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Tony El-Radi

Steven H. Bullard

Stephen F. Austin State University, Arthur Temple College of Forestry and Agriculture, bullardsh@sfasu.edu

Philip Steele

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A performance evaluation of edging and trimming operations in U.S. hardwood sawmills

TONY E. EL-RADI AND STEVEN H. BULLARD¹

*Department of Forestry, Mississippi Agricultural and Forest Experiment Station,
Mississippi State, MS 39762, U.S.A.*

AND

PHILLIP H. STEELE

*Mississippi Forest Products Utilization Laboratory, Mississippi State University,
Mississippi State, MS 39762, U.S.A.*

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Edger and trimmer operators must make constant decisions in short time periods on the amount of materials to remove from boards produced in the sawmill. Their decisions directly affect the total volume, grade, and value of the boards, and they therefore directly affect the total value of lumber produced. In recent years, many softwood sawmills have installed computer controlled edgers and trimmers with scanners and optimizers to achieve higher recovery rates. Before similar, relatively expensive, technologies can be seriously evaluated for the hardwood industry, however, the current performance of edging and trimming operations must be known. Using a sample of 3360 boards, compiled from 37 hardwood sawmills located in 16 states, lumber grade, length, width, and dollar values obtained in edging and trimming operations were compared with values predicted by USDA Forest Service scientists for the same lumber. Significant differences between edging and trimming performance and predicted values were determined via statistical tests. A linear regression model was formulated to study the influence of overedging, overtrimming, and grade difference on the percentage of predicted dollar value achieved. It was found that most sawmills edged a relatively low proportion of their total production. In 99% of the boards, edging and trimming operations achieved similar values for grade and length to those predicted by the USDA scientists. The value of the lumber increased significantly as the amount of overedging decreased.

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Les opérateurs de déligneuse et d'ébouteuse doivent continuellement prendre des décisions dans de courtes périodes de temps sur la quantité de matériel à enlever des planches qui sont produites dans une scierie. Leurs décisions influencent directement le volume total, la catégorie et la valeur des planches et affectent par conséquent directement la valeur totale du bois d'oeuvre produit. Plusieurs scieries de bois résineux ont depuis quelques années installé des déligneuses et des ébouteuses contrôlées par ordinateur à l'aide de systèmes de captage et d'optimisation pour obtenir des rendements supérieurs. On devrait cependant connaître la performance actuelle des opérations de délignage et d'éboutage avant d'évaluer sérieusement de telles technologies pour l'industrie des bois feuillus à cause de leur coût élevé. Sur la base d'un échantillon de 3360 planches, provenant de 37 scieries de bois feuillus situées dans 16 états, la catégorie de bois d'oeuvre, la longueur, la largeur et la valeur en dollars suite aux opérations de délignage et d'éboutage ont été comparées aux prédictions des scientifiques du Service forestier du USDA pour le même bois d'oeuvre. Des tests statistiques ont été effectués pour déterminer s'il y avait des différences significatives entre les résultats des opérations de délignage et d'éboutage et les prédictions. Un modèle de régression linéaire a été construit pour étudier l'influence d'un délignage et d'un éboutage excessif et de la différence de catégorie sur le résultat obtenu exprimé en pourcentage de la valeur en dollars qui avait été prédite. Nous avons constaté que la plupart des scieries éboutaient un proportion relativement faible de leur production totale. Pour 99% des planches, les opérations de délignage et d'éboutage produisaient des valeurs semblables à celles qui avaient été prédites par les scientifiques du USDA. La valeur du bois d'oeuvre augmentait significativement lorsque l'éboutage excessif diminuait.

[Traduit par la rédaction]

Introduction

Lumber edging is the lengthwise ripping of a board to square the sides, to remove wane and other gross defects, and to rip wide boards to standard widths (13). Lumber trimming is crosscutting the end of the board to square it, to reduce the board to a standard length, to remove end defects, and occasionally to raise the grade (11). Edging and trimming operations directly influence board values, and because wood is removed in both operations, they also directly influence recovery rates. Recovery rates for manual edging, for example, have been shown to range from 60 to 85% (3, 5, 10).

