PRODUCING HARDWOOD DIMENSION PARTS DIRECTLY FROM LOGS: AN ECONOMIC FEASIBILITY STUDY

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ABSTRACT

The economic feasibility and profitability of a direct processing system for converting Factory Grades 2 and 3 red oak logs directly into rough dimension parts were evaluated. Net present value (NPV) and internal rate of return (IRR) were used as the measurement of economic feasibility, and return on sales (ROS) was used as the measurement of profitability. NPV and IRR were estimated based on the predicted after-tax cash flow for a 10- year period. The results of this study indicate that converting Grade 2 and Grade 3 red oak logs directly into rough dimension parts is economically feasible. Under the given assumptions, an initial capital expenditure of $5.25 million to build a direct processing mill to process Grade 2 red oak logs can generate a $4.43 million NPV with an IRR of 27.5 percent. An initial investment of $4.42 million to build a direct processing mill to process Grade 3 red oak logs can generate a $3.93 million NPV with an IRR of 28.2 percent. It was found that the direct processing system is much more profitable than current sawmills and dimension mills. The predicted ROS values of the direct processing mills are 7 to 12 percent higher than the average upper quartile ROS values achieved by the hardwood sawmill industry and by the hardwood dimension and flooring industry from 1983 to 1992. A sensitivity analysis indicates that dimension part price, green cutting yield, and drying degrade and remanufacturing loss are the three most important factors affecting the economic feasibility and profitability of the direct processing systems. If the drying degrade and remanufacturing loss is too high, the proposed direct processing system may not be able to achieve its high profit potential.

As timber prices increase and environmental constraints limit the volume of logs that can be harvested, more and more wood products manufacturers are seeking alternative value-added processing methods that can more efficiently utilize the existing timber resource. Converting logs directly into rough dimension parts is one potential method in value-added processing. This direct processing system combines both hardwood sawmill and rough mill operations without considering the manufacturing step of standard grade lumber.

Two previous studies (7,8) explored the potential cutting yields, dollar value recovery, and production rate in a direct processing system for both Factory Grades 2 and 3 red oak logs. The results obtained from these previous studies provided valuable insights into characteristics of a direct processing system. The potential yield, dollar value recovery, and production rate of a direct processing system indicate that it can be a promising technique for value-added processing of hardwood logs, especially for low-grade logs.

Although cutting yield, dollar value recovery, and production rate make substantial contributions to economic performance, they are not direct indicators of economic performance. Many questions regarding the economic performance of this new system remain unanswered: Are direct processing systems economically feasible under current economic conditions? Are they more profitable than these sawmills and dimension mills currently in operation? Are they capable of withstanding changing economic conditions, such as rising raw material cost, increasing operating cost, and falling sale price? If an investment in a direct processing system cannot achieve an attractive return, potential investors will be unwilling to risk their capital in such a processing system. And if the direct processing system is no more profitable than current sawmills and dimension mills, hardwood sawmillers and dimension manufacturers will not be convinced to shift their current operations to the direct processing system.

The objectives of this study are to determine 1) the economic feasibility of establishing a direct processing mill for processing Factory Grades 2 and 3 red

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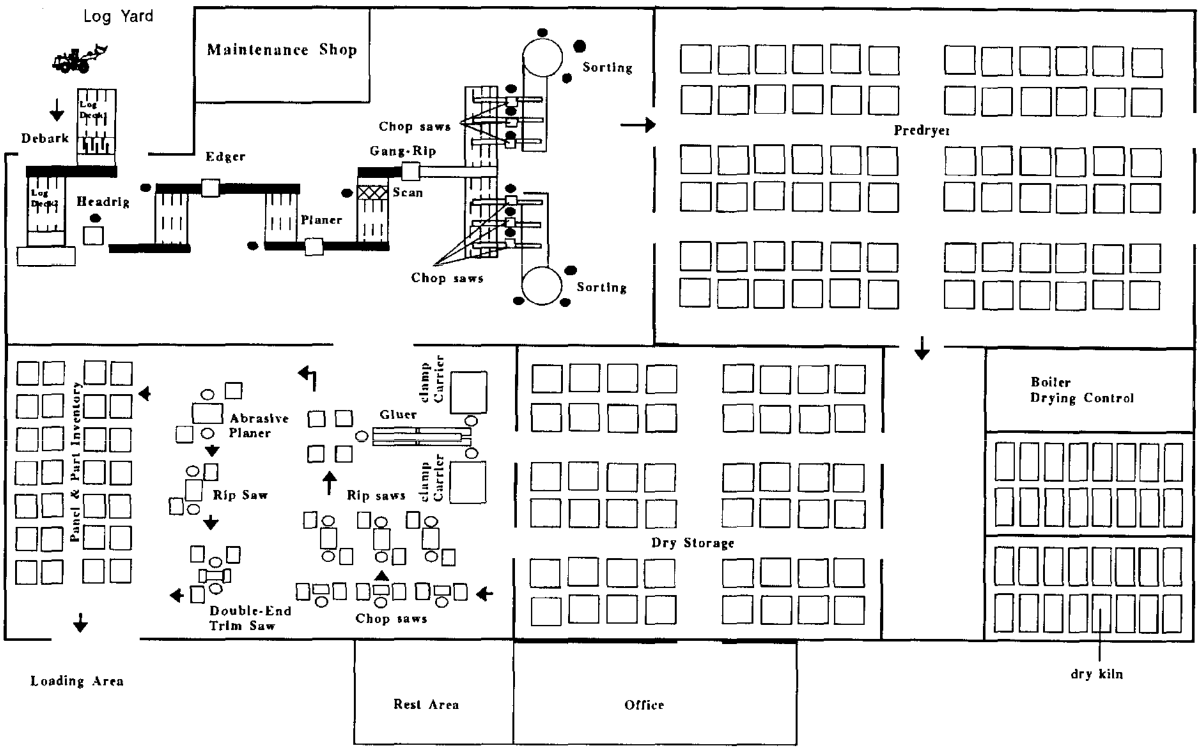

