Value of defect information in automated hardwood edger and trimmer systems

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Abstract

Due to the limited capability of board defect scanners, not all defect information required to make the best edging and trimming decision can be scanned for use in an automated system. The objective of the study presented in this paper was to evaluate the lumber value obtainable from edging and trimming optimization using varying levels of defect information as input. In an earlier study (5), a computer-based procedure for estimating optimum edging and trimming solutions was developed. The same procedure was used In the optimization experiments in this study. Instead of complete defect data that the procedure ideally requires, a combination of selected defect types was used for each optimization experiment. The sample for the study consisted of 120 unedged/untrimmed red oak boards collected from three hardwood mills. The value recovery calculated from the different defect information categories is presented and compared to the lumber values calculated from complete board defect data, as well as to the lumber values actually obtained in the sawmill from the same boards. The results showed that it is possible to obtain lumber values higher than actual sawmill output from a computer-based edging and trimming optimization procedure even if not all board defects are considered.

The first part of a continuing study on hardwood edging and trimming dealt with establishing the potential for improving dollar value recovery from red oak boards through edging and trimming optimization (5). A procedure for estimating optimum edging and trimming solutions was formulated and applied to a sample of unedged/untrimmed boards. In the three sawmills studied, it was found that actual lumber value obtained in each respective mill ranged from 62 to 78 percent of the optimum. Furthermore, although the optimization procedure was based on maximizing lumber value in dollars, the volume yield indicated by the optimized solutions was also substantially higher than the actual yield in two of the mills. It was therefore concluded that the manually operated edging and trimming systems used in these mills do not achieve the maximum obtainable value from the boards being processed, and that significant increases in value can be expected through optimizing hardwood edger and trimmer systems.

The computer algorithm for the optimization procedure used to arrive at the figures just cited was based on one important assumption: All information required for determining lumber grade can be detected. This information includes board geometry and the location, size, and identification of all features considered as defects by the National Hardwood Lumber Association (NHLA) (3) grading rules. While significant advances have been made in defect detection research, the type of detection system that can provide all of this information has not yet been developed. Systems that are considered technically feasible at present are able to detect only some of the features required for accurate lumber grade evaluation. For

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example, laser systems that give only wane or board geometry information have been applied in industrial operations for many years (9). A computer vision system that uses a camera can locate defect areas of a board but has difficulty in identifying the type of defect (1). Thus, a practical matter to address is how much lumber value recovery can be expected with limited input information for determining edging and trimming solutions.

The objective of this study was to evaluate lumber values obtainable from edging and trimming optimization given that information on only certain types of hardwood lumber defects is available. Different scenarios of available information are considered and the lumber values obtained from each are compared to those where decisions are based on complete board defect data.

Method and materials

The experiment focused on edging and trimming optimization based on the following four combinations of defect information:

1. Wane information only;
2. Wane, checks, splits, shake, and holes;
3. Wane, sound knots, unsound knots, and decay;
4. Wane and the location and size of all other defects without defect type identification.

Intuitively, board geometry is a basic information requirement for determining cutting solutions. Thus, wane was included in all input defect combinations. The combinations of defects listed were grouped according to common characteristics that make them identifiable by a particular kind of scanning system. Defect groups 1 and 2 can be detected by measuring variations in board thickness, with group 2 requiring a higher resolution system. An example of systems that detect variations in board thickness are laser scanner systems, which have been used for some time in the softwood industry (4,9). Knot and decay defects in group 3 are detectable by scanners based on wood density differentiation, e.g., x-ray systems (7). Group 4 defects can be detected by color scanning systems that are able to determine the presence of features but are not accurate in defect type recognition (1).

Data from the same 120 boards collected in an earlier study (5) were used. Forty unedged/ untrimmed 4/4 red oak boards were collected from each of three hardwood mills. 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 wide variety of boards was selected including boards containing crook and taper. A complete description of the appearance of each waney-edged board was recorded. This description included geometric shape and size, type, and location of all defects present. After the board information was recorded, 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 recorded. The surface measure of lumber produced from the boards ranged from 2 to 13 feet with an average surface measure of approximately 7 feet. Also, 57 percent of the resulting lumber graded No. 1 Common or better.

The coordinates defining board geometry and the location and size of all recorded defects were digitized using a 1/4-inch resolution. The type of each defect was coded as well. Thus, the database for the study contained all information pertinent to lumber grade evaluation. Furthermore, actual and optimum values and solutions were previously determined for each board. A more detailed description of the data collection, actual lumber value determination, and value optimization procedures is found in previous papers (5,6). For consistency and comparison purposes, the green 4/4 red oak lumber prices for September 1989 (8) that were used in the original study are also used in this study.

