# THE INFLUENCE OF SAWKERF AND TARGET SIZE REDUCTIONS ON SAWMILL REVENUE AND VOLUME RECOVERY

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## ABSTRACT

Sawmills can implement quality control procedures to lower their lumber target sizes and/or sawkerf widths, but the economic benefit of such programs has been uncertain. A methodology using sawmill simulation to estimate the value and volume recovery from changes in sawkerfs and target sizes is demonstrated. A specific example for an interior British Columbia sawmill producing dimension lumber is described. Reductions in target sizes and sawkerfs were shown to significantly increase mill revenues. Target size and sawkerf reductions were found to have a much larger effect on sawmill revenue than on volume recovery. Reductions in green target sizes are shown to have a significantly larger impact on mill net revenues and recovery than sawkerf reductions. It was also found that producing 1-inch lumber in the product line significantly increases lumber recovery, but has a minimal effect on mill net revenue. Equations were developed that predict the net effect in revenue and volume recovery of specific changes in target size and sawkerf for the study mill.

Environmental restrictions and increasing log costs have caused many sawmills to look at new ways to extract more value from their raw material. One of the more traditional ways to accomplish this is to increase volume recovery. This can be done in several ways. First, sawkerfs can be reduced through improvements in saw design that reduce either the plate thickness or the side clearances of the saw. However, it has been shown that changes in these two saw design factors can lead to increased within-board sawing variation, or deviation through the cut (6). As sawing variation increases, target sizes must also be increased to prevent skip in the planing process (9). Therefore, there is a tradeoff that must be balanced between recovery gains due to a smaller sawkerf, and recovery losses from the resulting oversizing required.

A second way to increase volume recovery is by reducing lumber target sizes. Lumber is deliberately oversized in the sawing process to allow for shrinkage in the drying process and to allow planing to produce a smooth finish and accurate sizes. The amount of material that must be planed off the lumber to get a smooth finish depends primarily on three factors: 1) surface roughness due to sawing variation in the cut (within-board sawing variation); 2) size variations between sawn pieces due primarily to variability in the setworks (between-board sawing variation); and 3) size variability caused by irregular drying.

Quality control procedures can be implemented to reduce the variation in all three of these factors (3). For example, more careful attention to sawfiling practices or machine feed speeds can lead to reduced within-board variation.

Many sawmills are unsure whether to invest in quality control programs that result in smaller target sizes, to

embark on thin-kerf sawing programs, to do both, or neither. This is because the net change in actual lumber volume or value recovery due to these reductions in sawkerf and target sizes is uncertain. While it is known that smaller sawkerfs mean less sawdust, and smaller target sizes mean less planer shavings, actually quantifying these reductions into additional lumber recovery is a difficult process. The translation into mill revenue is even more difficult to quantify.

This paper describes a methodology that can be used to estimate the value and volume recovery from changes in sawkerfs and target sizes and demonstrates a specific example for an interior British Columbia sawmill that produces dimension lumber. Equations are developed to help estimate the net increase in mill revenue or volume recovery for sawmills similar to the example mill.

## BACKGROUND

Previous mathematical studies and computer simulations have shown that reducing sawkerfs and lumber target sizes has a great influence on lumber recovery. However, the results are different in each case, due to the complexity and varieties of factors other than kerfs and target sizes in each study.

There are essentially five changes in sawing strategies that can influence lumber and value recovery occurring as a result of sawkerf and target size reductions. These changes in sawing

A. Original pattern, BF = 97;
kerf = 0.17; target size = 1.70 in.;
for 2-inch boards

B. One extra board, BF = 102;
kerf = 0.14; target size = 1.70 in.;
for 2-inch boards

C. Extra length or width on top or
side boards, BF = 10; kerf = 14;
target size = 1.67 in.; for 2-inch boards

D. Different pattern, BF = 110;
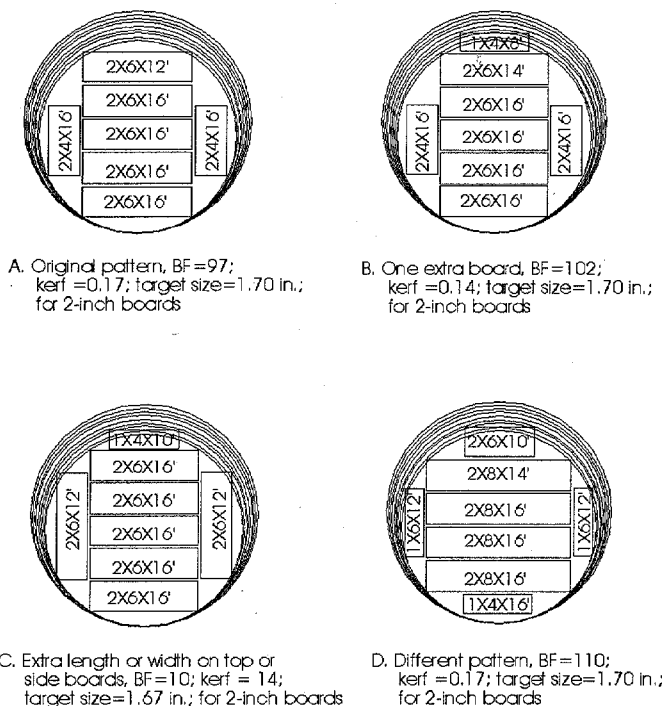kerf = 0.17; target size = 1.70 in.;
for 2-inch boards

Figure 1. — Effect of sawkerf and green target size changes on sawing patterns. All logs were 10.8 inches in diameter and 16 feet long.

strategies are discussed in order of increasing complexity.

