleaning removes sand, bark, dirt, and fine shives from the pulp; multiple stages of cleaning are generally required. The pulp is thickened by removal of water and stored in a high-density storage tower. Rejects (shives and wood particles) are collected, thickened, and fed into a refiner to reduce the particles into pulp, with subsequent heat recovery, screening, and cleaning.

Bleaching

A typical bleaching plant for a BCTMP mill is based on a two-stage hydrogen peroxide process. The process includes washing before bleaching, between the two bleaching stages, and finally after the final bleaching stage. Pulp from the high-density storage tower is diluted and washed on a dewatering press. Washed pulp is fed through mixers that blend it with steam and bleaching chemicals (prepared from hydrogen peroxide, sodium hydroxide, and other reagents) and then retained for the time required to accomplish bleaching in a bleaching tower. The process is repeated in the second stage, and the bleached pulp is washed again and discharged to a high-density storage tower.

Drying

Market pulp is seldom shipped wet. In general, pulp must be dried for storage, handling, and shipment. The drying process begins when the bleached pulp from high-density storage is fluffed and mixed with heated air. The fluffed pulp then enters a cyclone, which separates the partially dried pulp from the air. The fluffing, heating, and cyclone steps are repeated until the pulp is dry. Finally, the pulp enters a cooling cyclone, which introduces fresh air to cool the pulp. The air-dry pulp is then discharged to a slab press.

Baling, Storage, and Shipping

The fluffed pulp is discharged into press molds and compressed into slabs. Slabs are stacked in the form of a bale, further compressed, and baled in a bale press. Finally, the bale is weighed, bound by wire, wrapped in paper, and labeled. Bales are stored in a warehouse area before shipment to customers by truck or rail.

Handling of Effluent, Emissions, and Waste

Approximately 5,000 gal of waste water is generated for each air-dry tonne of pulp produced in a typical BCTMP mill. The waste water has a fairly high organic or oxygen demand content (BOD at around 160 lb per air-dry tonne), as a result of separation of organic materials from wood and pulp in wash water. Depending on local water quality standards and the level of mill effluent (influenced by size of facility and other factors), a substantial degree of mill effluent treatment may be required. This could typically involve settling ponds and pretreatment, anaerobic digestion, activated sludge oxidation, and final effluent storage and stabilization. Additional or more intensive processing may be required in localities with stringent water quality standards, and permits for a facility may not even be possible in some areas or would require uneconomical effluent treatment costs. Small volumes of nonhazardous solid waste are also generated and require disposal in a landfill. Air emissions from a BCTMP mill are usually relatively small (by comparison to a kraft mill for example). Particulate and organic material removal technology are required to meet applicable local and Federal standards.

Plant Size and Fiber Requirements

Most BCTMP mills that have either been built or placed under consideration have been scaled in the range of 200 to 500 tonnes per day. However, as mentioned in the previous section, the technology can be economically scaled in smaller increments, which are determined by the scale of a single, large, pressurized primary refiner. Thus, the economical capacity increments generally could be as low as around 150 tonnes/day, which would probably be about the smallest economically feasible capacity for a BCTMP mill. Fiber requirements for a 150-tonnes/day mill at 90 percent pulp yield and 10 percent moisture content in air-dry pulp would be roughly 150 tonnes of wood per day (dry weight), or approximately 375 m^3 (equivalent to roughly 150 cords/day or 52,500 cords/year; at approximately 50 short tons of wood available per acre, this is equivalent to roughly 1,050 acres/year). The approximate total capital investment cost for a 150 tonne/day BCTMP mill is estimated to be $77 million (Table 23).