Figure 1. — Mill layout of the studied dimension manufacturing plant.

oak logs; 2) if the direct processing system can be more profitable than current hardwood sawmills and dimension mills; and 3) the sensitivity of the economic feasibility and profitability of the direct processing system to the changes in market and operational conditions. The results obtained in previous studies (7,8), including cutting yield, dollar value recovery, and production rate, have provided essential information that will be used in this economic analysis.

MILL LAYOUT

The proposed layout of the direct processing mill used in this analysis is shown in **Figure 1.** This mill layout was selected from several different mill designs previously tested because it showed the best combination of yield and production rate (6-8).

The proposed dimension manufacturing plant consists of three major sections: green blank manufacturing section, drying and storage section, and remanufacturing section. In the green blank manufacturing section, logs enter the mill and are debarked and live-sawn into flitches on a headrig saw. The flitches are then cut into green dimension blanks using a gang ripsaw and six manual chop saws in a gang-rip-first sequence. At the end of the green blank manufacturing section, the green blanks are conveyed to two large revolving tables. The green blanks are sorted in lengths and stacked by six part sorters standing by these revolving tables. To handle these small pieces of blanks more efficiently, a series of pallets or skids are used to allow workers to sort parts and stack them in a unit package in one operation. The unit package can be tightened with a steel belt during drying, and workers can move the unit package with small forklifts. This method has been successfully used in Japan and France.

In the drying and storage section, the packaged green blanks are predried and then kiln-dried. Here, the combination of predryer drying and conventional kiln-drying is proposed for drying green blanks. The dry blanks are then put in a storage area for further processing.

In the remanufacturing section, the dry blanks are cut to remove drying defects and edged to obtain edge-gluing quality using three chop saws and three straight-line ripsaws. The blanks are then matched for color and grain and then edge-glued into panels. These edge-glued panels are then abrasively planed and sold as final products or cut into customer-sized parts using a straight-line ripsaw and a double-end trim saw.

In previous studies, the cutting yields of rough green blanks from Factory Grades 2 and 3 red oak logs (7) and production rates of several direct processing mill designs (8) were estimated. However, since the majority of hardwood dimension parts are bought and sold in dry condition, the economic performance of the direct processing system must also consider operations beyond green part manufacturing, including drying, storage, and remanufacturing. The capacities of these operations after green part manufacturing were selected such that they could keep up with the production capacity of the green part manufacturing section.

METHODS

The financial analysis was performed using discounted cash-flow methods. Net present value (NPV) and internal rate of return (IRR) were used to determine the economic feasibility of the direct processing mills for processing Factory Grades 2 and 3 red oak logs. These two measurements were calculated based on predicted after-tax cash flow, Return on sales (ROS), the ratio of net profit to net sales, was used as the measurement of profitability. The following assumptions were used in this analysis:

1. The proposed direct processing mills will be totally new.

2. The proposed direct processing mills will be fully equity financed.

3. The minimum attractive rate of return for investment will be 12 percent.

4. The profitability figures published by Dun and Bradstreet for the hardwood dimension and flooring industry and for sawmills and planer mills are representative of current hardwood dimension mills and sawmills.

5. The proposed mills will operate 250 days a year and one shift per day.

6. All final products produced by the proposed direct processing mills will be sold.

7. The mill will operate at 30 percent of its full capacity in the first operational year and 70 percent in the second operational year. Starting from the third operational year, the mills will enter normal operation and operate at 90 percent of full capacity.

8. The final products of the proposed direct processing mills will consist of 70 percent standard-size edge-glued panels (1) and 30 percent cut-to-size dimension parts with clear-two-face quality.

9. The volume loss of green blanks due to drying shrinkage will be 8 percent.

10. The volume loss of blanks due to drying degradation and post-drying remanufacturing will be 15 percent.

11. The average selling price for red oak edge-glued panels will be $2,200 per thousand board feet (MBF), and the price for cut-to-size parts will be equal to the price for edge-glued panels plus the cost of cutting to size.

12. The delivered prices for Factory Grades 2 and 3 red oak logs will be $385 per MBF and $125 per MBF (International l/4-in. Scale), respectively.