1. *Increased number of boards*: In certain cases, an extra board can be added to the sawing pattern. This is likely to be most important when 1-inch lumber is produced in the product set. Volume and value recovery are always increased. The effect of this change is shown in **Figure 1** as the difference between sawing pattern A (the original) and pattern B, which has an extra top board.

2. *Increased length of existing boards*: The length of top and side boards in the patterns can be increased. Either volume or value recovery are always increased by this change. The effect of this change is shown in **Figure 1**, pattern C, where the top 2 by 6 and 1 by 4 are both increased in length by 2 feet compared to pattern B.

3. *Increased width of existing boards*: Where logs have significant taper, the width of top and side boards in the patterns can be increased. Either volume or value recovery (or both) are always increased. The effect of this change is shown in **Figure 1**, pattern C. In this example, a wider but shorter jacket board is found to generate higher revenue.

4. *Changes in sawing patterns*: Because target sizes have changed, the sawing pattern should be re-optimized for maximum value recovery. This could lead to an entirely different pattern being sawn from the log, which could in fact have a lower volume recovery. **Figure 1**, pattern D shows a different sawing pattern that generates a completely different set of products from the log.

5. *Changes in overall production strategies*: Major changes to the sawing patterns described in 4, and to a lesser degree in 3, would likely cause the mill to re-optimize their log bucking solutions for maximum value. The fully re-optimized solution would always have a higher value, but could result in lower volume recovery.

Clearly, quantifying the change in *value* recovery is particularly difficult. To fully understand the effect of all five of these changes in sawing strategies, the entire mill process must be studied, not just the changes that would occur in isolated pre-bucked stems.

An early mathematical study to analyze the effect of reduced sawkerf sizes on lumber recovery (4) revealed that an average increase in lumber recovery of 7.31 percent occurs when the sawkerf of

cant-sawn logs is decreased from 12/32 inch (0.375 in.) to 9/32 inch (0.281 in.) (a 25% decrease in sawkerf size). The logs used in this study were assumed to be cylinders from 5.50 to 12.0 inches in diameter. The lumber produced was a mix of 2-inch and 1-inch dimension boards. The increase was found to be greater in small logs than in larger logs.

In other studies, White (12) and Allen (1) devised simple models using the fiber savings due to reduced sawkerf or target sizes to estimate changes in recovery. Wang (11) attempted to quantify lumber recovery increases by showing that as target sizes are decreased, a smaller cylindrical log could produce the same sawing pattern. The estimated results of these studies were found to be slightly higher than those found by computer simulation of individual logs.

Of the five ways to increase lumber recovery previously listed, the methods outlined in these two studies can only estimate the effects solely due to an extra board appearing in the pattern (item 1 in the list of changes). To quantify the effects of changes 1, 2, and 3, Hallock and Lewis (5) used Best Opening Face (BOF) on live-sawn tapered logs and found that when sawkerf was increased from 0.210 to 0.250 inch (16%), recovery decreased 2.1 percent. When sawkerf was increased from 0.125 to .210 inch (40%), a 4.4 percent decrease in volume recovery was reported. However, the BOF model they used maximized volume recovery rather than value, and did not consider the ability to re-optimize the bucking and sawing patterns given the new sawkerf and target sizes.

Steele (10) presented examples of individual tapered logs where sawkerf was reduced from 0.240 to 0.180 inch (25%). Recovery was increased from 4 to 8.3 percent depending upon the log diameter and length and whether or not the length or width of the boards were increased due to the reduced sawkerf sizes.

Clearly, the net benefit that a mill will realize due to these changes depends upon the log mix the mill saws, current lumber prices, and the existing mill technology. To determine the combined effect of all these factors, the entire mill must be simulated for a given production period. The recent availability of the Sawmill Production Control

Model (SPCM) (7) allows the simultaneous analysis of the effect of all five of the changes in sawing strategies on value recovery. This technique uses combined optimization of bucking and sawing (8), which optimizes manufacturing decisions based on the raw material input, marketing conditions, and sawmill technology facing the mill.

To quantify the effects of these changes for this study, SPCM was run under different sawkerfs and target sizes and the relationships between these two sawing factors and mill revenue and recovery were investigated. This study specifically analyzes the following three factors that have not been considered previously: 1) the effect of changes in sawkerfs and target sizes on mill revenue as well as lumber volume recovery; 2) the economic tradeoff between reducing sawkerf (at the expense of higher sawing variation) or reducing target size; and 3) the effect of the mill being allowed to re-optimize their overall production plan based on the changed sizes.

