Optimum edging and trimming of hardwood lumber

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Abstract

Before the adoption of an automated system for optimizing edging and trimming in hardwood mills, the performance of present manual systems must be evaluated to provide a basis for comparison. A study was made in which lumber values recovered in actual hardwood operations were compared to the output of a computer-based procedure for edging and trimming optimization. The optimization procedure was based on National Hardwood Lumber Association grading rules and market prices for green lumber. Using a sample of 120 red oak boards obtained from three sawmills in southwest Virginia, it was found that the respective mills recovered only 78, 65, and 62 percent of the value yielded by the optimization procedure. Given the level of value recovery actually attained by sawmills, it was concluded that substantial increases in value can be expected from optimizing edging and trimming. Other aspects of interest were investigated, such as the quality (grade) of lumber that benefitted most from optimization, the effect of volume loss on value recovery, and the relative impact on lumber value if each operation were optimized independently of each other.

Edging and trimming operations have been identified in several sawmill studies as processing steps where significant losses occur in lumber volume and/or value due to non-optimum operating procedures (2,3, 13). In softwood lumber manufacturing, edger and trimmer optimizers have been shown to increase volume recovery at these machine centers (1,8, 10). The need for edger and trimmer optimizers is now being recognized in hardwood sawmilling (4). It is hypothesized that benefits in the form of increased lumber value and/or volume may also be expected if optimization technology were applied to hardwood edging and trimming.

Before the development and adoption of an automated system for optimizing hardwood edging and trimming operations, the performance of existing manual systems should be evaluated. The primary goal in the move toward automation is to show that improvements can be made over the actual output of manual systems. Addressing this goal, the specific objectives of this study were to: 1) develop a general procedure for estimating the optimum edging and trimming solution for maximizing the lumber value obtained from unedged/untrimmed boards; 2) determine the difference between the value of 4/4 red oak lumber obtained with optimum edging and trimming, and that recovered in actual sawmilling operations; 3) compare the lumber value obtainable when only edging is optimized to the value obtainable when only trimming is optimized; and 4) identify the edging and trimming errors that most significantly contribute to the difference between the theoretical optimum and actual lumber values.

Methods and materials

The general approach of the study was to obtain a sample of unedged/untrimmed boards from several hardwood mills, collect data pertinent to lumber value evaluation, develop a computer procedure to estimate

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optimum edging and trimming solutions, and compare lumber value yielded by the optimization procedure to that actually recovered from the same boards by the sawmills.

Data collection

Three southwest Virginia sawmills were chosen for the study. Sawmill A is a family-owned mill that produces 3 to 5 million board feet (BF) per year. Sawmill B is part of a comparatively large corporation with an annual production of between 5 to 10 million BF. Sawmill C produces 2 to 3 million BF per year including a significant volume of pine lumber.

Forty unedged and untrimmed 4/4 red oak boards of varying lengths were pulled from the production line of each mill to comprise a total sample size of 120. A wide variety of boards was selected, including boards containing crook and taper. Although this study focused on red oak lumber, the following methods and procedures for estimating optimum hardwood lumber edging and trimming solutions can be applied to any number of hardwood species. Only those boards that had to go through both edging and trimming were selected. Thus, a requirement for the sample selection was that each board should have at least one waney edge.

A complete description of the appearance of each board after going through the headsaw was recorded. This included geometric shape and size, type, and location of all defects present. Getting the required data directly from the boards could take a considerable amount of time, during which board degradation due to drying could occur. This problem was circumvented by tracing the image of each board on a clear plastic sheet without measuring dimensions and coordinates. A sheet of clear plastic (1.5 by 13 ft.) was laid over each board (wane side up) with a 3/8-inch-thick plexiglass sheet between the plastic and the board for support. Defects appearing on the top face as well as the outline of all four edges were traced. Defects included in the study were wane, sound and unsound knots, stain, decay, pith, holes, checks, and splits. A coding system based on the codes used in Klinkhachorn's (5) lumber grading program was used to distinguish between defect types. The board was then turned over so that the opposite (wide face) was on top. Defects on this face were traced on the same plastic sheet as if looking through a transparent board. The result was a two-dimensional image in which defects on one face were distinguished from those on the opposite face by color-coding. The board and plastic sheet were then labeled with the same identification number.