Costs and Revenue

The manufacturing costs of $432/tonne translate to $22.7 million on an annual basis (Table 24). Bleached BCTMP at 85 GE brightness, produced primarily in Canada from aspen, sold in 1995 at prices in excess of $700/tonne (reportedly at $835/tonne delivered from Canada to Europe in the third quarter of 1995, which would be approximately $750/tonne to the Canadian producers after deducting shipping costs). Market pulp prices have risen substantially in recent years from an historical low point in the period from 1992 to 1993. As recent as the third quarter of 1994, for example, the price of BCTMP delivered to Europe was only $505/tonne (indicating a 65-percent increase in price during 1994 alone). Although pulp prices leveled out in mid-1995, it can be expected that BCTMP will remain in fairly good demand for some time, as paper and paperboard production worldwide continues to grow and with the general increase in the prices for fiber raw material. At an assumed stabilized price of $600/tonne (which is less than the 1995 price range of $700–$750), annual revenue for a 150 tonne/day BCTMP mill would be approximately $31.5 million. At the current price of $750/tonne, annual revenue would be approximately $39.4 million. The estimated costs for BCTMP along with the estimated revenue streams yield an annual "surplus" between $8.8 and $16.7 million. This corresponds to a maximum potential return to wood between $67/$m^3$ and $127/$m^3$ (roughly $1.90 to $3.60/$ft^3$).

Table 23—Estimated costs for BCTMP plant

	Cost ($\times 10^3$ \$)
Land	3,000
Engineering and permits	6,000
Contingency and escalation	8,000
Site preparation	2,000
Mobile equipment, wood yard	1,000
Mechanical pulp plant	15,000
Heat recovery	1,500
Screening and cleaning plant	4,500
Bleaching plant	4,500
Dewatering plant	4,500
Pulp drying facilities	4,000
Finishing and storage	5,000
Fuel, power, and air distribution	7,000
Chemical preparation facilities	1,000
Effluent treatment	10,000
Total	77,000

Table 24—BCTMP manufacturing costs[a]

	Cost ($/air-dry tonne)
Pulping chemicals	15
Bleaching chemicals	70
Effluent treatment chemicals	3
Purchased fuel (gas)	15
Electrical energy	175
Miscellaneous materials and losses	8
Operating labor and supervision	12
Maintenance labor and supervision	10
Maintenance, materials, supplies	14
Administrative salaries	5
Taxes and insurance (2.5 percent)	37
Depreciation/capital recovery (15 percent)	68
Total manufacturing costs (excl. wood)	432

[a]150 tonnes/day, excluding wood.

Particleboard and Medium Density Fiberboard

Particleboard and medium density fiberboard (MDF) are wood-based panel products that have gained acceptance as substitutes for increasingly expensive high-grade lumber and plywood. These industries developed in regions where many sawmills and plywood plants were located and had residues and wastes that were unsuitable for pulping (such as planer shavings, dried trim, and sander dust) and that provided an inexpensive source of fiber. Most particleboard and MDF manufactured in the United States and Canada continues to be made from byproducts of primary wood manufacturers because this is less costly fiber than roundwood. The exception has been in the U.S. North, where a number of particleboard and MDF plants have benefitted from their proximity to furniture manufacturing plants and thus can operate on roundwood.

Significant sawmilling and plywood manufacturing activity has occurred in the inland West. Three particleboard plants and one MDF plant were built to take advantage of the available waste fiber. These four plants need to be considered in the discussion of the feasibility of using roundwood thinnings for particleboard and MDF. As long as primary wood processing plants continue to operate and generate low value wastes in the region, a new or existing plant would find it hard to operate competitively with more expensive roundwood furnish. Therefore, as a practical matter, the use of thinnings as a particleboard or MDF furnish is not likely.

Plywood

Softwood plywood is a commodity product that is generally used in construction as wall and roof sheathing and subflooring. In the 15 years since the advent of oriented strandboard (OSB), plywood industry growth has been stalled. Oriented strandboard can be used for much the same purposes as plywood, but it costs less. As indicated by the recovery factors for laminated veneer lumber, a plywood plant needs relatively large logs to operate effectively. If the logs are too small, plant productivity and wood recovery fall. Given the relative economics of plywood and OSB and the growth prospects for the latter, the use of thinnings for plywood manufacturing is unlikely to be economical.