## SAWING SIMULATION

A hypothetical British Columbia interior spruce-pine-fir (SPF) sawmill producing 160 million board feet (MMBF) per year is simulated in the study. Raw material is input to the mill in the form of long-length stems, ranging from 4.0-inch to 15.0-inch small end diameter by 0.5-inch increments, and from 8 to 60 feet long by 2-foot increments (**Table 1**). Raw material cost is $45 per cubic meter.

The sawmill has one automated log bucking line that produces logs from 8 to 20 feet long in 2-foot increments. Two primary breakdown lines are used in the mill: an optimizing QUAD band line for larger logs and an optimizing chip-n-saw (CNS) line for smaller logs. The sawing method used is split-taper sawing at the headsaw and full-taper sawing at the gangsaw for both sawing lines. Edgers and trimmers are optimized circular saws. All production parameters concerning the equipment used in the simulation are shown in **Table 2**.

The sawmill produces random-length dimension lumber from 8 to 20 feet in length. Two different product lines were simulated. Product set 1 consists of lumber in the following sizes: 2 by 4, 2 by 6, 2 by 8, 2 by 10, and 2 by 12; product set 2 also includes 1 by 4 and 1 by 6 sizes, which are usually taken in the sawing pattern as jacket boards (shown in **Figure 1 B** and **D**). Two product sets were simulated to determine if changes in sawkerf and target size had a different impact when 1-inch boards were included in the product line. Sawmill operating costs per thousand board feet (MBF) are given in **Table 3**. Lumber prices used in the simulation were taken from *Random Lengths* (2) and are shown in **Table 4**.

*TABLE 1. — Raw material input parameters.*

| Parameter | Minimum | Maximum | Increment | Average |
|---|---|---|---|---|
| Stem small end diameter (in.) | 4.0 | 15.0 | 0.5 | 7.0 |
| Nominal stem length (ft.) | 8 | 60 | 2 | 34 |
| Taper: 1 inch in 8 feet | | | | |
| Sweep: none | | | | |

*TABLE 2. — Sawmill production information used in the study.*

| | Sawkerf (in.) | |
|---|---|---|
| | Line 1 | Line 2 |
| Saw position: | | |
| Vertical (in.) | 0.120 to 0.175 by .005 | 0.120 to 0.175 by .005 |
| Horizontal (in.) | 0.120 to 0.175 by .005 | 0.120 to 0.175 by .005 |
| | Mill productivity information | |
| Sawmill information: | Line 1 | Line 2 |
| Operating hours | 360 hr. | 360 hr. |
| Headsaw chain speed | 110 fpm | 110 fpm |
| Gap between logs | 9.9 ft. | 9.9 ft. |
| Downtime | 10% | 10% |
| Sawmill cost per hour | $2,033/hr. | $950/hr. |
| | Green lumber target sizes (in.) | |
| Product | Thickness | Width |
| 2 by 4 | 1.66 to 1.70 by 0.01 | 3.81 to 3.85 by 0.01 |
| 2 by 6 | 1.66 to 1.70 by 0.01 | 5.89 to 5.93 by 0.01 |
| 2 by 8 | 1.66 to 1.70 by 0.01 | 7.97 to 8.01 by 0.01 |
| 2 by 10 | 1.66 to 1.70 by 0.01 | 9.79 to 9.83 by 0.01 |
| 2 by 12 | 1.66 to 1.70 by 0.01 | 11.87 to 11.91 by 0.01 |
| 1 by 4 | 0.95 to 0.99 by 0.01 | 3.81 to 3.85 by 0.01 |
| 1 by 6 | 0.95 to 0.99 by 0.01 | 5.89 to 5.93 by 0.01 |

*TABLE 3. — Operating costs ($U.S.) per MBF by product.[a]*

| | 2 by 4 | 2 by 6 | 2 by 8 | 2 by 10 | 2 by 12 | 1 by 4 | 1 by 6 |
|---|---|---|---|---|---|---|---|
| | | | | ($) | | | |
| Maintenance S&E | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Energy | 17.00 | 17.00 | 17.00 | 17.00 | 17.00 | 17.00 | 17.00 |
| Operating S&E | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| Drying | 11.00 | 11.00 | 10.00 | 9.00 | 9.00 | 19.00 | 20.00 |
| Surfacing | 42.57 | 35.00 | 35.00 | 33.86 | 33.86 | 75.29 | 58.57 |
| Shipping | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |

[a] Prices used in the simulation vary by length and are presented here averaged over all lengths for each product.