Procedure for finding edging and trimming solutions

Optimization procedure

As discussed in a previous paper (5), optimum cutting solutions were found by iteratively generating combinations of edging and trimming lines, comparing lumber values from the different edging and trimming line combinations, and selecting a solution that gave the highest value. Lumber values resulting from the optimum solution were computed based on volume and grade according to NHLA rules. Similarly, actual lumber values were determined using the information collected at the mill as to where the boards were actually edged and trimmed. Potential furniture yield and market specifications on allowable wane were not taken into account. For evaluating lumber grade, Klinkhachorn's (2) grading program was incorporated into the procedure. Five lumber grades were considered: FAS, FAS 1 Face, No. 1 Common, No.2A Common, and No.3A Common.

Cutting combinations were generated by varying the coordinates of each edging and trimming kerf line between predetermined limits. Several guidelines were established in placing these limits. For example, the so-called 50-50 percent wane rule for well-manufactured boards (5) was used as a general guideline for determining the placement of outermost edging lines, while the placement of the innermost edging limit was determined by wane width and the presence of other edge defects. Such limits defined the solution space from which the optimum was selected. In the original study (6), the coordinates of these limits were determined manually by visual inspection of the board images. The procedure for setting cutting limits was later incorporated into one integrated computer program for estimating optimum edging and trimming solutions. The optimization algorithm is discussed in more detail in previous papers (5,6).

Edging and trimming solutions based on group 1 information

To determine edging and trimming solutions based on wane with the objective of maximizing value in dollars, the same optimization program just described was used. However, instead of providing complete defect data necessary for finding the true optimum solutions, only wane data were furnished to the program. In the lumber grading phase of the procedure, the computer graded apparently clear boards (with the exception of wane) and selected the optimum solution accordingly.

Edging and trimming solutions based on group 2 information

The next optimization experiment performed was one in which defects characterized by discontinuities or breaks in wood were added to the wane information of group 1. The search for the edging and trimming solution proceeded as if wane, splits, checks, shake, and holes were the only defects present. It was observed that splits, checks, shake, and holes were not commonly found in the actual sample boards. As such, the defect information for many boards was the same as that for the previous experiment, i.e., consisting of wane data only.

Edging and trimming solutions based on group 3 information

As with the previous optimization experiment, the procedure for finding the edging and trimming solution using information on wane, knots, and decay areas was based on the assumption that all areas on the surface of a board not occupied by any of these defects were areas of clearwood.

Edging and trimming solutions based on group 4 information

This optimization experiment differed from the ones discussed earlier in that all defects were included. The analysis assumes that all defects other than wane were detected but not identified. Therefore, in addition to wane information, only the coordinates defining the boundaries of all non-wane defect areas were supplied to the optimization program. However, Klinkhachorn's (2) grading routine requires defect identification information. Hence, an *artificial* input had to be selected to identify all non-wane defects. Stain was selected as the artificial input because it is a sound defect and has no restrictions on size, even for the higher lumber grades. The selection of an unsound defect with dimensional limitations would have made the boards appear more defective than they actually were. Thus, the optimum edging and trimming solutions would be biased for lower grade boards.

The optimization experiments just described estimate the optimum placement of edging and trimming lines based on the limited amounts of defect information inputted. Using the area defined by these edging and trimming lines, a lumber value was computed based on all the defects contained within this area. This lumber value was used to assess the performance