Conclusions

The key performance parameters of various processing alternatives for small-diameter timber are shown in Table 25. In terms of the return to wood, the results are best for laminated veneer lumber (LVL), followed by market pulp and OSB. Among the lumber alternatives, machine-stress-rated (MSR) lumber yields the greatest return.

In addition to the return to wood, the investment risk may be a consideration. A measure of the risk involved is represented by the investment/net income ratio. The lower the ratio, the more quickly the investment is recouped. This measure favors the lower-cost lumber alternatives over the capital-intensive OSB, market pulp, and LVL options.

The final consideration is the amount of fiber that would have to be supplied to operate the plants. As indicated in Table 25, the OSB option would require the most fiber, almost four times the amount required for market pulp.

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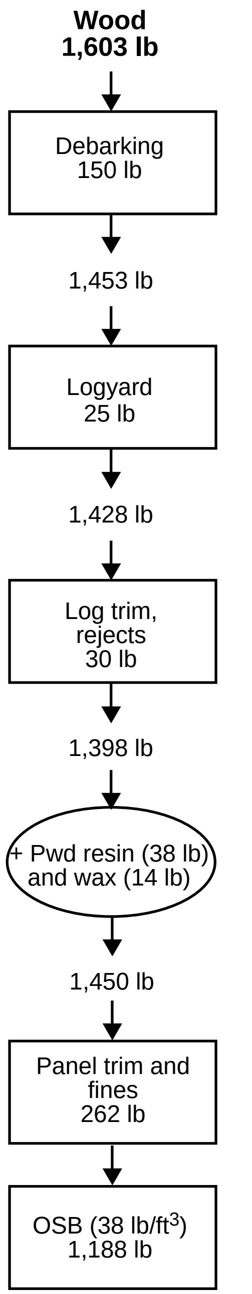
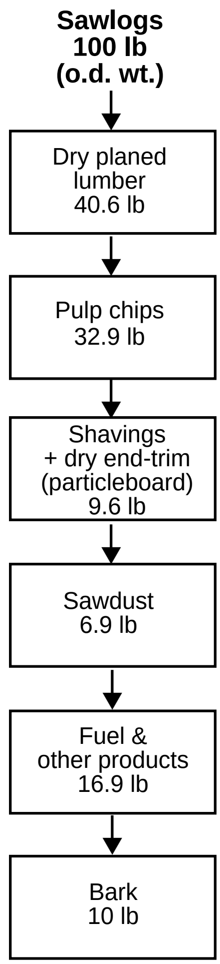
Table 25—Comparison of wood processing alternatives

	Return to wood ($/ft^3)		Investment to annual income (ratio)		Annual wood
Product	Low price	High price	Low price	High price	required ($\times 10^6$ ft^3)
Oriented strandboard	1.24	2.24	3.33	1.89	16.8
Stud lumber	1.10	1.31	1.39	1.17	14.0
Random-length dimension lumber	1.11	1.32	1.87	1.57	13.8
Machine-stress-rated lumber	1.24	1.45	1.73	1.48	13.8
Laminated veneer lumber	2.23	3.84	2.04	1.27	11.6
Market pulp	1.90	3.60	8.75	4.61	4.6

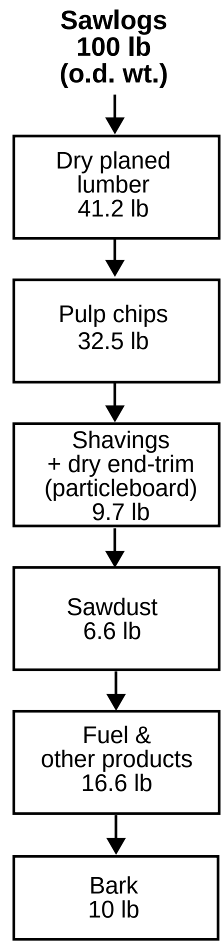
Appendix—Materials Balance Charts for Various Wood Products



Oriented strandboard



Stud lumber



Random-length dimension lumber