13. Waged workers will be paid 260 days a year at $7.50 per hour plus 30 percent fringe benefits.

14. The selling cost of final products will be 7.5 percent of the total sales.

TABLE 1. — Estimated initial capital investment for the direct processing mill that processes Factory Grades 2 and 3 red oak logs.

Log grade	Building cost[a]	Equipment cost	Land cost	Working capital	Total cost
	($)				
Grade 2	2,424,000	1,885,000	100,000	840,000	5,249,000
Grade 3	1,939,000	1,885,000	100,000	500,000	4,424,000

[a] Includes predryer and dry kilns,

15. The annual maintenance costs of equipment (including dry kilns) will be 10 percent of initial expenditures.

16. The costs of energy and sticking material for drying dimension parts will be $70 per MBF green parts.

17. The cost of glue (polyvinyl acetate) will be $12 per MBF of edge-glued panels.

ESTIMATING INITIAL INVESTMENT

Initial investment includes capital for the building, equipment, land, and site preparation, and working capital for starting the operation. Because of the differences in production rate when processing Grade 2 and Grade 3 logs, there are some differences in the total investment required to build a direct processing mill for processing Grade 2 logs and a mill for processing Grade 3 logs. The initial capital investment was estimated to be $5.25 million for a mill processing Grade 2 red oak logs and $4.42 million for a mill processing Grade 3 logs **(Table 1).** These represent two extreme cases. If a mix of Grades 2 and 3 are used, the results will be somewhere in between. The building cost (including predryer and dry kilns) was estimated to be $1.94 million for the mill processing Grade 3 logs. For the mill processing Grade 2 logs, an additional $485,000 will be needed to build additional predryer and kiln-drying capacity and additional storage space due to the higher production rate. Based on the estimates adjusted for inflation (1 1), the construction costs of predryer and dry kilns were assumed to be at $1,000 and $3,500 per MBF of drying capacity, respectively.

The capital requirement for equipment purchases was estimated based on the price of each piece of equipment quoted by equipment manufacturers, plus 10 percent installation cost. Overall, $1.89 million will be needed for purchasing and installing all equipment for the proposed direct processing mill **(Table 1).** It was estimated that 8 acres of land would be needed to build the proposed direct processing mill. Assuming a $10,000 per acre purchase price and $20,000 for site preparation and improvement, the total cost of land will be $100,000. The amount of working capital needed for starting operation was estimated based on the capital requirement covering the first 4 months of operating costs. Due to the higher price of Grade 2 logs, the mill processing Grade 2 logs will need more working capital for initial log purchases.

ESTIMATING ANNUAL REVENUE

To estimate the revenue generated from the sale of dimension parts, data on dimension yields, selling price, and the production rate of the mill are needed. The cutting yield of green blanks estimated in a previous study (7) was used as the base for estimating the yields of the edge-glued panels and cut- to-size parts. This green cutting yield was defined as the ratio of board footages of green blanks output to the International 1/4-inch Scale board footages of input logs. Since the previous yield data was obtained using a computer cut-up program called CORY (2), to be conservative, these yields were reduced by 5 percent to offset the possible yield difference between computer-optimized cutting and actual cutting. The reduced green cutting yields used in this study are 71.4 and 68.3 percent for Grade 2 and Grade 3 red oak logs, respectively. These reduced yields were then converted to the yield of edge-glued panels by reducing by another 8 percent to account for shrinkage losses and 15 percent to account for degrade and remanufacturing losses.

Based on information provided by several dimension producers at the time this study was conducted, the average price for clear-two-face, 414 red oak dimension (based on 33-in.-long edge-glued panels) was estimated to be $2,350 per MBF. To be conservative, $2,200 per MBF was used in this analysis. The prices for customer-size dimension parts will be slightly higher than the price for edge-glued panels to offset the costs of cutting to size. However, in this study, it was assumed that the cutting-to-size operation will not change net revenue. In other words, cut-to-size parts will be sold at a price of $2,200 per MBF plus the cost of cutting to size. The value of residue was conservatively estimated at $5 per dry ton.

A previous study (8) estimated that the direct processing mill as shown in **Figure 1,** if operated at full capacity, can process 6.9 million board feet (MMBF) (International l/4-in. Scale) of Grade 2 red oak logs and 4.9 MMBF (International l/4-in. Scale) of Grade 3 red oak logs annually. These estimated production rates were used in this study. The estimated annual revenues for processing Grade 2 and Grade 3 logs are listed in **Table 2.**

ESTIMATING OPERATING COSTS

Operating costs include raw material (logs and glue) cost, labor cost, utility cost, selling cost, maintenance cost, administrative cost, insurance cost, property tax, and other possible costs. The total cost of logs was estimated on the basis of the assumed delivered prices of $385 per MBF (International l/4-in. Scale) for Grade 2 and $125 per MBF for Grade 3 red oak logs. The cost of glue (polyvinyl acetate) was estimated on the basis of $12 per MBF of edge-glued panels, $2 more than estimated by Quick (9). The labor cost for hourly workers includes both wages and fringe benefits. The mill needs a total of 53 or 51 workers to operate in one shift when processing Grade 2 or Grade 3 logs, respectively. The assignment of these workers is listed in **Table 3.** These estimations are based on the simulation results of a previous study (8) and observations in sawmills and rough mills. The labor estimation for the remanufacturing section may not be very accurate due to the uncertainty of the drying quality of blanks. The impact of the possible underestimations of staff will be examined in the sensitivity analysis. The assumed wage rate of $7.50 per hour (plus 30% fringe benefits) was used in the estimation of total labor cost.