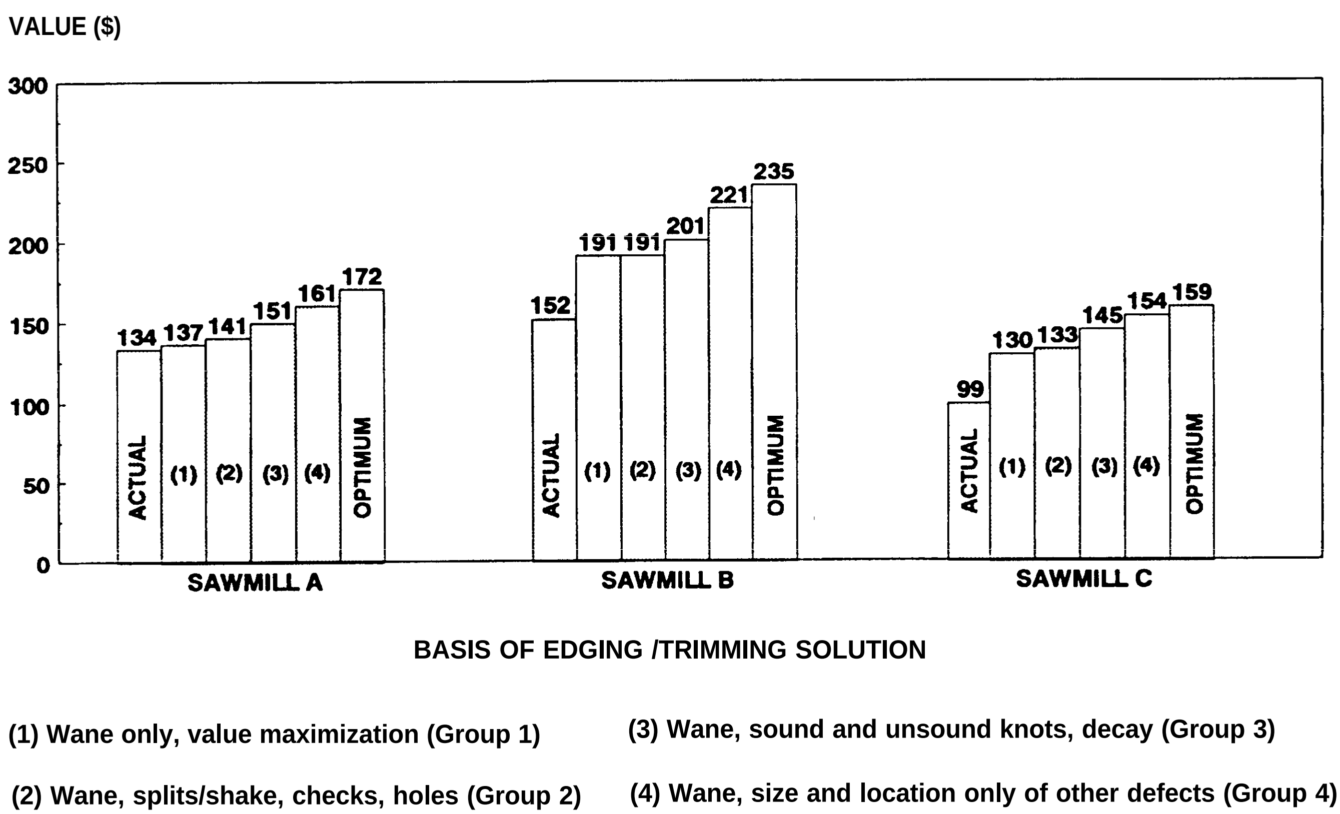

Figure 1. — Lumber value recovery from the different edging and trimming experiments.