After the drawing was completed, the board was returned to the production line to be edged and trimmed. The processed board was again retrieved and the place where it was actually edged and trimmed was marked on the plastic sheet containing the boards image.

Digitizing the board Images was the next phase of data collection. The method of representing defects by rectangular regions corresponds to the input information required by Klinkhachorn's (5) lumber grading program. Digitizing consisted of measuring the coordinates defining the outline of the edges and the location and size of defects. Each drawing was laid over a calibrated 1/4-inch grid with the lower left comer designated as (0,0). The coordinates of the lower left and upper right comers of the rectangle enclosing each defect were recorded, as well as the type of defect and the face of the board on which it appeared. To facilitate the digitization process, wane included not only the sloping side where bark was removed but also areas where wood was missing entirely. Wane was represented by a series of adjacent rectangles. The inner side of each rectangle (i.e., the side toward the board centerline) was made as close as possible to the actual outline of the board edge, as close as the 1/4-inch resolution would allow. With this procedure, the more irregular the shape of the edges, the more rectangles were needed to define the shape of the board. No adjustment was made for wane that would be eliminated when surfacing to standard thickness.

Optimization procedure

To appreciate the edging/trimming optimization procedure discussed next, a basic understanding of hardwood lumber grading rules is necessary. A detailed description of the grading procedure is beyond the scope of this paper, but can be found in other publications (7,9). Basically, lumber is evaluated using several criteria such as overall lumber size, type and size of defects, the relative area of clear-face cutting pieces, and the total lumber surface area or surface measure. Higher grades require larger lumber dimensions, and require a higher percentage of clear-face cutting areas in very few cuttings.

A computer procedure was developed for estimating optimum edging and trimming solutions. An optimum solution, in this context, was defined as the combination of edging and trimming lines that maximizes lumber value from a given board in dollars. Only the grading rules of the National Hardwood Lumber Association (NHLA) (4) were considered in the selection of the optimum solution. Other considerations such as potential furniture part yield and market specifications were not taken into account.

To estimate the optimum cutting solution for a given board, the general method was to 1) iteratively generate combinations of edging and trimming lines; 2) evaluate grade and volume yielded by each edging and trimming line combination; and 3) select the combination of edging and trimming lines that maximized lumber value. To implement these procedures, a computer algorithm (CUTCOMB) was developed. This program's function was to generate the different edging and trimming line combinations and decide for each cutting combination which defects had been edged or trimmed away, which defects remained on the board, and the new coordinates of each remaining defect relative to the current edging and trimming lines. The program algorithm and FORTRAN code can be found in Regalado's master's thesis (11).

Cutting line combinations were generated by varying the coordinates of each edging and trimming line between predetermined limits. To minimize the number of iterations needed to arrive at the optimum solution, Regalado (11) established several guidelines for setting these limits. The location of these limits are largely a function of the shape of the waney edges and the location of end defects. The so-called 50-50 percent wane rule for well-manufactured boards (6,9) was used as a general guideline for determining the placement of outermost edging lines. According to this rule, edging and trimming lines should be placed so that the amount of wane left on the board is approximately equal in area to the amount of clear wood discarded in the edgings. No cutting solutions beyond the boundaries set by this rule were considered, except in a few cases where such placement of edging lines became more restrictive than the wane allowed for the FAS grade. In these cases, the maximum allowable wane for the FAS grade was used as a guideline in placing the outer limits for edging line variation.

To utilize as much of the board as possible, the outermost trim lines were set at the farthest section where a full-width square end could be produced. Innermost edge and trim limits were based on the size and location of defects that appear at the edges and ends of a board (e.g., wane, splits, or stain), and hence, some degree of subjectivity was involved. A more detailed discussion of the guidelines for edging and trimming limits is found in Regalado (11).