The utility cost was estimated based on the total power consumption for all equipment included in the manufacturing facility, except for the energy consumed by predryer and dry kilns, which was included in the drying cost. Based on the figures provided by Lamb and Wengert for drying lumber (5) and taking account of inflation and possible additional handling costs for drying dimension parts, the energy cost for drying 4/4 red oak dimension parts was estimated to be $60 per MBF of green parts. Drying dimension parts needs extensive sticking and stacking, therefore, an additional $10 per MBF for stacking and sticking material (sticks and unit package skids) cost was assumed. The $70 per MBF drying cost does not include costs of labor, equipment, and insurance. These costs were included in the overall labor cost, equipment depreciation, and insurance cost of the mill.

The administrative cost was assumed to be a fixed amount of $200,000 per year. It will cover the salary and fringe benefits for one plant manager, one floor supervisor, one secretary, and one receptionist, and the costs of phone bills and office supplies. The insurance costs include general liability insurance and property insurance. Based on the quotations provided by two insurance companies who specialize in providing insurance for the lumber manufacturing industry, the annual cost of the general

TABLE 2. — Estimated annual revenue of the direct processing mill that processes Factory Grades 2 and 3 red oak logs into dimension parts.

Log grade	Item	Year 1[a]	Year 2[b]	Years 3 to 10[c]
		($)		
Grade 2	Dimension products	2,715,000	6,335,000	8,145,000
	Residue	13,000	31,000	40,000
	Total	2,728,000	6,366,000	8,185,000
Grade 3	Dimension products	1,821,000	4,230,000	5,464,000
	Residue	11,000	24,000	32,000
	Total	1,832,000	4,254,000	5,496,000

[a] Mill assumed to operate at 30 percent of full capacity.
[b] Mill assumed to operate at 70 percent of full capacity.
[c] Mill assumed to operate at 90 percent of full capacity.

TABLE 3. — List of workers.

Working duty	Number of workers: When processing Grade 2 logs	Number of workers: When processing Grade 3 logs
Log loader driver	2	2
Log receiving and scaling	1	1
Forklift driver	3	3
Debarking	1	1
Headrig saw	1	1
Edging saw	1	1
Rough planner	1	1
Gang-rip scan	1	1
Chop saws (6 saws for green cutting)	6	6
Sorting	6	6
Stacking and unstacking	4	6
Kiln-drying	3	3
Single arbor ripsaws for resawing	6	6
Salvage chop saws (3 saws for resawing)	3	3
Panel gluing	3	3
Abrasive planer	2	2
Double-end trim saw	2	2
Packaging and shipping	2	2
Saw sharpener	1	1
Floating worker	1	1
Clean-up	1	1
Total	51	53

[a] Does not include maintenance personnel whose costs were included in maintenance cost.

liability insurance was estimated to be 2.5 percent of the total direct labor wage, and the annual cost of the property insurance was estimated to be $0.65 per $100 of assets. An annual property tax rate of $0.38 per $100 of assets was used in calculating property tax. These insurance costs, property taxes, and other costs may vary in different areas. The effects of cost variation on the economic analysis results will be examined in the sensitivity analysis. Operating costs also include other possible costs such as accounting fees. The itemized annual operating costs are listed in **Table 4.**

TABLE 4. — Estimated annual operating costs of the direct processing mill that processes Factory Grades 2 and 3 red oak logs into dimension parts.

Log grade	Item	Year 1	Year 2	Years 3 to 10
		($)		
Grade 2	Direct labor	537,500	859,800	1,074,800
	Log cost	800,600	1,868,200	2,402,000
	Glue cost	18,000	42,000	54,000
	Utility[a]	49,300	98,400	110,700
	Drying costs[b]	104,000	243,000	312,300
	Selling costs[c]	242,800	545,700	614,000
	Maintenance[d]	116,300	232,500	232,500
	Administration	200,000	200,000	200,000
	Insurance and property tax	70,400	70,400	70,400
	Others	15,000	35,000	50,000
	Total	2,155,000	4,195,000	5,120,700
Grade 3	Direct labor	517,000	827,000	1,034,000
	Log cost	182,800	426,500	548,300
	Glue cost	12,000	28,000	36,000
	Utility[a]	49,300	98,400	110,700
	Drying costs[b]	70,000	163,000	210,000
	Selling costs[c]	183,000	366,000	412,000
	Maintenance[d]	106,700	213,500	213,500
	Administration	200,000	200,000	200,000
	Insurance and property tax	64,000	64,000	64,000
	Others	12,000	28,000	35,000
	Total	1,396,800	2,414,400	2,863,500

[a] The utility cost listed does not include the energy consumed by the drying operation.
[b] The drying cost includes only the cost of energy and stacking material. Other drying-related costs are included in other mill costs such as labor, maintenance, insurance costs, etc.
[c] Selling expense was assumed to be 7.5 percent of dimension parts and cants sales.
[d] Maintenance cost was assumed to be 10 percent of equipment expenditures (including dry kilns), excepting installation costs.