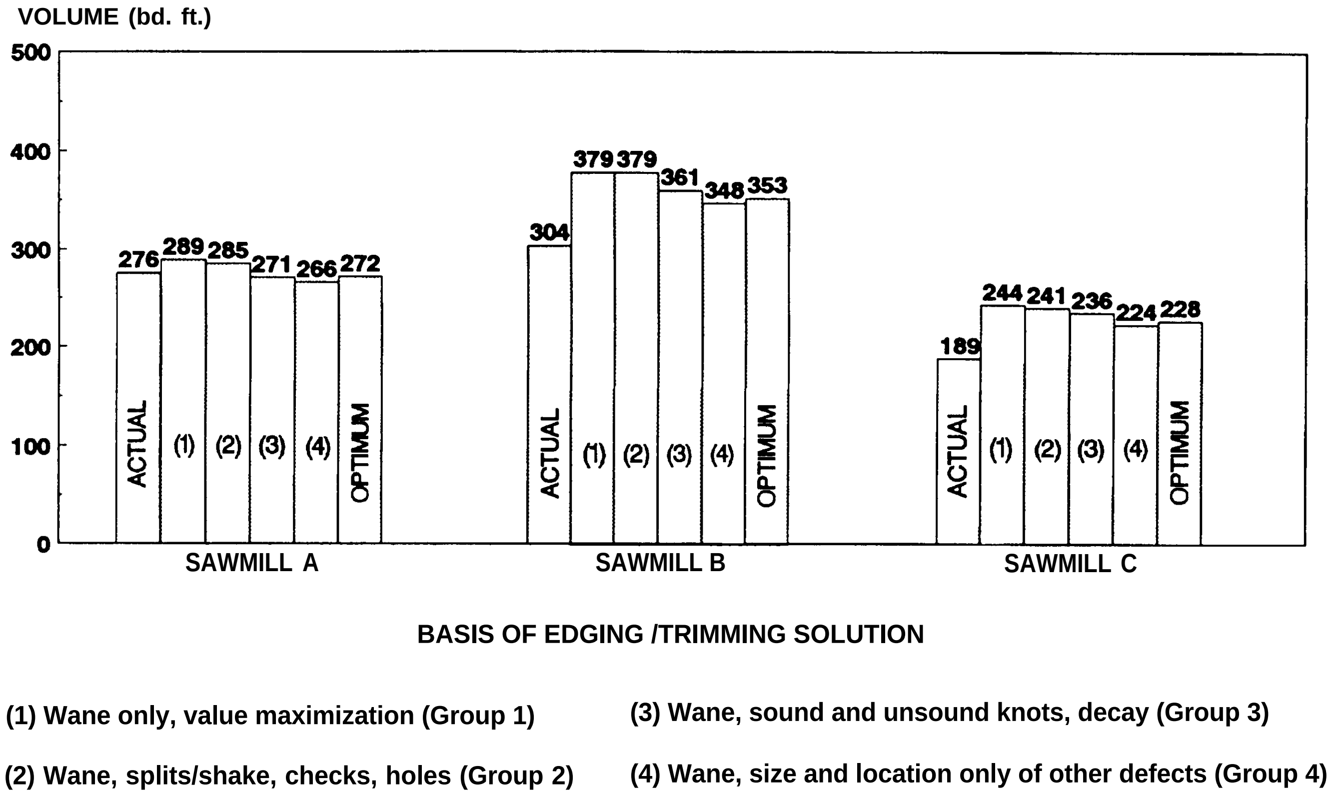

Figure 2. — Lumber volume recovery from the different edging and trimming experiments.

of each optimization group compared to the actual and optimum lumber values.

Results and discussion

The results of the study are summarized in Figures 1 and 2 and Table 1. The numbers in Table 1 are lumber values recovered from the different optimization experiments expressed as a percentage of the optimum value. As shown in Figure 1, all optimization experiments resulted in higher value recoveries than actual sawmill output. However, for mill A, a paired t-test showed that the 2 percent difference ($134 vs. $137) between actual values and values from computer optimization based on wane only was not statistically significant. During data collection at the mill, it was found that the edger operator in mill A was familiar with the NHLA grading rules, whereas the same was not observed with the operators in the other two mills.

The results in Table 1 show that a potential does exist to exceed the value recovery attained by manual edging and trimming systems by the use of computer optimization procedures even if only a limited amount of board defect information is available. The results also indicate that, in general, lumber value recovery from edging andtrimming optimization increases with the number of defect types used in the input data. Thus, the optimization based only on wane information yielded the lowest value recovery (an average of 81% of the optimum), while optimization based on the location and size of all defects gave the highest value recovery (an average of 95% of the optimum).

TABLE 1. – *Value recovery from edging and trimming optimization each of the four different board groups studied, expressed as a percentage of the optimum.*

	Actual	Group 1	Group 2	Group 3	Group 4
	(%)				
Mill A	78	80	82	88	94
Mill B	65	81	81	86	94
Mill C	62	81	83	91	97
Average	68	81	82	88	95

The defect type classification used in this study followed the same system used in Klinkhachorn's (2) lumber grading program. In information group 2, shake defect was classified under the same type as splits. Decay in group 3, on the other hand, included not only rot (wood deterioration due to fungal attack), but also bark pockets because no separate classification was made for the latter defect in the grading program. In effect, there were essentially the same number of defect types included in information groups 2 and 3. Value recovery from using information group 2 was only marginally higher than the wane-only group (82% vs. 81%, shown by a paired t-test to be not significantly different). The results of the optimization using group 3 was substantially greater (88% vs. 81%). This observation may be attributed to the fact that the defects in group 3 were more commonly found on the boards in the sample studied. Table 2 shows the frequency of occurrence of each defect type in terms

TABLE 2. – *Frequency of occurence of each defect type.* [a]

Defect	Frequency
	(%)
Stain	74
Checks	7
Sound knots	76
Unsound knots	69
Wane	100
Spilt/shake	28
Pith	1
Holes	19
Decay	76

[a]For example, 74 percent of the 120 boards had stain.

TABLE 3. – *Value distribution among different grades for each information group.*

	Actual	Group 1	Group 2	Group 3	Group 4	Optimum
	($)					
FAS	37.72	36.76	37.60	40.47	41.31	42.57
FAS 1 Face	214.38	264.68	271.56	300.96	335.47	344.60
No. 1 Common	98.13	114.97	115.25	115.15	119.18	135.72
No. 2A Common	26.65	32.51	31.99	30.60	30.60	33.16
No. 3A Common	7.83	9.42	9.42	9.80	9.38	10.15

of the number of boards out of the 120 on which they appeared, e.g., 76 percent of the boards contained sound knots. The entries in the table do not reflect the number of times a particular defect type occurred per board. The results indicate that ignoring knots and decay areas in the calculation of edging and trimming solutions was more costly than excluding splits, checks, and holes.

