Economics of cutting hardwood dimension parts with an automated system

Henry A. Huber
Steven Ruddell
Kalinath Mukherjee
Charles McMillin

Abstract

A financial analysis using discounted cash-flow decision methods was completed to determine the economic feasibility of replacing a conventional roughmill crosscut and rip operation with a proposed automated computer vision and laser cutting system. Red oak and soft maple lumber were cut at production levels of 30 thousand board feet (MBF)/day and 5 MBF/day to produce furniture and kitchen cabinet parts. Potential before-tax savings per day were determined from yield improvement as a direct result of reducing only the kerf width and labor costs, and ranged from $3,440/day to $406/day at production levels of 30 MBF/day and 5 MBF/day, respectively. A daily lumber volume break-even analysis shows the required production level ranged from 5.8 MBF/day for a plant currently using 5 MBF/day, to 14.9 MBF/day for a plant capable of using 30 MBF/day. The after-tax net present values of the laser system investment were positive at production levels of 30 MBF/day, and negative at production levels of 5 MBF/day. Under the assumptions of this study, plant production levels and the price structure of lumber used were the important factors in determining the feasibility of making an Automated Lumber Processing System investment.

A technical and economic analysis of cutting wood parts with a laser under the control of a computer vision system to detect and identify defects and calculate optimum yields was reported by McMillin et al. (7) and Huber et al. (5). This initial analysis indicated that a plant using an Automated Lumber Processing System (ALPS) could save $1,210/day when processing 32 thousand board feet (MBF) of red oak lumber/day for solid wood furniture and $1,198/day if the same daily volume of sap gum were processed. These savings were based solely on a 5 percent increase in yield due to decreased kerf associated with laser cutting. In effect, such an automated plant could reduce its input of raw materials by 6 to 8 percent and produce the same volume of parts by increasing yield 5 percent.

Huber's (5) conservative financial analysis produced a very favorable net present value (NPV) and internal rate of return (IRR), indicating an excellent investment opportunity. Although this analysis presented the sensitivity of savings per day in relation to lumber grade and yield improvement, it lacked an analysis of savings required to at least financially break even at different ALPS investment levels.

Since the original analysis in 1982, several factors have affected the feasibility of implementing ALPS. Image processing technology has developed to higher levels of sophistication and increased demand for this technology has reduced costs. Vision systems that will identify defects based on specific product quality requirements are under development. Software has been developed to optimize the yield of boards with random lengths and widths for a specific cutting bill, given board geometry and defect locations. Both laser and vision systems are currently operating in hostile industrial environments in metal cutting, automotive, food processing, and wood processing industries and have shown reliability.

The Tax Reform Act of 1986 has also affected the feasibility of ALPS. With this legislation, the investment

The authors are, respectively, Professor, Dept. of Forestry, Michigan State Univ. (MSU), East Lansing, MI 48824; Purchasing Mgr., Nucraft Furniture Co., Grand Rapids, MI; Professor, Dept. of Metallurgy, Mechanics and Material Science, MSU; and Senior Scientist, USDA Forest Serv., Southern Forest Expt. Sta., Alexandria, LA 71303. This paper was supported in part by a USDA grant and the Eastern Hardwood Research Program, and was received for publication in May 1988.

Forest Prod. J. 39(5):46-50.

tax credit has been eliminated, the accelerated cost-recovery system changed, as well as corporate tax rates. Material costs associated with hardwood lumber have also escalated. These developments may affect the initial economic assessment of replacing a conventional crosscut and ripsaw operation with an automated machine vision and laser cutting system. The objective of this study was to update Huber's (5) 1982 financial analysis to account for provisions in the new tax laws, to reassess the changes in the technological costs, and account for changes in lumber and processing costs. Also considered was a sensitivity analysis to identify break-even savings per day and volume per day levels at two production and investment levels.

Method

The roughmill costs of cutting furniture and kitchen cabinet parts at two production levels with conventional equipment were compared with the costs of cutting the same parts using ALPS. Two wood species, soft maple (*Acer rubrum*) and southern red oak (*Quercus falcata* Michx. var falcata) are used in the analysis. These were selected because 1) both are currently extensively used in the furniture and kitchen cabinet industries; 2) the price ($/MBF) of grade lumber between species is currently relatively wide; and 3) the price differential between grades in soft maple is currently relatively narrow, while the price differential between grades for red oak is currently relatively wide. Price variations between species and within grades of the same species occur primarily from supply and demand forces working in the marketplace. This relative difference is an important factor in the decision to invest in ALPS.