*TABLE 4. — Product prices ($U.S.) used in the simulation.[a]*

| Product | 8 ft. | 10 ft. | 12 ft. | 14 ft. | 16 ft. | 18 ft. | 20 ft. |
|---|---|---|---|---|---|---|---|
| 1 by 4 | 280 | 280 | 280 | 280 | 280 | 280 | 280 |
| 1 by 6 | 288 | 288 | 288 | 288 | 288 | 288 | 288 |
| 2 by 4 | 355 | 360 | 310 | 340 | 405 | 370 | 375 |
| 2 by 6 | 265 | 258 | 250 | 270 | 300 | 375 | 375 |
| 2 by 8 | 325 | 310 | 310 | 335 | 360 | 400 | 400 |
| 2 by 10 | 320 | 320 | 355 | 445 | 410 | 390 | 360 |
| 2 by 12 | 395 | 370 | 410 | 370 | 405 | 405 | 405 |

[a] Source: *Random Lengths*, May 6th, 1994.

The experimental procedure consisted of 60 SPCM simulations for each product set: 1 simulation for each sawkerf ranging from 0.120 to 0.175 inch with an increment of 0.005 inch, and for 5 different target thickness and width sizes with an increment of .010 inch. All target size changes are summarized in **Table 2**.

Each SPCM run simulated the operation of the sawmill for a 1-month period (360 hr.). All other aspects of the runs were held constant. For each of the 120 simulations, the production results, total mill net revenues, and lumber recovery factors were recorded. This information was then used to estimate the impact of changes in sawkerf and target size on value and volume recovery.

## RESULTS AND DISCUSSION

### IMPACT ON VALUE RECOVERY

The influences of sawkerf and target size reductions on the mill net revenues for product sets 1 and 2 are shown in **Figures 2** and **3**, respectively. As can be seen from these figures, both sawkerfs and lumber target sizes have a significant impact on mill revenue. To determine the relative impact of changes in sawkerf and target sizes, a multiple-regression equation was estimated from these data.

*Impacts of sawkerf and target sizes on revenue for product set 1.* — The model for determining the influence of sawkerf and lumber target sizes on mill revenue was:

$$NET\_REV = BaseRev + b_1\,\Delta TS + b_2\,\Delta KF \qquad [1]$$

where:

NET_REV = mill net revenue for 1 month of operation in millions of dollars

BaseRev = baseline revenue for a sawmill with largest sawkerfs and target sizes (intercept estimated by multiple regression)

$\Delta TS$ = decrease in lumber target sizes from baseline case

$\Delta KF$ = decrease in sawkerf from baseline case

$b_1, b_2$ = coefficients to be estimated from multiple regression

The resulting equation estimated for product set 1 is presented in **Table 5**. The equation and all three of the estimated model parameters are highly significant at the 0.01 level. The resulting equation is:

$$NET\_REV = 0.809 + 2.716\,\Delta TS + 1.481\,\Delta KF \qquad [2]$$

We conclude that the baseline revenue for this mill is $0.809 million when sawing product set 1. This mill's net
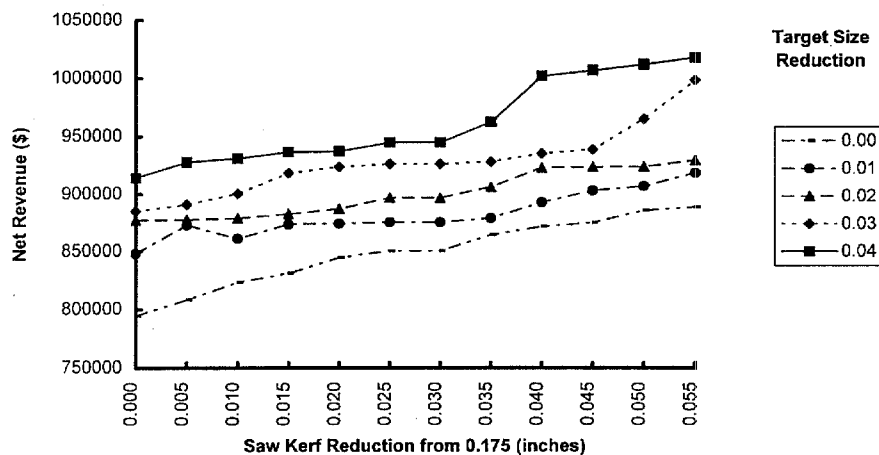


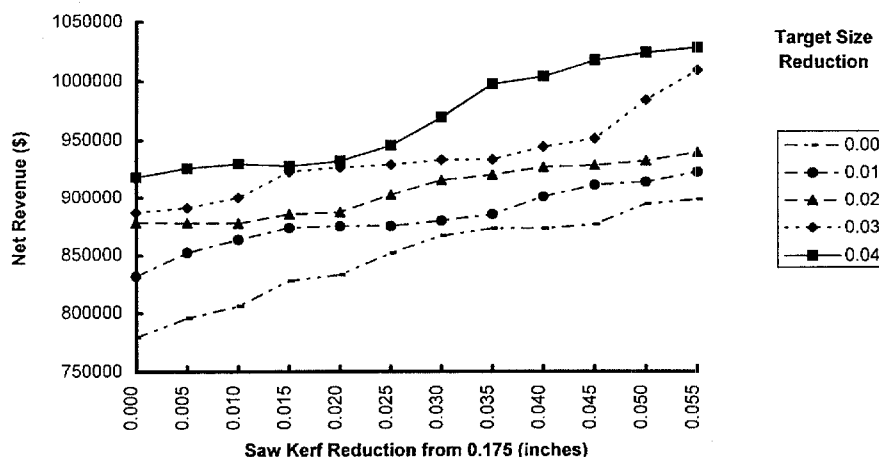Figure 2. — Relationship between net revenue and sawkerf and target size reductions for product set 1.