¹Author to whom all correspondence should be addressed.

Edger and trimmer operators make decisions that impact board value and rates of lumber recovery. Their decisions, therefore, are very important to overall sawmill profitability. Decisions on how to maximize the value of each board must be made quickly, however. Edger feed rates, for example, typically range from 10 to 20 boards per minute, depending on the capacity of the edger, the number of edgers per headrig, and the dimensions of the final product.

The actual edge and trim solution applied to a board is the result of the interaction of a number of factors. Generally, the solution is guided to some extent by the National Hardwood Lumber Association (NHLA) grading rules (9). These rules limit wane on firsts and seconds (FAS) lumber

to one twelfth of the surface measure and to no more than 50% of total length on the board edges (9). The lower lumber grades, with the exception of first and seconds one-face (F1F) which is subject to the FAS rules on one face, have no stated limitation on wane. However, the rules do stipulate that all lumber must be "properly manufactured" and "be edged and trimmed carefully to produce the best possible appearance while conserving the usable product of the log" (9). Often, the FAS wane rules are applied to the lower lumber grades to meet the "properly manufactured" definition.

Some hardwood sawmills practice overedging for marketing reasons. Lumber containing a limited amount of wane is more attractive to the buyers, thus this marketing technique makes these sawmills more competitive in the market. Hardwood sawmills that produce for some export markets over-edge their lumber because of the export market's demand that the lumber have no wane.

Technologies have been developed to assist edger and trimmer operators in their decisions. Many sawmills have added the technology of shadow lines and laser lines to their edgers; the lines are rigged with the sawlines to make it easier for the operator to position the saws for maximum board value (13). Recently, many softwood sawmills have integrated computer technology, such as scanners and optimizers, with the edger and trimmer machines. Computerized edger systems have been shown to raise recovery rates for softwood sawmills to 97% of the theoretical optimum (1). However, this technology is relatively expensive; costs range from around \$750 000 for sophisticated systems with a 95% optimization level, to between \$200 000 and \$300 000 for systems with a 90% optimization level (3).

Despite the success of scanning technologies in softwood sawmills, their use in the hardwood industry has been limited. The reasons presented by Steele et al. (12) for limited implementation of "best opening face" technologies in hardwood sawmills also apply to the application of computer technologies for hardwood edging and trimming. Most hardwood sawmills cut grade lumber to random widths and 1-foot (1 foot = 0.3048 m) increments in length, while softwood sawmills cut lumber in 2-inch (1 inch = 2.54 cm) increments in width and 2-foot increments in length. Hardwood lumber production practices should therefore have a lower probability of substantial yield loss than softwood practices in case of poor sawline placement in edging and trimming (12).

Hardwood sawmills generally have lower levels of production than softwood sawmills, and it is therefore more difficult to justify investments in expensive technologies. Mason (8) stated that hardwood sawmills must cut 20×10^6 – 25×10^6 board feet of lumber per year to justify investments in modern computer technologies. Most hardwood sawmills, however, produce less than 10×10^6 board feet per year (2), much less than the production capacity required to recover large capital investments.

The current scanning and optimizing technologies used in softwood sawmills have some limitations when used for hardwood sawmills. These scanners and optimizers detect wane but are unable to recognize other defects. Consequently upgrading of the board through the selective removal of defects is not possible using the current technology. The present scanning and optimizing technologies, therefore, are not entirely suited for use in hardwood sawmills.

There have been previous studies on hardwood edging and trimming operations, and these studies generally report



FIG. 1. Distribution of 37 edging and trimming studies.

poor recovery rates (3, 5, 10). Most of these studies, however, were based on relatively small sample sizes. Before the potential for implementing expensive high-technology scanning and optimizing systems in the hardwood industry can be fully evaluated, a thorough assessment is needed of current manual edging and trimming operations. The objectives of this study, which analyzed data obtained from a relatively large number of study sawmills, were therefore: (i) to evaluate the performance of edging and trimming operations in the U.S. hardwood sawmill industry, and (ii) to identify areas where potential improvement is greatest for edging and trimming operations.