ESTIMATING NPV AND IRR

Because equipment and building depreciation is tax deductible, the depreciation schedules will affect the mill's tax liability. All equipment, including dry kilns, was depreciated using the depreciation schedule specified in the Modified Accelerated Cost Recovery System (3, 10). Buildings were depreciated using the straight-line method over a period of 31.5 years (10).

The effective income tax rate used in this analysis was 38 percent (based on 34% of federal income tax rate and 6% of state income tax rate). NPV was calculated as described by Weston and Copeland (12) as:

$$NPV = \sum_{t=1}^{10} \frac{CF_t}{(1+r)^t} - I_0$$

where:

I_0 = initial capital investment
CF_t = after-tax cash flow in year t
t = periods in years, t = 1 to 10
r = minimum attractive return rate or discount rate (assumed to be 12%)

IRR was calculated from the following equation:

$$\sum_{t=1}^{10} \frac{CF_t}{(1+IRR)^t} - I_0 = 0$$

ESTIMATING ROS

The ROS for each individual year was obtained by dividing the annual net profit after taxes by the annual net sales in that particular year. The net profit after taxes for a particular year was obtained by subtracting the equivalent annual cost of the initial capital expenditures (3), the various operating costs, and the taxes for this particular year from the before-tax earnings of the same year. The 12 percent minimum attractive rate of return was used as the interest rate in calculating the equivalent annual cost. In calculating the annual equivalent costs of the equipment and buildings, the useful life was assumed to be 10 and 20 years, respectively.

The average ROS value from the 3rd to the 10th year was used in comparison with the ROS value of the hardwood dimension industry and sawmill industry reported by Dun and Bradstreet (4). The upper quartile value of ROS data presented in Dun and Bradstreet's reports over the last 10 years (from 1983 to 1992) was averaged and used in comparing with the ROS value of the proposed direct processing system.

SENSITIVITY ANALYSIS

In some circumstances, the assumptions used in the initial analysis may not be representative of a particular situation. There are many factors that can have tremendous effects on the economic performance of the direct processing system. For example, dimension part price and log price may change over time and place. And other variables such as labor costs, maintenance costs, selling expenses, and other operating costs can vary greatly among individual mills. More importantly, the estimated cutting yields and the assumed drying degrade and remanufacturing loss can vary substantially in practice. It is necessary to find out whether the direct processing system would still be economically attractive for situations where the assumptions prove inaccurate. Therefore, a sensitivity analysis was carried out for both NPV and ROS

TABLE 5. — Estimated NPV, IRR, and ROS of the direct processing mill for processing Factory Grades 2 and 3 red oak logs into dimension parts.[a]

Log grade	NPV	IRR	ROS
	($)	(%)	
Grade 2	4,434,000	27.53	14.45
Grade 3	3,932,000	28.23	18.65

[a] NPV = net present value (at cash discount rate of 12%); IRR = internal rate of return; ROS = return on sales.

considering changes in dimension price, log price, green cutting yield, drying degrade and remanufacturing loss, and other operating costs. In carrying out the sensitivity analysis on one variable, all assumptions for other variables remained unchanged.

RESULTS AND DISCUSSION

ECONOMIC FEASIBILITY OF THE DIRECT PROCESSING SYSTEM

The NPV, IRR, and ROS of the selected direct processing mills for processing Grade 2 and Grade 3 red oak logs are presented in **Table 5.** The direct processing mills for processing Grade 2 and Grade 3 red oak logs can generate as much as $4,434,000 and $3,932,000 in NPV, respectively, in a 10-year period. These large numbers of positive NPVs strongly indicate that the direct processing system is economically feasible both for processing Grade 2 and Grade 3. Investment in the direct processing mills for processing Grade 2 and for processing Grade 3 logs can generate an IRR of 27.53 and 28.23 percent, respectively. These high return rates would be very favorable to potential investors. The decision rule based on IRR would be to accept the project with an IRR greater than the minimum attractive rate of return that was used to discount the after-tax cash flows. The predicted IRRs of the direct processing mills are far greater than the minimum attractive rate of return of 12 percent.

The results of this analysis show that the direct processing mills for processing Grade 2 and Grade 3 logs can have an average ROS of 14.45 and 18.65 percent, respectively **(Table 5).** These ROS values are much higher than the reported ROS for sawmills and hardwood dimension mills from 1983 to 1992. In other words, the direct processing system, when processing Grade 2 and Grade 3 red oak logs, has the potential to be much more profitable than most current sawmills and hardwood dimension mills. According to Dun and Bradstreet's annual report on key business ratios (4), the average ROS for sawmills and planer mills and for the hardwood dimension and flooring industry from 1983 to 1992 are only 3.1 and 3.8 percent, respectively. Even the upper quartile ROS values for these two sectors are only 6.7 and 7.5 percent. **Figure 2** shows the reported ROS for sawmills and planer mills and for the hardwood dimension and flooring industry from 1983 to 1992. ROS is an indicator of a firm's ability to withstand adverse conditions such as falling prices, rising costs, and declining sales. The higher ROS values will make the direct processing system more capable of withstanding adverse conditions than current sawmills and hardwood dimension mills.