The two production levels used were 30 MBF/day and 5 MBF/day, corresponding to a high and low production level. Two cutting bills were used, one for furniture and one for kitchen cabinet parts. The cutting bills differed primarily because kitchen cabinet cutting bills require more parts with shorter lengths and narrower widths than do furniture cutting bills.

The Optimum Furniture Cutting Program (2,4) (OFCP) was used to determine the least-cost combination of lumber grades required to produce the cutting bills at each production level. The OFCP was run for each cutting bill, species, and production level to determine the total costs and savings that occur with a 5 percent yield increase due to kerf reduction and a reduction in labor costs associated with automated laser cutting.

The daily production levels required to produce given cutting bills vary with lumber grade, processing costs, and yields. Therefore, the amount of lumber required to process the equivalent of conventional production of 30 MBF/day and 5 MBF/day depends on the number and size of pieces of each part in the cutting bills, the price structure of lumber, processing costs, labor costs associated with a given grade of lumber, and the yield.

The investment necessary to replace conventional wood cutting equipment with ALPS includes an automated lumber handling system, optical image analyzing equipment to identify and locate defects, and the laser cutting system itself. These costs are estimated based on similar hardware systems currently in use or under development. The costs of the conventional wood cutting equipment being replaced includes cut-off saws, straight line ripsaws, and salvage cut-off saws. The cost of this conventional roughmill equipment reflects two production levels. An estimated $90,000 and $440,000 investment would be required to conventionally process 5 MBF/day and 30 MBF/day, respectively.

The following assumptions were made in the analysis:

1. The number of pieces cut will be in proportion to the production levels of the plants for each product. For example, the high production plant (30 MBF/day) cutting bill will cut six times the quantity of lumber of the low production plant (5 MBF/day).
2. Both plants operate 250 days per year.
3. The difference in kerf reduction by cutting with a laser will increase yields by 5 percent/day. The economic effect of using an automated system will be to reduce the required lumber and labor inputs while producing the same quantity of parts.
4. Costs for lumber, including a premium, were based on the Hardwood Market Report (1), Southern Hardwood Section.
5. The initial capital investment required for the ALPS system for the 30 MBF/day production level is $1,100,000 and $590,000 at the 5 MBF/day production level.
6. The new depreciation schedules were developed using the 200 percent declining balance method over a 5-year period as provided for in the Internal Revenue Code Sec.168 (b) and (c).
7. No salvage value will be allowed in the depreciation schedule for the laser system as provided in the Internal Revenue Code Sec.168 (b).
8. The conventional wood cutting system being replaced is completely depreciated and carries a salvage value of 10 percent of the original purchase price.
9. The discount rate used was an after-tax cost of debt of 10 percent.
10. Taxable income at both production levels is greater than $335,000, therefore incurring a marginal tax rate of 34 percent.
11. The labor input cost required for a cutting laser will be 50 percent less than that for conventional woodcutting equipment.
12. The automated system produces parts at the same rate as the conventional wood cutting equipment.

These assumptions, along with the lumber, processing, and labor costs, are tabulated in Tables 1 and 2, and were used to determine the economic feasibility of ALPS investment. Financial analyses were based on two currently employed capital budgeting decision rules, NPV and IRR.

The NPV_i was calculated as described by Schall and Haley (8) as:

$$NPV_i = -I_i + \sum_{t=1}^{5} \frac{X_t}{(1+r)^t}$$

where:

I_i = initial investment of project i, which equals the

TABLE 1. — *Plant costs for lumber and processing.*

4/4 lumber costs ($/MBF)		
Grade	Southern red oak	Soft maple
FAS	$930[a]	$315
No. 1 Common	$585	$295
No. 2 Common	$275	$210

Processing costs (both species)

Process	$/MBF or computer entry
Delivery	50
Drying[b]	75 (−7.0% shrinkage)
Interest	10% per annum for 90 inventory days (based on lumber costs)
Stacking/handling	10
Gluing of random-width pieces	50

Roughmill labor costs (both species)

Grade	Conventional equipment	Laser equipment
	($/MBF)	
FAS	85	42.50
No. 1 Common	105	52.50
No. 2 Common	115	57.50
Value of salvage pieces	50 at 5% usage	50 at 5% usage