Figure 3. — Relationship between net revenue and sawkerf and target size reductions for product set 2.

TABLE 5. — *Regression of revenue on target size and kerf for product set 1.*

| Regression statistics | | | | | | |
|---|---|---|---|---|---|---|
| Multiple R | 0.973 | | | | | |
| $r^2$ | 0.974 | | | | | |
| F-value | 514.31768 | | | | | |
| Standard error | 0.011 | | | | | |
| Observations | 60 | | | | | |
| | | | | | Confidence limits | |
| | Coefficients | Standard error | t statistic | p-value | Lower 95% | Upper 95% |
| Intercept | 0.809 | 0.003 | 239.069 | 8.11E-90 | 0.803 | 0.816 |
| KF | 1.481 | 0.083 | 17.770 | 2.31E-25 | 1.314 | 1.648 |
| TS | 2.716 | 0.102 | 26.699 | 1.23E-34 | 2.512 | 2.919 |

revenue would then increase by $27,160/month for every 0.010-inch reduction in lumber target size, and $14,810/month for every 0.010-inch reduction in sawkerf. It can be seen from these data that the effects of target size reductions are higher compared to sawkerf reductions, by a factor of 183.4 percent, which is the ratio of the two coefficients (2.716/1.481). We define this ratio of the two coefficients as the Target Size - Sawkerf Sensitivity Factor for mill revenue for product set 1 ($TKS_{R1}$). When the confidence limits on the coefficients (**Table 5**) are taken into account, we can put a 95 percent confidence limit[1] on this ratio as:

$$2.512/1.648 \leq TKS_{R1} \leq 2.919/1.314$$

$$152.5\% \leq TKS_{R1} \leq 222.2\%$$

Therefore, we conclude that changes in target size have a significantly higher effect on mill net revenue than changes in sawkerf for product set 1. This finding is even more important when it is considered that sawkerf size reductions almost always cause a rise in target size requirements due to sawblade instability. Therefore, all else being equal, a prudent sawmill should concentrate on quality control programs that result in target size reductions to get a higher lumber recovery.

This result is contrary to previous research, as both White (12) and Wang (11) suggest that the reductions of kerfs and target sizes have the same influence. The logical explanation for this result is that all reductions in target size contribute directly to increased recovery, while only *internal* sawkerfs contribute to increased recovery. All initial opening face sawkerfs do not contribute to increased recovery at all, even if they could be decreased to zero. Therefore, the influence of target size is expected to be greater than the influence of sawkerf changes for small-diameter logs, since large-diameter logs would have more internal sawlines.

[1] The confidence interval on ΔTS / ΔKF is obtained in the following manner. The 95 percent lower confidence limit on this ratio can be obtained on this ratio by dividing the lower confidence limit on ΔTS by the upper confidence limit on ΔKF — this represents the smallest possible value this ratio can attain if both variables are at their limit at the 95 percent level. To obtain the upper confidence limit on TKS, divide the upper confidence limit on ΔTS by the lower confidence limit on ΔKF.

[2] A cunit (or CCF) is 100 cubic feet.

TABLE 6. — *Regression of revenue on target size and kerf for product set 2.*

| Regression statistics | | | | | | |
|---|---|---|---|---|---|---|
| Multiple R | 0.978 | | | | | |
| $r^2$ | 0.957 | | | | | |
| F-value | 629.384 | | | | | |
| Standard error | 0.011 | | | | | |
| Observations | 60 | | | | | |

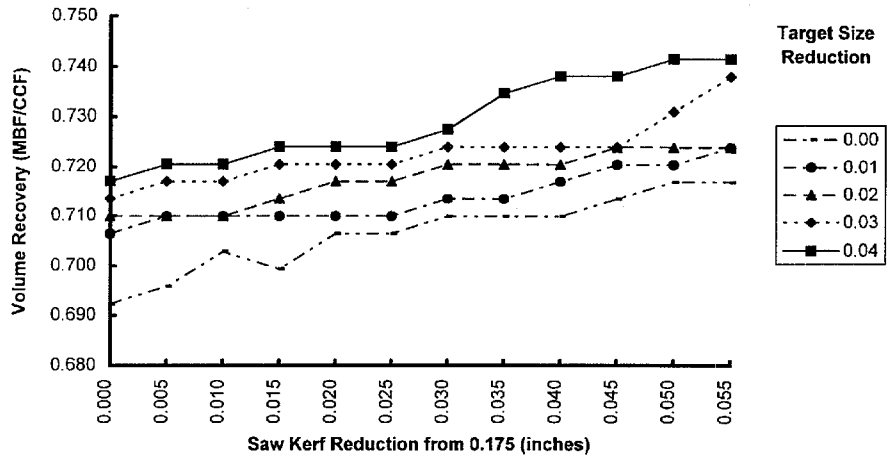| | Coefficients | Standard error | t statistic | p-value | Confidence limits Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| Intercept | 0.799 | 0.003 | 231.349 | 5.61E-89 | 0.792 | 0.806 |
| KF | 1.819 | 0.085 | 21.396 | 1.73E-29 | 1.649 | 1.989 |
| TS | 2.937 | 0.104 | 28.302 | 5.04E-36 | 2.729 | 3.145 |



Figure 4. — Relationship between volume recovery and sawkerf and target size reductions for product set 1.