Materials and methods

Data

The data used in this analysis were obtained from Sawmill Improvement Program (SIP) studies of edging and trimming practices in 37 hardwood sawmills in the eastern United States (Fig. 1). The SIP was a cooperative effort of the USDA Forest Service, state and private forestry, and state forestry organizations. These agencies conducted studies of sawmill conversion efficiency at the request of sawmills. The SIP studies of hardwood sawmills were begun in 1977, and the data evaluated in this paper were from studies done between 1977 and 1987. This study includes only sawmills cutting lumber grades that meet the standards of the NHLA (9). Sawmills producing export lumber were not included in this sample.

In the SIP edging and trimming studies, a 100-board sample was recommended for each sawmill. In some sawmills, however, fewer boards were sampled; for the 37 sawmills, a total of 3360 boards were studied. The lumber thicknesses included were 1, 1.25, and 2 inches. Most of the sawmills in the study produced oak (*Quercus* sp.) lumber from species in the red oak family and the white oak family as their major product; however, a few sawmills cut a variety of other hardwood species. It was assumed that the percentages of lumber sampled by grade,

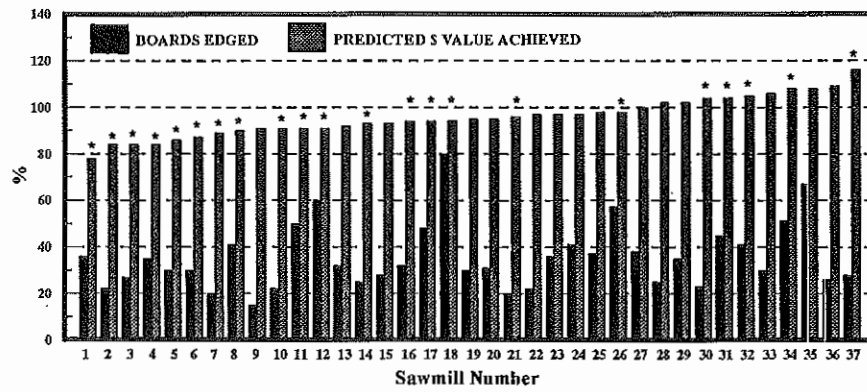


FIG. 2. Percentage of boards edged and percentage of predicted value achieved by sawmills (*Statistically significant difference between predicted and actual dollar values, $\alpha = 0.05$).

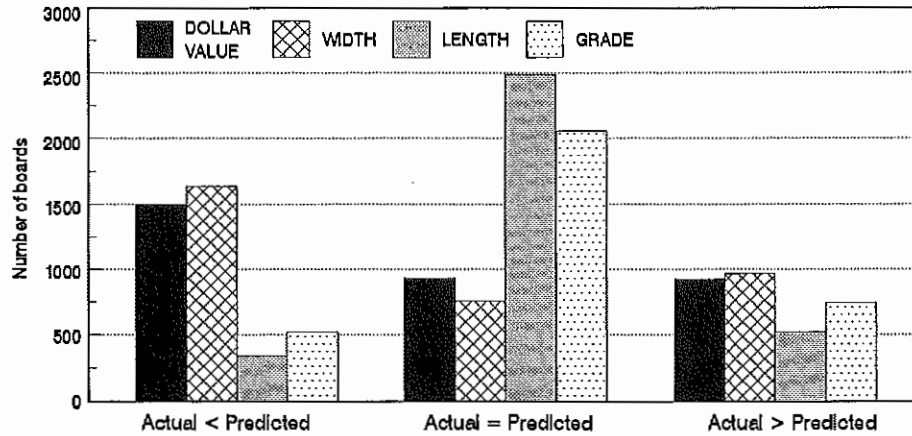


FIG. 3. Actual versus predicted values by board width, length, grade, and dollar value.