The potential high profitability of the direct processing system may be attributed to its operation characteristics that differ from traditional sawmills and dimension and flooring mills. First, integrating the sawmill operation and the rough mill operation will actually merge two management levels into one, therefore the overall management cost will be reduced. Second, integrating the sawmill operation and the rough mill operation reduces two sale activities (lumber and dimension parts) into one (only dimension parts), therefore sales cost will be reduced. Third, directly converting logs into dimension parts will eliminate the shipping of lumber from a sawmill to a dimension mill, therefore the overall shipping cost will be reduced. Another important reason is that directly converting logs into dimension parts will increase the conversion efficiency from logs to dimension parts. A significant part of the material that otherwise will be edged off as waste in lumber manufacturing can be converted into usable parts in the direct processing system (7).

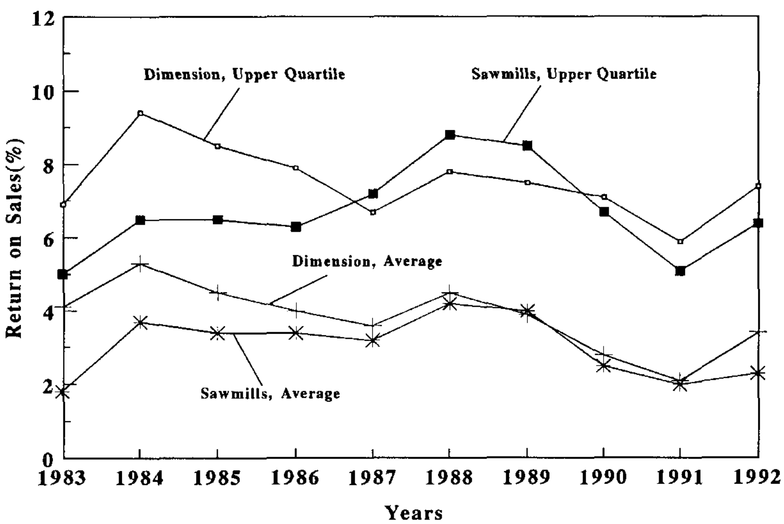

Figure 2. — Historic data of ROS for hardwood sawmills and planer mills, and for the dimension and flooring industry from 1983 to 1992 (4).

TABLE 6. — Average changes in NPV and ROS resulting from 1 percent change in selected variables.[a]

Selected variables	Processing Grade 2 logs: Change in NPV	Processing Grade 2 logs: Change in ROS	Processing Grade 3 logs: Change in NPV	Processing Grade 3 logs: Change in ROS
	($)	(%)	($)	(%)
Dimension part price	+232,600[c]	+0.491	+155,000	+0.443
Log price	-76,600	-0.189	-18.600	-0.069
Labor costs	-34,000	-0.082	-33,200	-0.117
Overhead costs[b]	–36,600	-0.085	-29,700	-0.100
Green cutting yield	+316,000	+0.736	+219,300	+0.684
Drying degrade and remanufacturing loss	-276,000	-0.671	-184,000	-0.604

[a] NPV = net present value (at cash discount rate of 12%); ROS = return on sales.

[b] Overhead costs include selling, maintenance, administration, insurance, property tax, and other indirect costs.

[c] A positive number indicates that NPV or ROS will increase as the selected variable increases, and decrease as the selected variable decreases; a negative number indicates that NPV or ROS will decrease as the selected variable increases, and increase as the selected variable decreases.

The results of this analysis also indicate that the direct processing system does not have to use high quality material to be profitable. The direct processing system can profitably process low quality logs (Grade 3 logs) into dimension products. This makes the direct processing system particularly attractive in processing the abundant low quality timber resource into high-valued dimension products. In fact, the direct processing system has a higher ROS when processing Grade 3 logs than when processing Grade 2 logs. The major reason is that the cost of Grade 2 logs is much higher than Grade 3 logs.

SENSITIVITY ANALYSIS

Table 6 shows the average changes in NPV and ROS caused by a 1 percent change in selected variables. These results indicate that dimension price, green cutting yield, and drying degrade and remanufacturing loss are the three most significant factors affecting the economic feasibility and profitability of the direct processing system. For example, if the green cutting yield from Grade 2 logs decreases by 1 percent, then the NPV will decrease by $316,000, and the ROS will decrease by 0.74 percent. If the dimension price drops by $100 per MBF, the NPV of the mill for processing Grade 2 logs will decrease by $1,061,000, and the ROS will decrease by 2.52 percent.

The effects of changes in log cost, overhead, and labor costs on the profitability of the direct processing system are relatively less significant than changes in dimension price, green cutting yield, and drying degrade and remanufacturing loss. For example, if an additional five workers are needed to handle the small parts, the labor costs will increase about 10 percent. This 10 percent increase in labor costs will only cause about an 0.8 percent decrease in ROS when processing Grade 2 logs.