*Impacts of sawkerf and target size on revenue for product set 2.* — The regression of sawkerf and lumber target size on revenue for product set 2 is presented in **Table 6**. The equation and all three of the estimated model parameters are highly significant at the 0.01 level. The resulting equation is:

$$NET\_REV = 0.799 + 2.937\,\Delta TS$$
$$+ 1.819\,\Delta KF \quad [3]$$

We conclude that the baseline revenue for this mill is slightly lower for the baseline case when 1-inch boards are included in the product line. This mill's net revenue would then increase by $29,370/month for every 0.010-inch reduction in lumber target size, and $18,190/month for every 0.010-inch reduction in sawkerf. Therefore, the Target Size - Sawkerf Sensitivity Factor for mill revenue for product set 2 ($TKS_{R2}$) for this case is 2.938/1.819 (190.7%), which is higher than that obtained when 1-inch boards are not sawn. When the confidence limits on the coefficients are

taken into account, we can put a 95 percent confidence limit on this ratio as:

$$2.729/1.989 \leq TKS_{R2} \leq 3.145/1.649$$

$$161.4\% \leq TKS_{R2} \leq 271.6\%$$

We again conclude that changes in target size have a significantly higher effect on mill net revenue than changes in sawkerf.

## IMPACT ON VOLUME RECOVERY

Sawmill conversion efficiency is often explained by the lumber recovery factor (LRF). The mill's LRF usually gives the ratio of total lumber produced in thousands of board feet (MBF) divided by the total log volume consumed in cunits[2] (CCF) as in Equation [4].

$$LRF = \frac{\text{Total Lumber Volume Produced (MBF)}}{\text{Log Volume Consumed (CCF)}} \quad [4]$$

SPCM maximizes mill revenue, not LRF. However, the mill's LRF should increase as sawkerf and lumber target

size decrease. **Figures 4** and **5** show the influence of sawkerf and target size on the LRF obtained by maximizing the mill's net revenues. The impacts on LRF are very similar to the impacts on mill net revenues.

**Figures 4** and **5** also suggest that the relationship between sawkerf and target size on LRF is linear. To determine the relative impacts of these two variables on LRF, a multiple-regression was performed for both product set 1 and 2.

The model used for determining the influence of sawkerf and lumber target size on mill LRF is:

$$LRF = BaseLRF + b_1 \, \Delta TS + b_2 \, \Delta KF \qquad [5]$$

where:

$LRF$ = lumber recovery factor

$BaseLRF$ = baseline LRF for a sawmill with largest sawkerfs and target sizes (intercept estimated by multiple regression)

$\Delta TS$ = decrease in lumber target sizes from baseline case ·

$\Delta KF$ = decrease in sawkerf from baseline case

$b_1, b_2$ = coefficients to be estimated from multiple regression

*Impacts of sawkerf and target size on LRF for product set 1.* — The regression of sawkerf and lumber target size on LRF for product set 1 is presented in **Table 7**. The resulting equation is:

$$LRF = 0.697 + 0.545 \, \Delta TS + 0.367 \, \Delta KF \qquad [6]$$

We conclude that the baseline recovery for this mill is 0.697 MBF per CCF when sawing product set 1. This mill's LRF would then increase by 0.00545 for every 0.010-inch reduction in lumber target size, and 0.00367 for every 0.010-inch reduction in sawkerf. It can be seen from these data that the effects of target size reductions are higher than those of sawkerf by a factor of 0.545/0.367 (148.6%). We define this ratio as the Target Size - Sawkerf Sensitivity Factor to Volume Recovery for product set 1 ($TKS_{V1}$). When the confidence limits on the coefficients (**Table**
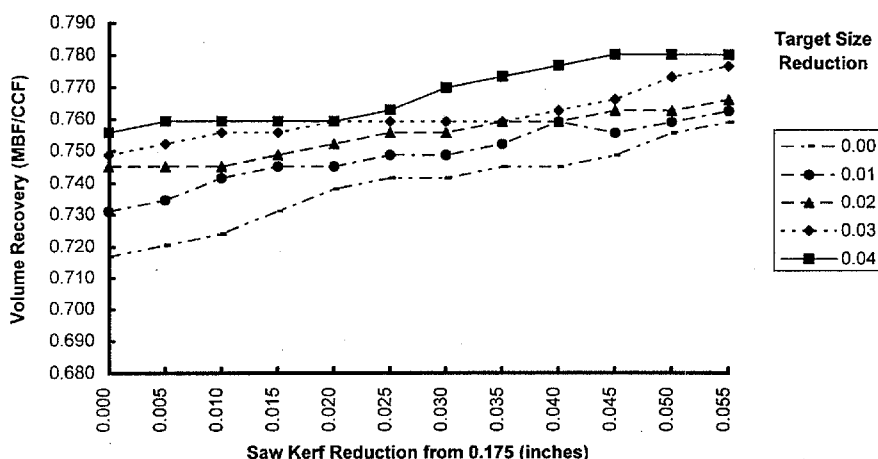


Figure 5. — Relationship between volume recovery and sawkerf and target size reductions for product set 2.