[a] Includes premium of $160 (a cost added to values published in *Hardwood Market Report* (1)).
[b] Includes additional processing charge added to values published in *Hardwood Market Report* (1).

cost of new equipment minus proceeds from sale of the old equipment

X_t = cash flow in year t, which equals (annual savings realized from new equipment)(1−tax rate) + (annual depreciation of new equipment)(tax rate)

t = periods in years

r = discount rate (after-tax cost of debt = 10%)

Σ = sum of the present values of five future cash flows

IRR_i (6) is calculated from the equation:

$$NPV_i = -I_i + \sum_{t=1}^{5} \frac{X_t}{(1+IRR_i)^t}$$

where:

IRR_i = rate that yields a net present value of zero for project i

I_i and X_t are determined from the previous net present value calculations.

Results and discussion

Processing costs

Two standard cutting bills were used based on data developed from past yield studies in representative plants. The two cutting bills were designed to process 30 MBF/day of lumber; one for cutting furniture parts and one for kitchen cabinet parts. Table 3 shows two sample cutting bills used to process red oak furniture and kitchen cabinet parts at production levels of 30 MBF/day. The number of pieces cut at 30 MBF/day were then reduced proportionately by a factor of 6 to obtain the cutting bills for a plant processing 5 MBF/day. The furniture cutting bill lengths and widths ranged from 15 to 76 inches and from 1 to 18 inches, respectively. The kitchen cabinet cutting bill lengths and widths ranged from 14 to 80 inches and from 1 to 12 inches. The minimum salvage was 12 inches in length by 1 inch wide for both products. The net

TABLE 2. — *Assumptions used in the financial analysis.*[a]

New ALPS	
Production level = 5 MBF/day	
Primary laser and optics (includes 1 line plus computer)	$350,000
Image analyzer/computer interface	90,000
Main control unit and XY table	100,000
Mechanized lumber handling equipment	50,000
Total cost	$590,000
Production level = 30 MBF/day	
Primary laser and optics (includes 2 lines plus computer)	$500,000
Image analyzer/computer interface	150,000
Main control unit and XY table (includes 2 lines and 1 computer)	300,000
Mechanized lumber handling equipment (more sophisticated than 5 MBF/day)	150,000
Total cost	$1,100,000
Price of old system	
Production level = 5 MBF/day	
Two cut-off saws	$20,000
One salvage saw	10,000
Two straight line rip saws	60,000
Total cost	$90,000
Production level = 30 MBF/day	
Two optimizing cut-off saws	$200,000
Seven straight line rip saws	210,000
Three salvage saws	30,000
Total cost	$440,000
Salvage values and current book value of old system	
Production level = 5 MBF/day	$9,000
Production level = 30 MBF/day	$44,000

[a] Tax rate = 34 percent, debt rate (cost of borrowing funds) = 10 percent.

TABLE 3. — *Red oak furniture parts cutting bill for 30 MBF/day production level.*

No. of pieces	Length of piece[a]	Width of piece		Width[b]
	(in.)	(in.)	(1/8-in.)	
	Furniture parts			
1,786	15	10	0	R
171	18	5	4	S
979	24	12	0	R
171	26	4	4	S
2,090	34	18	0	R
389	36	3	4	S
637	38	2	4	S
637	40	6	1	R
637	42	7	0	R
380	49	6	1	R
350	55	6	1	R
300	61	1	4	S
400	62	1	4	S
450	74	1	4	S
95	76	1	0	S
	Kitchen cabinet parts			
1,183	14	5	4	S
5,618	15	12	0	R
1,774	18	4	1	S
4,731	24	3	1	S
4,731	26	2	1	S
2,957	28	2	4	S
2,957	30	1	4	S
799	38	8	0	R
799	42	1	0	R
770	44	6	0	S
591	53	1	4	R
591	60	0	1	S
178	62	1	1	S
591	74	1	1	S
709	80	1	1	S

[a] No fractional lengths were considered; however, the computer program will take fractional lengths to 1/8-inch increments.
[b] R = random width to be glued up; S = specified-size width.