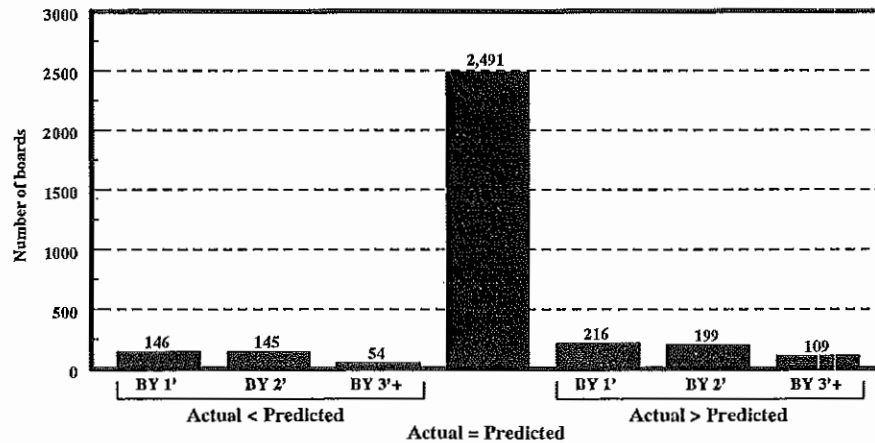


FIG. 4. Actual versus predicted board length, by category of length difference.

width, and length reflected average percentages of production in the sawmill.

Two data sets for edged width, length, grade, yield, and relative dollar value were compared for each board. The first set of values, referred to in this study as predicted values, was obtained by USDA Forest Service scientists using a clear overlay with an imprinted grid to assist in the calculation of the best size and grade combination for a board to yield maximum value by edging and trimming. Using the overlay, each board was hypothetically edged to obtain the optimum volume and grade. The FAS wane limitations stipulated by the NHLA rules (9) were applied to all grades in the study. It was presumed that this amount of edging was required to obtain properly manufactured lumber. An implication

of applying FAS wane-limitations to all grades is that where overedging is noted for some mills across grades, the overedging is probably extreme in the lower grades. After grading by USDA scientists, the boards were then put back into the stream of lumber going to the edger and trimmer. After the boards were edged and trimmed by the operators, the scientists again evaluated the lumber using the grid overlay, to determine the actual values obtained by edger and trimmer operators, referred to in this study as actual values.

The predicted and actual grades were calculated according to NHLA grading rules; hence, 0.5 board foot (1 board foot = 0.0009 m³) fractions were alternately rounded off to the next higher or lower board foot when tallying surface measure. Because

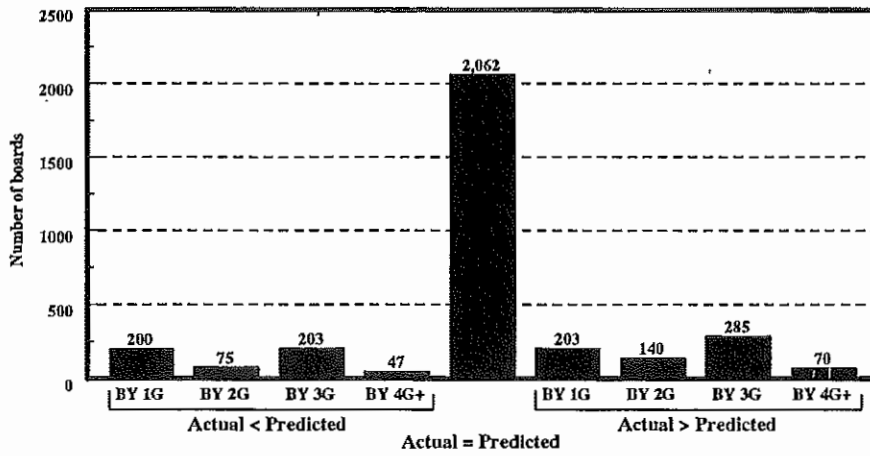


FIG. 5. Actual versus predicted board grade, by category of grade difference.