TABLE 7. — *Regression of LRF on target size and kerf for product set 1.*

| Regression statistics | | | | | | |
|---|---|---|---|---|---|---|
| Multiple R | 0.971 | | | | | |
| $r^2$ | 0.943 | | | | | |
| F-value | 471.317 | | | | | |
| Standard error | 0.003 | | | | | |
| Observations | 60 | | | | | |
| | | Standard | | | | Confidence limits |
| | Coefficients | error | t statistic | p-value | Lower 95% | Upper 95% |
| Intercept | 0.697 | 0.001 | 912.503 | 4E-124 | 0.696 | 0.699 |
| KF | 0.367 | 0.019 | 19.490 | 2.17E-27 | 0.329 | 0.404 |
| TS | 0.545 | 0.023 | 23.723 | 7.3E-32 | 0.499 | 0.590 |

TABLE 8. — *Regression of LRF on target size and kerf for product set 2.*

| Regression statistics | | | | | | |
|---|---|---|---|---|---|---|
| Multiple R | 0.974 | | | | | |
| $r^2$ | 0.948 | | | | | |
| F-value | 518.178 | | | | | |
| Standard error | 0.003 | | | | | |
| Observations | 60 | | | | | |
| | | Standard | | | | Confidence limits |
| | Coefficients | error | t statistic | p-value | Lower 95% | Upper 95% |
| Intercept | 0.726 | 0.001 | 737.140 | 1.2E-118 | 0.724 | 0.728 |
| KF | 0.526 | 0.024 | 21.703 | 8.19E-30 | 0.478 | 0.575 |
| TS | 0.703 | 0.030 | 23.777 | 6.47E-32 | 0.644 | 0.763 |

7) are taken into account, we put a 95 percent confidence limit on this ratio as:

$$0.499/0.404 \leq TKS_{v1} \leq 0.590/0.329$$

$$123.3\% \leq TKS_{V1} \leq 179.5\% \quad [7]$$

Therefore, we conclude that changes in target size have a significantly higher effect on LRF than changes in sawkerf for product set 1. However, the sensitivity factor for revenue ($TKS_{R1}$) appears to be greater than the sensitivity factor for volume recovery ($TKS_{V1}$). This indicates that target size reductions may have a larger relative impact on revenue than on volume recovery.

*Impacts of sawkerf and target size on LRF for product set 2.* — The regression of sawkerf and lumber target size on LRF for product set 2 is presented in **Table 8**. The equation is highly significant by an F-test, and all three model coefficients are very highly significant. The resulting equation is:

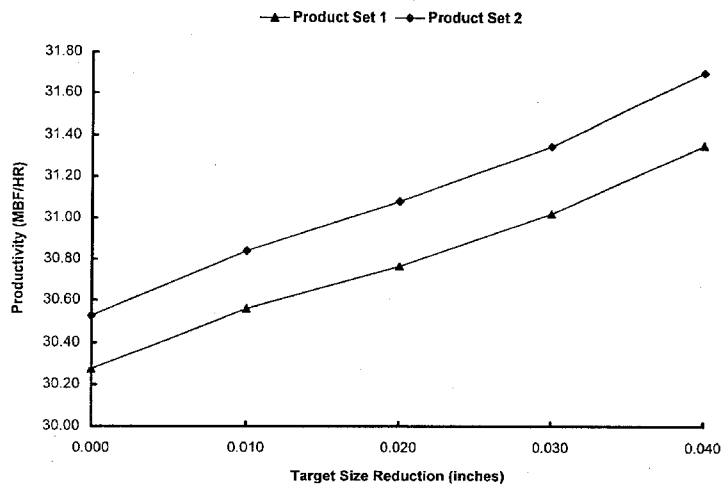$$LRF = 0.726 + 0.703 \, \Delta TS + 0.526 \, \Delta KF \qquad [8]$$

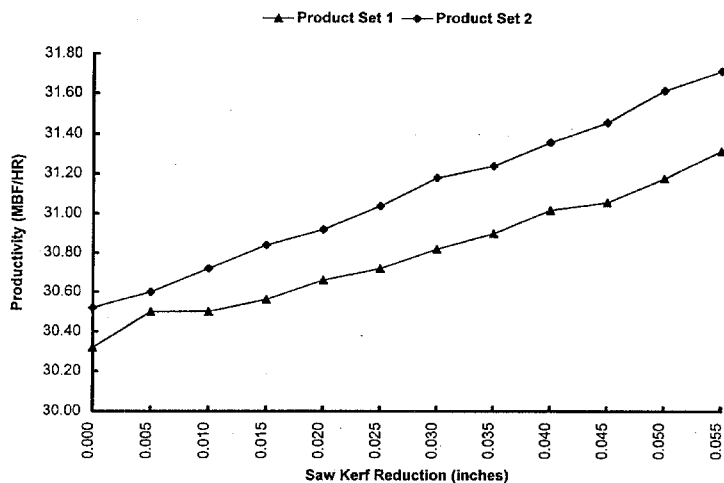Figure 6. — Relationship between sawmill productivity and target size reductions.