TABLE 4. — *Daily savings from a 5 percent increase yield using optimum lumber mix.*

	Production level	
	30 MBF/day	5 MBF/day
	($)	
Furniture parts		
Red oak	3,440	573
Soft maple	2,445	407
Kitchen cabinets parts		
Red oak	3,394	566
Soft maple	2,435	406

TABLE 5. — *Cost and savings summary of red oak furniture cutting bill for 30 MBF/day production level.*

	Conventional roughmill	ALPS	Daily savings	Change
				(%)
Board feet cut (MBF)	32.4	30.0	2.4	7.4
Lumber cost	$12,360	$11,445	$ 915	7.4
Labor cost	$ 3,636	$ 1,688	$1,958	53.7
Processing cost	$ 5,717	$ 5,150	$ 567	9.9
Total cost	$21,723	$18,283	$3,440	15.8

TABLE 6. — *Net present value and internal rate of return for the ALPS investment.*

	Production level			
	30 MBF/day		5 MBF/day	
	NPV	IRR	NPV	IRR
Furniture parts	($)	(%)	($)	(%)
Red oak	1,398,500	56.4	−60,200	5.5
Soft maple	776,100	37.3	−164,000	−2.8
Kitchen cabinet parts				
Red oak	1,369,700	55.5	−64,600	5.2
Soft maple	769,900	37.1	−164,600	−2.9

TABLE 7. — *Daily savings and volume break-even point analysis.*

	Initial investment			
	$1,100,000		$590,000	
	Savings/day	Volume/day	Savings/day	Volume/day
Furniture parts	($)	(MBF)	($)	(MBF)
Red oak	1,205	10.5	670	5.8
Soft maple	1,205	14.8	670	8.2
Kitchen cabinet parts				
Red oak	1,205	10.7	670	5.9
Soft maple	1,205	14.9	670	8.3

roughmill costs were generated using OFCP (2,4).

Table 4 shows by product type, species, and production level, the potential savings per day that could be realized by installing a laser cutting/image analysis system. These savings are primarily the result of the combination of the 1) price structure of lumber between species and between grades of the same species; 2) increased 5 percent yield due to reduced kerf; and 3) reduced labor costs associated with automation in ALPS.

Huber (3), using two different cutting bills for a conventional and punch cut type of roughmill, found yield increases due to kerf reduction of between 9.2 and 11.2 percent, depending on grade and type of cutting bill. Schumann and Englerth (9) found that sawkerf elimination could account for between 5.2 and 9.0 percent additional yields, depending on the lumber grade. In this analysis, a 5 percent increase in yield was conservatively used, and is due only to a reduction in, but not an elimination of, the kerf.

The savings per day in Table 4 were further broken down into three components: lumber, labor, and processing savings. Table 5 shows a summary of costs and savings for those components for a red oak cutting bill processed at 30 MBF/day. An increase in yield by reducing the kerf is realized as a reduction in the lumber required to produce the same cutting bill. In the case of red oak, a 5 percent increase in yield translates to a 7.4 percent reduction in the lumber required to produce the same number and sizes of parts.

Lumber, labor, and processing savings accounted for 27 percent, 57 percent, and 16 percent, respectively, of the $3,440/day total potential savings (Table 5). Similar component savings percentages were obtained for all cutting bills at both production levels.

For a furniture plant using red oak, the optimum mix of lumber is 26 percent No. 1 Common and 74 percent No. 2 Common. For kitchen cabinets using red oak, the optimum mix is 21 percent No. 1 Common and 79 percent No. 2 Common. For both furniture and kitchen cabinets using soft maple, the optimum grade is 100 percent FAS. This grade mix was generated by computer and may differ from plant usage, but is consistent with optimizing cost for these species.

Financial analysis

The financial analysis was based on the NPV and the IRR of the annual after-tax cash flows. Annual cash flows were developed from the savings per year realized for a plant at two different production levels and the previously stated assumptions.

Table 6 shows the results of this analysis. The NPV was positive for both furniture and kitchen cabinet plants at the 30 MBF/day production level but was negative at the 5 MBF/day level. The decision rule would be to accept projects with a positive NPV, as any positive NPV indicates an investment that would produce a net increase in the company's total value. The IRR indicates the rate of return at which the discounted after-tax cash flows equal the initial investment. In other words, the IRR is the discount rate at which the NPV equals zero. The decision rule here would be to accept projects with an IRR greater than the rate used to discount the cash flows; in this case, the cost of capital of 10 percent was used as the discount rate. The results of this analysis show that employing an ALPS system would be financially advantageous at the 30 MBF/day production level, but not advantageous at the 5 MBF/day level.