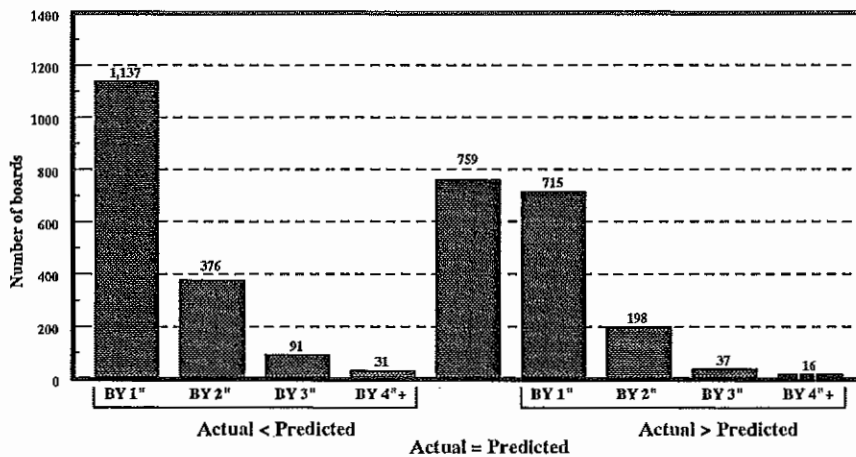


FIG. 6. Actual versus predicted width, by category of width difference.

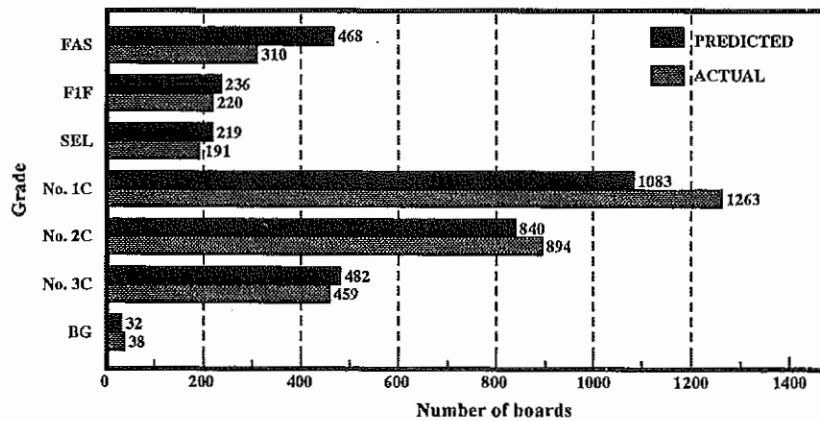


FIG. 7. Actual versus predicted grade, by grade category.

the data were collected in various locations and over an 11-year period, different sets of prices were used to compute lumber values; the prices used varied by location, time, and species.

Procedures

Edger and trimmer operator performance was evaluated by using paired *t*-tests to identify statistically significant differences at the 0.05 level between predicted and actual values for board width, length, grade, and dollar value. Predicted and actual values were compared for the total sample as well as for individual sawmills.

To examine the relative impact of width, length, and grade on

board value, the following linear regression model was specified:

$$PPVA = \beta_0 + \beta_1DW + \beta_2DL + \beta_3DG$$

where PPVA is the percentage of predicted value achieved, β_0 is the intercept, β_1 - β_3 are the regression coefficients to be estimated, DW is the predicted minus actual width (inches), DL is the predicted minus actual length (feet), and DG is the grade difference between predicted and actual values.