CUTCOMB required two types of input data: 1) data describing the unprocessed board; and 2) the coordinates of the limits for varying edging and trimming lines. The digitized board images served as the data describing the unedged/ untrimmed board. The coordinates of the cutting limits just discussed were visually determined from the board diagram on the plastic sheet. Edging lines were varied using 1/4-inch increments. Half-foot increments were used for trimming variation. Thus, if there were n_1 increments between the edging limits for one edge of a board, n_2 increments between the edging limits for the other edge, and n_3 and n_4 trimming increments for the two board ends, a total of ($n_1 \times n_2 \times n_3 \times n_4$) combinations of cutting lines were evaluated.

Ripping to produce two lumber pieces was allowed in cases where these operations were thought to possibly improve lumber value beyond that obtainable from the iterative variation of cutting lines just discussed. This particularly applied to very wide boards where defects are concentrated on one side of the board width.

The output of the program CUTCOMB was data describing the lumber produced by each cutting combination, in the format accepted by Klinkhachorn's lumber grading program (5). The grading program was used to evaluate lumber grade for each iteration. Surface measure was numerically equivalent to board footage since 4/4 boards were used in the analysis. Necessary changes were made in the lumber grading program to accommodate the specifications for the FAS 1 Face grade, which was used in the analysis instead of the alternate grade of Selects. In the Appalachian region where the study's sawmills were located, the FAS 1 Face grade is traditionally used instead of Selects as the second highest hardwood lumber grade.

The NHLA grading manual recommends alternately rounding off 1/2-foot fractions to the next lower or higher foot in tallying surface measure. However, each board was considered individually in this study. Therefore, the procedure used in such cases must be consistent for all boards. In the computation of surface measure for grade evaluation only, Klinkhachorn's grading program always rounds off 1/2-foot fractions to the next higher foot. This reduces the bias that may otherwise potentially innate the grade due to a lower denominator (total board cutting units) in the computation of percentage clear cuttings, if the board surface measure were rounded down. On the other hand, when used for computing volume and value for the purpose of comparing edging and trimming solutions, 1/2-foot fractions were always rounded down to the next lower foot.

The following prices per thousand BF of green 4/4 Appalachian red oak were used in computing the lumber value (12):

FAS	$990
FAS 1 Face	$980
No. 1 Common	$520
No. 2A Common	$255
No. 3A Common	$195

For each board, the highest computed lumber value was the optimum value and the combination of edging and trimming lines that produced this value was the optimum cutting solution. In many cases, the optimum solution was not unique; several different cutting solutions could produce the same grade and volume.

Evaluation of actual yield

Actual lumber values were evaluated using the same computer programs used in optimization. Coordinates of actual edging and trimming lines were fed to the program CUTCOMB along with data describing the unedged/ untrimmed board. Since no iterative search for a solution was involved, the cutting lines were not varied but were kept constant and equal to the actual edging and trimming coordinates. As with the optimization procedure, results were input to Klinkhachorn's (5) lumber grading program, which computed the grade and volume of the lumber resulting from the edger and trimmer operator's decision.

Method for independent optimization of edging and trimming

True edging and trimming optimization involves the interactive optimization of the two operations. Whether the placement of edging lines is optimum for a given board cannot be ascertained until the subsequent trimming decision, and vice versa if trimming was done prior to edging. It is therefore ideal to have these two operations within one integrated processing system. However, since edging and trimming occur independently, it is of interest to investigate how much improvement in lumber value can be achieved if only one of these operations were optimized.

The method for the optimization of edging only followed the same steps as the general optimization procedure described earlier with one exception – the iterative search for the best cutting solution involved only the variation of edging lines. Coordinates of trimming lines at both ends of a board were kept constant and equal to the coordinates of actual trim. Similarly, in the optimization of trimming only, combinations of various trim lines were run to locate the optimum trim, given the coordinates of actual edging lines.