Within the relevant range of ALPS, capacity constraint savings is a positive linear function of production level. Therefore, the question that needs to be asked is, What level of production, under these assumptions, is needed before a plant will be willing to invest? Break-even analyses were done to determine the production levels and minimum savings per day required to justify an before-tax savings per day and production level required to make the NPV of the investment equal zero. Table 7 shows the savings per day and volume per day required to financially break even at two different investment and production levels. For example, a plant producing 5 MBF/day of red oak or soft maple furniture parts and requiring an initial investment of $590,000, would need to increase daily production to 5.8 MBF, and 8.2 MBF, respectively, before investing in ALPS would be economically feasible. From Table 7, the before-tax savings per day break-even point for a plant processing 30 MBF/day or 5 MBF/day of parts is $1,205/day and $670/day, respectively. If a plant cannot save at least these amounts (before-tax), it will not be returning the assumed 10 percent rate of return on the ALPS system.

Conclusion

The feasibility of replacing conventional roughmill machinery with an automated computer image analysis and laser system was found to depend primarily upon the plant production level and the price structure of hardwood lumber. The benefits derived in this replacement decision were solely based on the savings derived from increasing lumber yield 5 percent as a result of reducing kerf width with laser cutting and by reducing labor requirements due to automation. Other advantages, such as improved safety, no tool wear, and low energy consumption were not considered and, therefore, the results are considered conservative. Additional savings could also be expected from yield increases due to computer placement of parts on the lumber. Based on the results of the NPV/IRR analysis, investing in ALPS for a plant with a production level of 5 MBF/day would not be feasible, but would be an outstanding investment at a production level of 30 MBF/day. Daily break-even production levels ranged from 10.5 MBF/day to 14.9 MBF/day for plants producing parts at a level of 30 MBF/day, and ranged from 5.8 MBF/day to 8.3 MBF/day for plants producing parts at a level of 5 MBF/day.

The results of this study show ALPS technology is economically feasible at medium-sized production levels. More valuable wood, such as cherry and walnut, would provide a faster investment return than lower priced wood lows that an introduction of ALPS should first be initiated in plants using high-value species. The feasibility for a particular plant will differ depending on the company's specific costs. One interesting finding was that approximatetly 61 percent of the total potential savings per day resulted from reduced labor costs associated with an automated system.

At the present time, laser cutting speeds are slower than conventional sawing equipment and research on laser cutting is underway to improve cutting speed. Also, computer models that "cookie cut" lumber when given the board geometry, defect location, and a cutting bill, are presently being developed and tested (6). Such programs can be expected to significantly increase lumber yields.

Literature cited

1. Anonymous. 1987. Hardwood Market Report. Lumber Newsletter. Vol. 65. Memphis, Tenn.
2. Englerth, G.H. and D.R. Schumann. 1969. Charts for calculating dimension yields for hardwood maple. Res. Pap. 118. USDA Forest Serv., Forest Prod. Lab., Madison, Wis.
3. Huber, H.A. 1969. The economics of cutting hardwood lumber by two different methods. Ph.D thesis. Univ. of Michigan, Ann Arbor, Mich.
4. ________ and S.B. Harsh. 1977. Rough-mill improvement program. Woodworking and Furniture Digest 79(2):26-29.
5. ________, C.W. McMillin, and A. Rasher. 1982. Economics of cutting wood parts with a laser under optical image analyzer control. Forest Prod. J. 32(3):16-21
6. Klinkhachorn, P., J.P. Franklin, C.W. McMillin, and H.A. Huber. 1989. ALPS: yield optimization cutting program. Forest Prod. J. 39(3):53-56.
7. McMillin, C.W., R.W. Conners, and H.A. Huber. 1984. ALPS—A potential new automated lumber processing system. Forest Prod. J. 34(1):13-20.
8. Schall, L.D. and C.W. Haley. 1977. Introduction to Financial Management. McGraw-Hill, N.Y. pp. 82-84.
9. Schumann, D.R. and G.H. Englerth. 1967. Yields of random-width dimension from 4/4 hard maple lumber. Res. Pap. 81. USDA Forest Serv., Forest Prod. Lab., Madison, Wis.