The variables DW and DL (the difference between predicted and actual width and length) represent the amount of overedging and overtrimming. To identify areas of improvement, only the

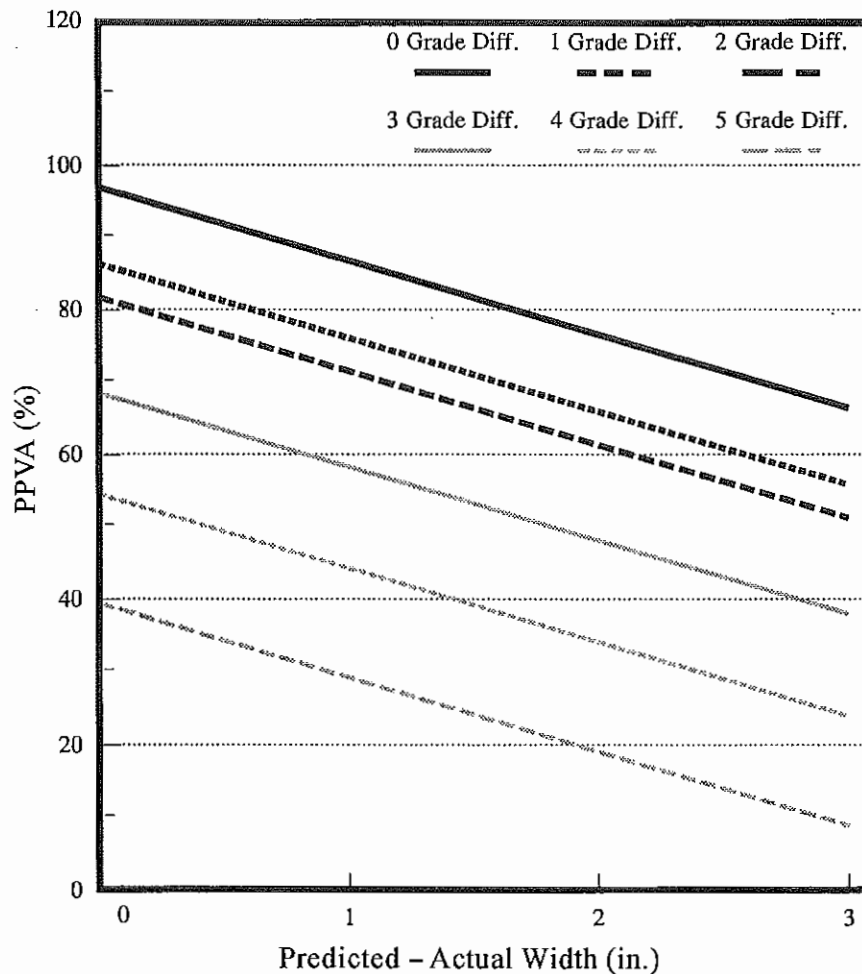


FIG. 8. Estimated relationship between width difference and the percentage of predicted value achieved.

TABLE 1. Estimated coefficients and regression coefficients for the model

Parameter	Estimated value	SE
β_0		
No grade difference	0.982*	0.047
1 grade difference	0.875*	0.048
2 grades difference	0.829*	0.048
3 grades difference	0.697*	0.048
4 grades difference	0.557**	0.054
5 grades difference	0.407*	0.047
β_1	-0.101*	0.003
β_2	-0.072*	0.003
Regression coefficients		
$F = 400.4 \quad R^2 = 0.64 \quad S_{y,x} = 0.009^a$		

^a $S_{y,x}$, standard error of the estimate.

*Significantly different from zero ($\alpha = 0.001$).

**Significantly different from zero ($\alpha = 0.005$).

boards that had higher predicted values for width and length were used to estimate the model parameters.

Because the sets of prices used to compute lumber values were collected over an 11-year period and varied by location, time, and species, the PPVA was used as the dependant variable in the model. The PPVA was computed as the actual board value divided by the predicted board value (then multiplied by 100). The dependent variable is therefore not influenced by differences in prices over time, and is also not influenced by differential price changes among grades. The PPVA is unaf-

ected by the relative price of different grades because each of the individual observations over time, actual and predicted, is based on the prices prevailing at the time of the SIP study. In general, PPVA reflects the relative level of overall edging and trimming efficiency.