Results and discussion

Optimum versus actual lumber values

Figure 1A summarizes the optimum versus actual value comparisons for the three sawmills in the study. In terms of percentage value recovery, Mill A was able to obtain 78 percent of the optimum value, while Mills B and C recovered 65 and 62 percent of the optimum, respectively. The noticeably higher recovery in Mill A was attributed to edger operator performance. It was evident during the data collection at Mill A that the edger operator was knowledgeable about lumber grading rules. This did not appear to be so at Mills B and C.

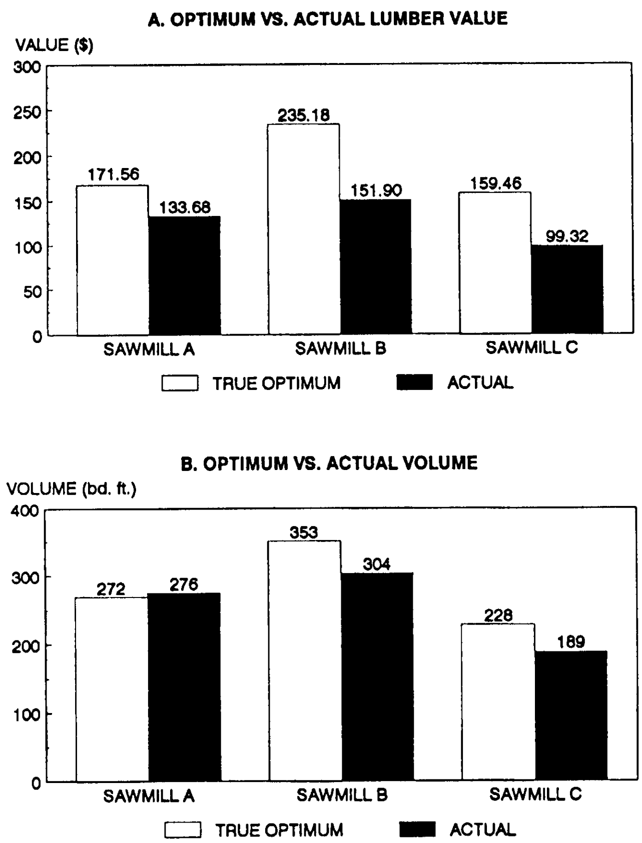

Figure 1. — Comparison of the true optimum versus the actual lumber value (A) and lumber volume (B) at each sawmill studied.

A detailed tabulation of the total optimum and actual lumber grade distribution is shown in Table 1. The table shows that of the 120 original boards, 46 graded No. 1 Common after edging and trimming at the mills. Of these 46 boards, 1 could have been FAS with optimization, and 23 could have been FAS 1 Face. Similarly, of the 38 No.2 Common boards, 8 could have been raised to FAS 1 Face and 18 pieces to No. 1 Common through optimum edging and trimming. For two boards with an actual grade of FAS, the optimum value lumber was found to be a lower FAS 1 Face grade. In these two cases, the drop in grade was offset by an additional gain in volume. In Table 1, numbers in parentheses are extra pieces produced by cross-cutting or ripping. The extra No.2 Common piece in the actual output was produced by cross-cutting at the mill's trim saw, while the extra four pieces tabulated under "Optimum Grades" were from boards for which the optimum solution involved ripping boards into two pieces.