Figure 7. — Relationship between sawmill productivity and sawkerf reductions.

We conclude that the baseline recovery for this mill is 0.726 MBF per CCF when sawing product set 2 (which includes 1-in. boards). Thus, the mill's baseline LRF increased by 0.029 points due to producing 1-inch boards. This mill's LRF would then increase by 0.00703 for every 0.010-inch reduction in lumber target size, and 0.00526 for every 0.010-inch reduction in sawkerf. The sensitivity factor when sawing 1-inch boards (TKS$_{V2}$) is 133.71 percent. When the confidence limits on the coefficients are taken into account, we put a

95 percent confidence limit on this ratio as:

$$112.1\% \leq TKS_{V2} \leq 159.7\%$$

Therefore, we again conclude that changes in target size have a significantly higher effect on LRF than changes in sawkerf for product set 2.

## RELATIVE IMPACTS OF SAWING FACTORS ON VOLUME RECOVERY AND REVENUE

Sawkerf and lumber target sizes have a significant influence on LRF. The sawmill's LRF increased 0.53 and 0.72 percent, respectively, with product sets 1 and 2, when the sawkerf was reduced by 0.010 inch from the baseline case. These would translate to 4.5 and 6.2 percent LRF increases when the sawkerf thickness is reduced from 0.210 inches to 0.125 inches.

Thesepercent increments are closer to agreeing with the 4.4 percent volume increment found by Hallock and Lewis (5) using the BOF program than the 11.76 percent volume increment prediction of Wang's mathematical estimation model (11)[3].

However, the effect on the mill's net revenue is dramatically higher. Mill revenue increases 1.83 and 2.28 percent with product sets 1 and 2, respectively, when the sawkerf is reduced by 0.010 inch from the baseline case. These translate to 17.0 and 21.41 percent revenue increases when the sawkerf thickness is reduced from 0.210 to 0.125 inches.

This can be explained by the fact that sawkerf and target size reductions affect both sides of the revenue equation: more lumber is recovered from every log (higher value), fewer logs must be purchased (lower costs), and productivity increases (lower cost). Mill productivity increases because when more lumber is obtained from each log it also means that more lumber is output for the same number of mill hours. This effect is clearly demonstrated in **Figures 6** and **7**, which show that productivity (as expressed by the cut per hour) increases substantially when sawkerf or target size is reduced.

LRF only shows the effect of purchasing fewer logs while maintaining the same volume of lumber production. The findings in this study show that traditional methods based on LRF increases alone seriously underestimate the effect of size control programs on the sawmill's profitability.

## EFFECT OF PRODUCING 1-INCH LUMBER

The results of this study show that producing 1-inch lumber has very little impact on the mill's net revenue, but a very large impact on LRF. This is because in this study 1-inch lumber had a relatively low sales value and high production costs. It can also decrease productivity due to the higher piece count if the mill is limited in edger or trimmer capacity (which was not the case in this study). In the baseline case, mill LRF increased by 0.029, but net revenue was unchanged.

## CONCLUSION

Sawmill quality control is often misunderstood as an expensive process resulting only in enhanced product qual-

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[3] The reader should keep in mind that the sawkerf used in this study was 0.120 to 0.175 inch, so these previous studies are outside this range. The numbers are presented here for comparison purposes only.

ity to the customer. Therefore, the cost of a quality control program is often difficult to justify for mills that produce dimension lumber. However, quality control programs become much more attractive when it is considered that they can also help reduce costs and increase productivity by reductions that occur in green target sizes and sawkerfs.

A specific case study was analyzed in this paper. Reductions in target sizes and sawkerfs are shown to significantly increase mill revenues. Target size and sawkerf reductions were found to have a much larger effect on sawmill revenue than on volume recovery. Reductions in target size are shown to have a significantly larger impact on mill net revenues and recovery than sawkerf reductions. This is particularly true when it is considered that sawkerf reductions often result in larger target sizes. The study has also shown that producing 1-inch lumber in the product line significantly increases lumber recovery, but has a minimal effect on mill net revenue.

Equations were developed that predict the net effect in revenue and volume recovery of specific changes in target sizes and sawkerf. These equations may be useful for sawmills whose production conditions are fairly close to the mill described in this study. Future research should concentrate on modeling sawmills under many different conditions to establish more general guidelines.

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