The variable DG represents the difference in grade predicted for the board and the actual grade achieved. DG was a "dummy" variable to represent six classes; zero, or no grade difference, and differences of one, two, three, four, and five grades between predicted and actual boards.

Results

For most of the sawmills in the analysis, a relatively low proportion of total lumber production was edged. The proportion of lumber edged varied from 15 to 80% (Fig. 2), but only five of the 37 sawmills edged more than half of their production. There was no significant relationship between the proportion of lumber edged and overall efficiency as measured by the PPVA.

The overall mean PPVA for the 3360 boards studied was 99%, indicating that on average the operators achieved virtually the same results as the scientists. Predicted dollar value was significantly different from actual dollar value for 22 of the 37 sawmills (Fig. 2). Six of the 22 sawmills had PPVA values greater than 100%. In these mills, edging and trimming operations had higher average lumber values than the USDA scientists predicted. One reason for higher actual values at some mills is the application of FAS wane rules to all grades in the scientists' calculations. This, of course, may

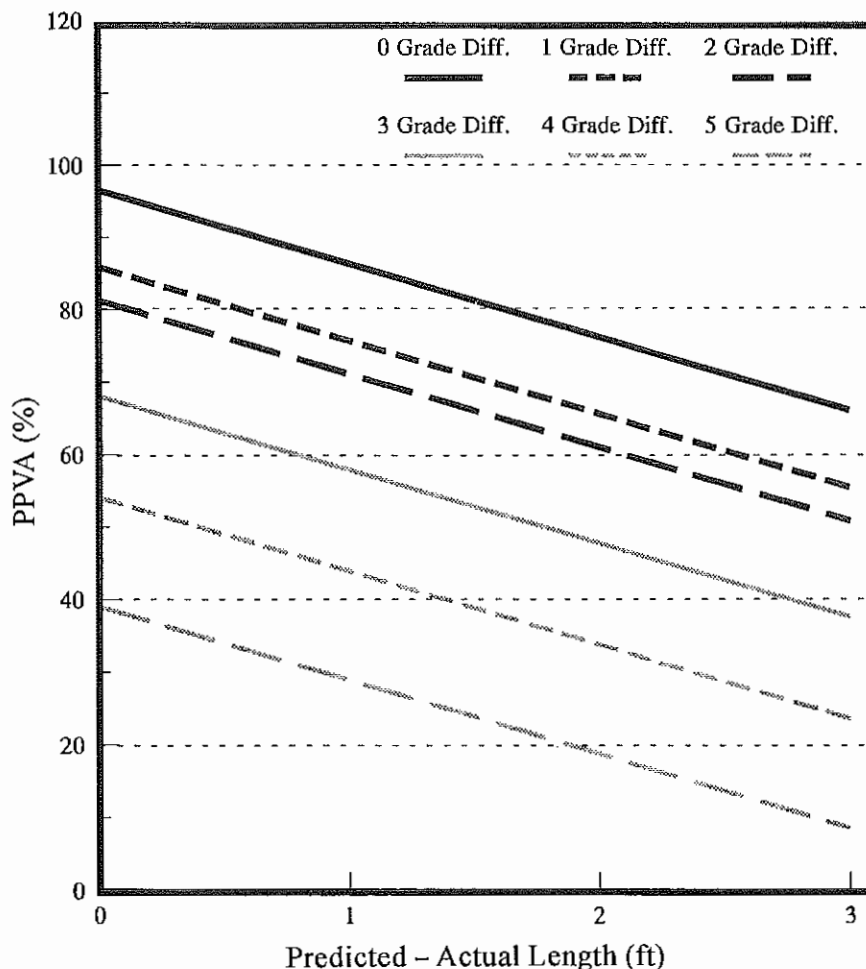


FIG. 9. Estimated relationship between length difference and the percentage of predicted value achieved.

not have been applied to lower grades at all mills. Sixteen sawmills had PPVA values less than 100%.