There are two reasons why knowing only board geometry and the size and location of defects without information on defect type is not sufficient to always arrive at the true optimum solution. First, to determine whether a clear cutting can be made at any segment of a board, it is necessary to know whether the back of the cutting is sound or unsound. This requires information on the type of defects at the back of the cutting. Second, the higher lumber grades have restrictions on certain types of defects, e.g., average knot diameter, length and orientation of splits, etc. Obviously, these rules cannot be applied unless the defects involved are properly identified. In this study, all defects other than wane were input to the grading program as stain, a sound defect with no special restrictions. The selection of the edging and trimming solution proceeded as if the back faces of all clear areas were sound and no rules concerning the dimensions of certain defect types were violated. Nevertheless, a high overall average value recovery was obtained with information group 4 (approximately 95% of the optimum value).

To determine the relative performance of each optimization group among the different lumber grades, boards were grouped according to optimum grade. For example, all pieces of lumber that graded FAS according to the optimum solution were assigned to the FAS group, even though these boards may have been assigned a different grade based on other optimization groups. The value of the boards in these groupings was computed using 1) the actual solution; 2) solutions obtained from each of the optimization groups; and 3) the optimum solution. Table 3 gives a summary of this comparison. All pieces that graded FAS 1 Face with the optimum solution would have a total optimum value of $344.60. For this same group of boards, edging and trimming solutions based on group 4 Information would yield a total value of $335.47; solutions based on group 3 information would yield a total value of $300.96, etc. The FAS 1 Face grade does not require sound back cuttings, therefore the lack of information on defect soundness in group 4 did not strongly affect the solutions from this category. This fact explains the relatively high value obtained from FAS 1 Face boards by edging and trimming optimization based on information group 4. The true optimum solutions for two of the boards in the FAS 1 Face group involved ripping to produce two pieces, a procedure not performed by the optimization program. Value recovery using group 4 information could have been even closer to the optimum if the optimization program accommodated cross-cutting or ripping to two pieces to increase value.

Figure 2 shows the volume recovery from each optimization experiment. The general trend indicated is that volume yield decreases with increasing information on defects. Using information group 1, the program treated both faces of a board as defect free (other than wane), and consequently allowed a larger surface measure in the solution. With more defects in the input, the program removed more wood to meet the requirements of the perceived optimum grade.

Comparison of Figures 1 and 2 indicates that to an extent, value recovery is inversely related to volume recovery. However, as exemplified by the lumber values actually obtained in mills B and C, an excessively low volume yield is accompanied by a low value recovery. Such findings may be explained by the way the grading rules and lumber prices are structured. A higher ratio of clear wood areas to total board area means a higher lumber grade. Thus, the removal of more defective areas increases this ratio and tends to raise the board's grade. The large gap in prices from one grade to another for red oak lumber compensates for the volume loss involved. On the other hand, severe cutting (as observed in mills B and C) typically involves the removal of clearwood along with the defects, which reduces clear cutting areas and may reduce the boards 'size below the minimum dimensional requirements of the higher lumber grades. In this case, both grade and volume (and consequently, lumber value) are adversely affected.

Summary and conclusions

A computer-based procedure for estimating optimum edging and trimming solutions for unedged/untrimmed hardwood boards was developed in an earlier study (5). The same procedure was used in this study to evaluate the lumber value obtainable if edging and trimming solutions were based only on limited board

defect information. The following categories of information data were used in the optimization study: 1) wane information only; 2) wane, checks, splits, shake, and holes; 3) wane, sound knots, unsound knots, and decay; and 4) wane and the location and size of all other defects. A sample of 120 red oak boards was used for the study. Lumber value evaluation was based only on NHLA grading rules.

The following conclusions can be drawn from the results of the study:

1. It is possible to obtain lumber values higher than actual sawmill output from a computer-based edging and trimming optimization procedure even if not all board defects are considered.

2. Lumber value recovery from edging and trimming optimization increases with the number of defect types included.

3. Using wane as the only basis for determining edging and trimming solutions, edging and trimming optimization yields an average value recovery of approximately 81 percent of the optimum value.

4. The addition of information on splits, shake, checks, and holes to wane data does not significantly increase value recovery over that attained by using wane information only.

5. Edging and trimming optimization based on wane, knots, and decay information gives an average value recovery of approximately 88 percent of the optimum value.

6. Edging and trimming optimization based on wane information and the location and size of all other defects without information on defect type gives an average value of 95 percent of the optimum value.

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