To determine the grade(s) where value recovery was lowest, i.e., where the greatest difference between optimum and actual values occurred, boards were grouped together according to optimum grade. Table 2 gives a summary of this grouping. The total optimum value for all pieces with an optimum grade of FAS was compared to the actual value obtained in the sawmills from the same boards. Similar groupings and compar-

Table 2. – *Comparison of optimum and actual lumber values among lumber grade groups. The values represent totals for all three mills.*

Optimum grade	Optimum value	Actual value	Difference
	($)		
FAS	42.57	37.72	4.85
FAS 1 Face	344.60	214.38	130.22
No. 1 Common	135.72	98.13	37.59
No. 2 Common	33.17	26.65	6.52
No. 3 Common	10.15	7.83	2.32

TABLE 1. – *Optimum and actual lumber distribution among lumber grade groups for all three mills. Numbers in parentheses are extra pieces produced by crosscutting or ripping.*

		Optimum grades				
	Actual	FAS	FAS 1 Face	No. 1 Common	No. 2 Common	No. 3 Common
FAS	6	4	2			
FAS 1 Face	16		16			
No. 1 Common	46	1	23	22	(1)[b]	
No. 2 Common	38 (1)[a]		8	18	12 (1)[b]	(2)[b]
No. 3 Common	13			1	4	8
Below grade	1					1
Total	120 (1)[a]	5	49	41	16 (2)[b]	9 (2)[b]

[a]Extra piece produced by crosscutting board to two pieces.
[b]Extra piece(s) produced by ripping board to two pieces.

TABLE 3. – *Difference between actual and optimum value and the categories that explain the difference. Boards with equal optimum and actual values are not included in the tabulation.*

Board category[a]	No. of boards	Optimum value	Actual value	Difference
		($)		
Sawmill A:				
1 (grade improvement)	16	73.14	41.88	31.26
2 (volume increase)	7	33.13	27.92	5.21
3 (grade and volume)	1	3.19	1.79	1.40
Sawmill B:				
1 (grade improvement)	7	25.62	12.32	13.30
2 (volume increase)	18	112.33	93.50	18.83
3 (grade and volume)	14	94.63	43.89	50.74
Sawmill C:				
1 (grade improvement)	6	17.46	9.28	8.18
2 (volume increase)	12	60.78	47.02	13.76
3 (grade and volume)	13	59.36	21.19	38.17

[a]Category 1 = boards where the value difference was due only to the difference In grade: category 2 = boards where the value difference was due only to the difference in volume; category 3 = boards where the value difference was due to the combined effect of the grade and volume difference.

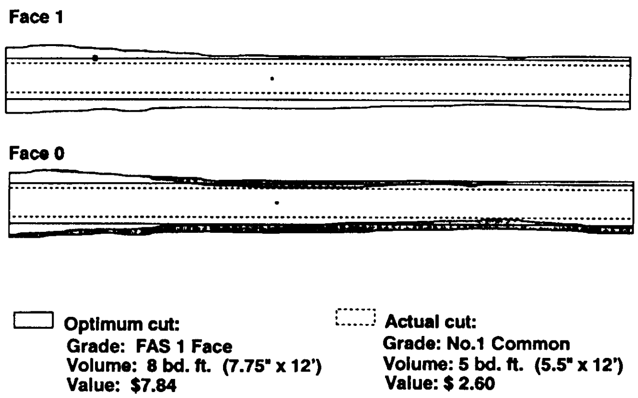

Figure 2. — Illustration of severe edging at the sawmill.

isons were made for the rest of the lumber pieces. It was found that pieces which optimally graded FAS 1 Face had the largest contribution to the overall difference between optimum and actual values. This was attributed to lumber price structure and the substantial number of boards that could have graded FAS 1 Face with optimization but actually graded only No. 1 or No.2 Common due to non-optimum edging and trimming at the mills. Thus, it maybe concluded that the greatest opportunity for value improvement through edging and trimming optimization is with boards that can potentially grade FAS 1 Face. To a lesser extent, the same was observed with potential No. 1 Common boards.

Figure lB compares actual volume recovery from mill edging and trimming and the volume recovery associated with the optimum solutions. Even when optimizing for lumber value, substantial volume recovery increases could be realized for Mills B and C, the two sawmills with the relatively lower value recovery. To further analyze volume/grade interaction with lumber value, boards with actual values that were less than optimum were grouped according to the following categories:

1. Boards where the value difference between optimum and actual values was due only to the difference in grade;

2. Boards where the value difference between optimum and actual was due only to the difference in volume;

3. Boards where the value difference was the combined effect of the volume and grade difference, i.e., both actual volume and grade were less than optimum.