Figure 3 compares the predicted values for width, length, grade, and dollar value with the actual values for the 3360 boards studied. The figure illustrates the close relationship between width and dollar value, and also shows the relatively high number of observations (2491) for which predicted and actual board lengths were equal and for which grades were equal (2062). However, almost half of the boards had been overedged; 1635 boards had actual widths less than predicted. The relative edging performance of manual operations in obtaining predicted length and grade is also summarized in Figs. 4 and 5, respectively. For almost 75% of the boards, the trimming operation achieved an actual length equal to the length calculated as optimal by USDA scientists. In over 60% of the boards, the grades obtained by the operators were identical to those predicted. Actual values for width, on the other hand, were significantly lower than predicted values (Fig. 6). Approximately 49% of the boards were overedged, while 22% were edged the same as predicted.

Predicted and actual values for grade were compared for different grade classes (Fig. 7). Actual grade yield was significantly different from the predicted grade yield in two of the seven grade classes studied (FAS and No. 1 common). Of the 468 boards predicted as grade FAS, only 310 achieved that grade after edging and trimming. The predicted and actual grade division for No. 1 common showed a different distribution than the one obtained with FAS. The num-

ber of boards that graded No. 1 common after edging and trimming was 1263 boards, 180 more than predicted.

The relationship between the percentage of predicted value achieved and the predicted minus actual width and length for the six classes of grade difference is illustrated in Figs. 8 and 9 respectively. As the figures illustrate, the relationship between PPVA and overedging is downward sloping for all grade differences, indicating that as overedging increases the board value decreases. The coefficients of the regression model were estimated using the ordinary least squares method. The intercept and the regression coefficient estimates for DW, DL, and DG were significantly different from zero at the 0.001 level and R^2 was equal to 0.64 (Table 1). As expected, PPVA decreases with overedging and overtrimming. A decrease of one inch in width decreased the predicted value achieved by 10.16% (holding length constant at its mean). Similarly, a decrease of one foot in length decreased the predicted value achieved by 7.27% (holding width constant at its mean). The greatest decrease in PPVA due to grade reduction occurred when the difference between predicted and actual exceeded three grades.

Summary and conclusions

The performance of manual edging and trimming operations was examined and potential areas for improving lumber value recovery were evaluated for U.S. hardwood sawmills. A sample consisting of 3360 boards collected from 37 SIP sawmills, was analyzed via paired *t*-tests for statistical dif-

ferences between data predicted by USDA scientists and actual data obtained in edging and trimming operations. In 22 of the 37 sawmills studied, there was a significant difference between predicted and actual lumber value. The PPVA, which is the actual board value divided by the predicted board value in percent, was used as an indicator of edging and trimming efficiency in hardwood sawmills.

Edging and trimming operations in U.S. hardwood sawmills are efficient in terms of board length and grade; in 99% of the boards, edging and trimming operations achieved similar values for length and grade to those predicted by USDA scientists. Board width, on the other hand, was the main variable influencing the dollar value of the lumber. Edging therefore, had a greater impact on the dollar value of hardwood lumber than trimming. The significance of this result is underscored by the conservative application of FAS wane rules to all grades.

A regression model using predicted minus actual width (DW), length (DL), and grade (DG) as regressor variables and PPVA as a response variable was formulated to quantify the influence of overedging and overtrimming and grade difference on lumber value. The results of the regression indicate that a 1-inch difference in width would decrease the predicted value achieved by 10.16% (holding length constant), and a 1-foot difference in length would decrease the predicted value achieved by 7.27% (holding width constant).

The practice of overedging was the major factor contributing to the lower lumber value recovery. Removal of more material than necessary from the board is a potential result of several factors. The most obvious causes of overedging are sawmill management policy and operator error.

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