Although dimension price, cutting yield, and drying degrade and remanufacturing loss are all important factors that impact the economic results of the direct processing system, to the manager of a direct processing mill they may not be equally important. The price of dimension products is determined by external markets, while cutting yield and drying degrade and remanufacturing loss can be controlled to some extent through internal production changes. Under given market conditions, maintaining cutting yield and controlling drying degradation will be critical to the success of the direct processing system.

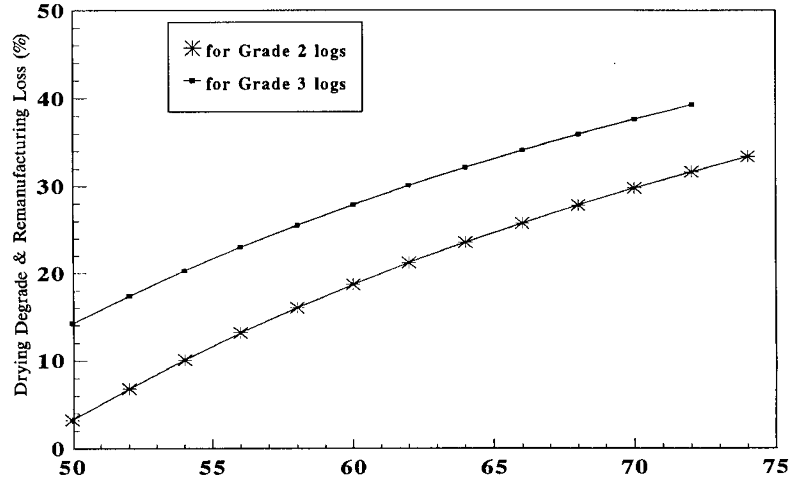

Figure 3. — Breakeven green cutting yield and drying degrade and remanufacturing loss that make NPV=0 (at cash discount rate of 12%).

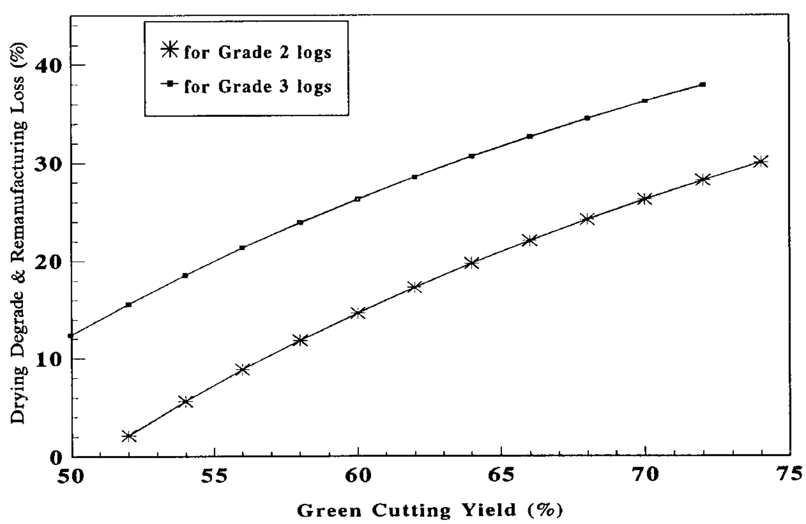

Figure 4. — Breakeven green cutting yield and drying degrade and remanufacturing loss that make ROS=7.5 percent, which is the average upper quartile value for the hardwood dimension and flooring industry from 1983 to 1992.

Figure 3 shows the breakeven cutting yield and drying degrade and remanufacturing loss that will result in NPV = 0. The breakeven curves in **Figure 3** show the drying degrade and remanufacturing loss under a given green cutting yield that will maintain the economic performance of the direct processing system at an acceptable level (i.e., NPV ≥ 0). For a given log grade, the area below the breakeven curve **(Fig. 3)** is the economically acceptable area, while the area above the breakeven curve is economically unacceptable. For example, if the green cutting yield is 60 percent, to achieve the acceptable investment return, the mill must be able to control the drying degrade and remanufacturing loss below 18.8 and 27.9 percent when processing Grade 2 and Grade 3 logs, respectively. From **Figure 3** we can also see that there is more area under the curve for Grade 3 logs, which means that reduced cutting yields and/or increased drying degrade and remanufacturing loss have less effect on Grade 3 logs compared to Grade 2 logs.