From the 120 original unedged/untrimmed boards, only 26 were correctly edged and trimmed for maximum value. Therefore, the "Number of Boards" column in Table 3 shows the distribution of the remaining 94 boards within each category for each mill. For Mill A, the number of boards fell mainly under grade differences (Category 1). For Mills B and C, the number of boards fell primarily under volume differences (Category 2) or combined grade and volume differences (Category 3). Comparison of the "Optimum Value" and "Actual Value" columns in Table 3 indicates that for Mill A, the largest difference between optimum and actual lumber value was mainly attributed to differences in grade. For Mills B and C, the largest difference was observed to fall in the third category. Analysis of some individual boards in Mills B and C revealed that grade was actually lowered by excessive loss of volume. The excessive volume losses resulted in insufficient clear cutting units or in not satisfying the minimum size requirements for the next higher lumber grade. Thus, differences in lumber value in Mills B and C were inmost cases associated with excessive loss in volume due to severe edging and trimming.

Figure 2 shows a specific example of severe edging at Mill C. The optimization procedure produced a board with a grade of FAS 1 Face and a volume of 8 BF. All wane was unnecessarily eliminated in the actual sawmill solution, which dropped the board width to 5.5 inches. The minimum width for the FAS 1 Face is 6 inches. Thus, despite having a large defect-free area, the board graded as No. 1 Common with a volume of 5 BF. This particular board illustrates the result when operators fail to incorporate lumber grading rules into their edging or trimming decisions.

Result of independent optimization of edging and trimming

Figures 3A and 4A show how lumber values from edging-only optimization and trimming-only optimization, respectively, compare with the optimum edging and trimming solutions. With edging-only optimization, an overall average value recovery of 93 percent of the optimum was obtained, while an overall average of 75 percent was obtained with trimming-only optimization. As mentioned earlier, the total number of correctly edged and trimmed boards was 26 out of 120. In Mills A, B, and C, the number of boards correctly edged were 22, 3, and 12, respectively, and the number of boards correctly trimmed were 27, 29, and 29, respectively. These findings suggest that mills do a good job at trimming. Therefore, edging optimization will have a greater impact on lumber value than trimming for waney edged boards.

As discussed earlier, the loss in lumber value in Mills Band C was mostly attributable to severe volume loss. As seen from the volume charts in Figures 3B and 4B, edging optimization had a greater effect on volume recovery than trimming optimization – an observation indicating that in Mills B and C, much of the recoverable volume loss occurred at the edger.

This discussion does not imply that edging is a more important operation than trimming, since more boards typically go through the trimmer than the edger. However, it is the conclusion of this study that for boards that undergo both operations (i.e., waney-edged boards), errors are more likely to occur in edging than in trimming. This is one consideration if an optimizer were to be developed for one operation or the other. In any case, the higher values obtained with optimizing either procedure compared to actual values in Figure 1A imply that value improvements are possible even if only one operation were optimized.

Summary and conclusions

A computer-based procedure for estimating optimum edging and trimming solutions for unedged/untrimmed boards was developed. The procedure was applied to 120 sample red oak boards obtained from 3 sawmills in southwest Virginia. The output of the optimization procedure was compared to the lumber values that sawmill operators actually recovered from the same boards. The following are the conclusions drawn from the results of the study:

1. Manually determined edging and trimming solutions usually do not achieve the maximum values obtainable from red oak boards. Value recoveries of 78, 65, and 62 percent of the simulated optimum were achieved in the hardwood mills tested. Given this level

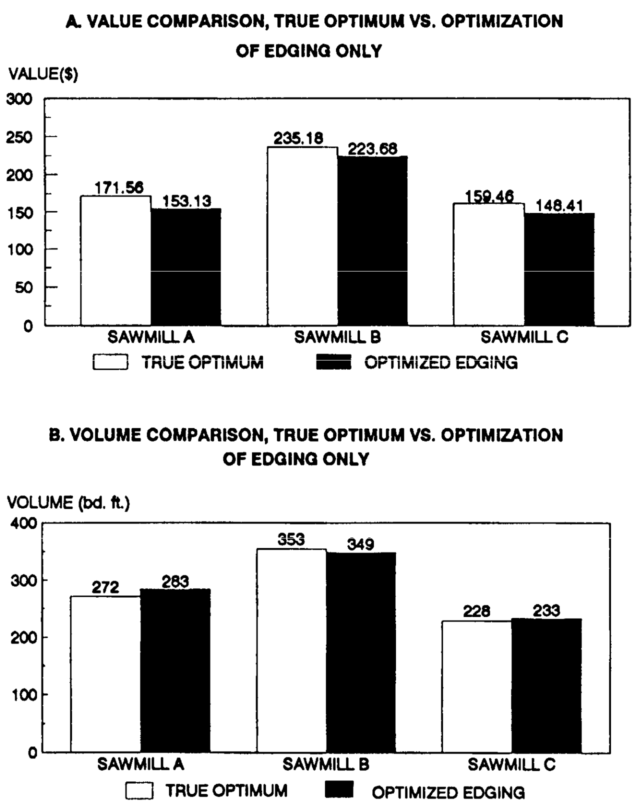

Figure 3. — Comparison of the true optimum versus edging-only optimization for lumber value (A) and lumber volume (B) at each sawmill studied.

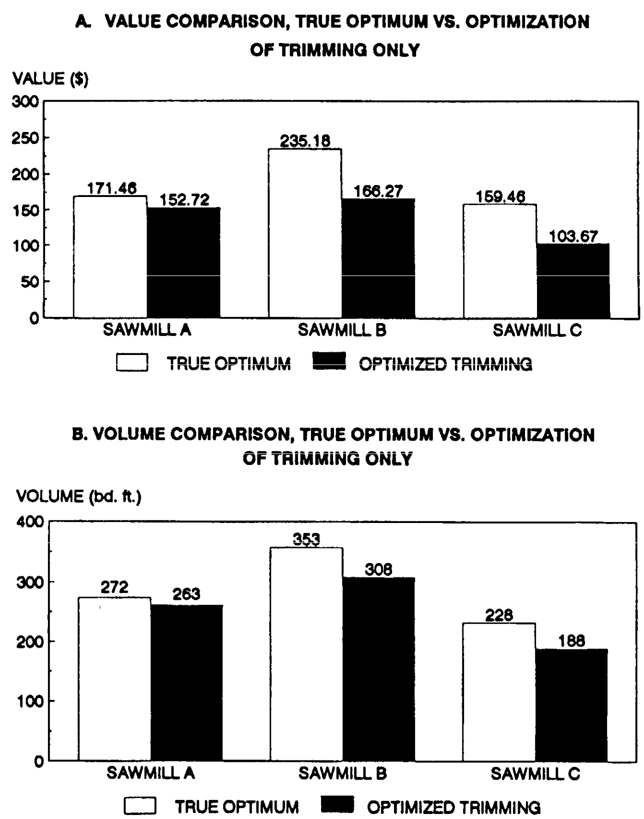

Figure 4. — Comparison of the true optimum versus trimming-only optimization for lumber value (A) and lumber volume (B) at each sawmill studied.

of lumber value recovery attained by sawmills, it can be concluded that substantial increases in value can be expected from edging and trimming optimization.

2. The practice of overedging was found to be the main factor that contributed to the low lumber value recovered in some hardwood mills.

3. The greatest opportunity for value improvement through edging and trimming optimization is with boards that can potentially grade FAS 1 Face, and to a lesser extent, with boards that can optimally grade No. 1 Common.

4. By independently optimizing edging and trimming waney-edged lumber, it was found that edging has a greater impact on lumber value than trimming.

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