TABLE 7. — *Breakeven dimension price ($/MBF) under changing green cutting yields and drying and remanufacturing loss.*[a]

Green cutting yield	Log grade	Drying degrade and remanufacturing loss 10%	15%	20%	25%	30%	35%
(%)		($/MBF)					
50.0	Grade 2	2,366	2,505	2,661	2,839	3,041	3,275
	Grade 3	2,096	2,220	2,359	2,516	2,695	2,903
52.5	Grade 2	2,257	2,390	2,539	2,708	2,902	3,125
	Grade 3	2,001	2,118	2,251	2,401	2,572	2,770
55.0	Grade 2	2,158	2,285	2,428	2,590	2,775	2,989
	Grade 3	1,914	2,026	2,153	2,296	2,461	2,650
57.5	Grade 2	2,068	2,190	2,327	2,482	2,659	2,864
	Grade 3	1,834	1,942	2,064	2,201	2,358	2,540
60.0	Grade 2	1,986	2,103	2,234	2,383	2,553	2,749
	Grade 3	1,761	1,865	1,982	2,114	2,265	2,439
62.5	Grade 2	1,910	2,022	2,148	2,292	2,455	2,644
	Grade 3	1,694	1,794	1,906	2,033	2,179	2,346
65.0	Grade 2	1,840	1,948	2,070	2,208	2,365	2,547
	Grade 3	1,633	1,729	1,837	1,959	2,099	2,261
67.5	Grade 2	1,775	1,879	1,997	2,130	2,282	2,457
	Grade 3	1,575	1,668	1,772	1,890	2,025	2,181
70.0	Grade 2	1,714	1,815	1,929	2,057	2,204	2,374
	Grade 3	1,522	1,612	1,712	1,827	1,957	2,108
72.5	Grade 2	1,658	1,756	1,866	1,990	2,132	2,296
	Grade 3	1,473	1,559	1,657	1,767	1,893	2,039

[a]Dimension prices that make NPV = 0

Figure 4 shows the minimum cutting yield and allowable drying degrade and remanufacturing loss under which the direct processing system will still have a 7.5 percent ROS, which is the average upper quartile value for the hardwood dimension and flooring industry from 1983 to 1992(4). For example, if the green cutting yield is 60 percent, to keep the ROS above 7.5 percent, the drying degrade and remanufacturing loss must be controlled below 13.8 percent when processing Grade 2 logs and below 25.6 percent when processing Grade 3 logs. Likewise, if the drying degrade and remanufacturing loss increases to 30 percent, the green cutting yield for Grade 2 and Grade 3 logs must be higher than 75 percent and 64 percent, respectively, to keep the ROS above 7.5 percent.

Table 7 shows the breakeven dimension prices that result in NPV = 0 under given green cutting yield and drying degrade and remanufacturing loss. This breakeven-price approach was used in the analysis of the potential for short lumber in the furniture and cabinet industries by Wiedenbeck (13). For this direct processing mill to be economically acceptable, the dimension parts must be sold at a price that is higher than the breakeven price. For example, if the mill operates at a 60 percent green cutting yield and a 20 percent drying degrade and remanufacturing loss when processing Grade 2 logs, the dimension parts must be sold at a price higher than $2,234 per MBF for the mill to be profitable.

Because of its uncertainty, drying degrade and remanufacturing loss can become a very critical factor to the success of the direct processing system. If the drying degrade and remanufacturing loss is too high, the direct processing system may not be able to achieve the potential high profit as predicted in this study. Future research to determine and minimize drying degrade and remanufacturing loss will be necessary. If green blanks drying is a constraint to the success of the direct processing system, an alternative processing system could be considered. This alternative processing system still processes hardwood logs directly into dimension parts, but it will saw the logs into flitches, then dry the flitches, then cut them into dimension parts. With this alternative processing system, mills can avoid drying dimension parts. However, the drying costs of this alternative processing system will be higher because: 1) a higher volume of material will need to be dried; and 2) flitches with defects may have a higher level of drying degrade. Future research will be needed to determine the advantages and disadvantages of these two processing systems.

CONCLUSION

The results of this study indicate that the direct processing system is economically feasible in converting Grade 2 and Grade 3 red oak logs into rough dimension parts. The direct processing mills for processing Grade 2 and Grade 3 red oak logs can generate an NPV of $4,434,000 and $3,932,000, and an IRR of 27.5 and 28.2 percent, respectively. These NPV and IRR values are much higher than the minimum attractive level of investment return. Therefore, it can be concluded that the direct processing system that converts logs directly into rough dimension products offers a good investment opportunity. It was estimated that the direct processing mills for processing Grade 2 and Grade 3 red oak logs would have an ROS of 14.45 and 18.65 percent, respectively. These values are much higher than the averaged upper quartile ROS values reported by Dun and Bradstreet for hardwood sawmills (6.7%) and dimension mills (7.5%) in the last decade. Thus, it can be concluded that the direct processing systems can be more profitable than current sawmills and dimension mills.

The results of this analysis also show that the direct processing system can be profitable when processing low quality logs (Grade 3) as well as high quality logs (Grade 2) into value-added dimension products. This should add to the attractiveness of the direct processing system by offering a value-added processing opportunity for the abundant low quality hardwood timber resource that many sawmills experience difficulties in profitably processing.

It was found that dimension part price, green cutting yield, and drying degrade and remanufacturing loss are the three most important factors that affect the economic feasibility and profitability of the direct processing system. Because of its uncertainty, drying degrade and remanufacturing loss can become a very critical factor to the success of the direct processing system. If the drying and remanufacturing loss is too high, the direct processing system may not be able to achieve its high profit potential.

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