The Effects of Wane Allowance, Kerf and Target Size Reduction on Sawmill Optimization

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Submitted to:

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FP 413

Senior Project Report

June 5, 2002

TABLE OF CONTENTS

ABSTRACT

As average log size decreases and timber costs increase, sawmills must increase log throughput in an efficient manner to stay competitive. Sawmill managers, in an effort to keep costs down and simplify their lives, sometimes operate run machine centers at optimum capacity because of the additional monitoring and effort required for changing machine centers. In order to run at optimum capacity, target and kerf sizes should be reduced as much as possible, while ensuring maximum grade recovery. This project quantified the values associated with changing wane allowance, lumber target size, and kerf size in a sawmill using MaxiView, a commercial simulation software program (MaxiMill Corporation, Albany, OR). Current market prices and real mill-run samples of logs were integrated into this analysis. Individual and composite sawing variable effects were quantified and analyzed. The study found that a 0.01-inch reduction in kerf or lumber target size has the potential increase the recovery or revenue in a mill by more than 0.60 %. Changing a mill to cut the maximum wane allowance as opposed to zero wane allowance, had the potential to show almost an 8 % gain in recovery in a small log sawmill and almost 5.5 % in a medium log sawmill. Sawmill managers can use the results from this project to assess the benefits of higher capacity with the disadvantages of increased monitoring or machine center changeover requirements.

INTRODUCTION

As average log size decreases and timber costs increase, sawmills must increase log throughput in an efficient manner while maintaining sawing accuracy and grade recovery in order to stay competitive. Optimization essentially improves production capacity with minimal cost. Machine centers must run smoothly and saw accurately. A lumber size control program identifies, locates, and works to overcome problems in sawing systems, sawing-machine centers, and setwork systems (2). It is important to apply quality control techniques when measuring sawing accuracy to determine the capability of sawmill systems (2). Information from quality control programs, such as those designed to maintain lumber size control, can be used to determine if the equipment is sawing at the highest possible accuracy. In a small log sawmill, boards should be sawn to the smallest green target size possible without losing grade from planer skip and undersizing (2). Quality control is the feedback loop for optimization to ensure that product quality does not diminish with incremental decreases in saw kerf and target size.

Sawmill managers, in an effort to reduce costs and simplify the efforts required by machine operators, sometimes operate machine centers below optimum sawing accuracy to reduce the level of quality control monitoring required (1). Intuitively, managers know that size control is good, but maintaining control requires more work to keep a mill running at peak efficiency. Many mill managers are content to select a sub-optimal level where the mill still makes an adequate profit. The lack of a quantifiable economic benefit for increasing sawing accuracy leads many sawmill managers to avoid the additional optimization. However, the availability of more quantifiable information on the benefits of size control may encourage sawmill managers to work harder toward reducing saw kerfs and green target sizes.

Quantifying the benefits from different optimization levels in an operating sawmill can be costly, since machine centers must be continually adjusted for different green target sizes and saw kerf thicknesses. Current software simulation programs make it possible to adequately predict the dollar values associated with size control and kerf reduction without having to manually collect real-time data. These programs allow many variables to be changed while running simulations with real mill run data.

This project: (1) quantified the dollar value associated with changes in wane allowance, size control and kerf in the sawmill, (2) developed lumber recovery tables for each incremental sawmill parameter change, and (3) used the information from the study to calculate the impacts of parameter changes on sawmill profitability.

LITERATURE REVIEW

Increasing lumber recovery from a log will generally improve profitability. The factors that determine lumber recovery include: log geometry, kerf width, sawing variation, product mix, decision making by personnel, condition and maintenance of mill equipment, and sawing method (15). A variety of studies analyzed ways to improve lumber recovery by changing these variables (2,6,8,9,11).

Before changing machine centers or running simulation studies, it is important to analyze effects associated with reducing the green target and saw kerf sizes. Reductions in the saw kerf and green target sizes often do not increase the number of boards produced from a log. However, size reduction allows for production of longer and wider boards that can increase lumber recovery substantially (4). For example, a 0.06-inch kerf reduction could result in as much as an 8% increase in recovery (15).

Quality control (QC) and process control (PC) programs have been implemented to monitor and determine the capabilities of sawmill systems (13). Research has been performed to determine the best methods and components for good quality and process control programs. PC and QC programs should maximize the value of raw material and lumber products through all phases of the manufacturing process and provide quality assurance in products produced (8). The following list of key elements has been proven successful in lumber quality control (QC) programs: management involvement, quality policy, stated measurement objectives, measurement methods, employee training, employee and production center evaluation, feedback and corrective action, maintenance, communications, recognition, and periodic program review

(8). Statistical process control (SPC) and statistical quality control (SQC) programs enable a quality control manager to monitor, adjust, and predict process and quality changes (13).

A major portion of a lumber quality control program is lumber size control (10). Several size control programs such as Si-Cam®, SizeCheck™, and the LSIZE Program® are available for sawmills (11). These size control programs are designed to minimize kerf, sawing, variation, and roughness. Companies that have successfully implemented size control programs have shown gains from $300,000 to over $1,000,000 per year in additional lumber recoveries (10). However, the actual amounts of lumber recovery improvement associated with specific changes in kerf or target size have not been quantified and published with any degree of certainty.

There are two aspects to size control: measurement and analysis (9). The measurement portion involves the collection of accurate size control data. Examining raw data enables a manager to make corrections to obvious problems (10). Analysis of raw data creates the greatest benefit to a lumber size control program. Size control information can be used to troubleshoot sawing variation and estimate appropriate rough green target sizes (10). The data analysis is most often performed through the use of SQC and SPC programs.

Analysis of target size has been thoroughly studied (6,8,9,10,11). Green lumber target size consists of the final product size, planing allowance, sawing variation, and shrinkage allowance if dried. Target size can be estimated by using the following equation:

Target size = ((final size + planer allowance) / (1 - (% shrinkage / 100))) +

standard normal variation * total sawing variation.

Several studies have been performed to determine the best ways to improve sawing accuracy in order to lead to potential decreases in saw kerf and green target sizes. Those studies have shown that high sawing accuracy and small sawing variation in all sawing, planing, and sanding machine centers enabled thinner green target sizes to be cut (7). Reducing sawing variation, surface roughness, warp and minimizing shrinkage all enable the target size to be reduced by 0.01 to 0.05-inches or more (11). Target size reduction should only be started after quality control personnel are certain they can maintain a reduced total sawing variation over at least one month (10). Reducing the target size by very small increments has been proven successful (10). Intuitively, changing machine centers over to use narrower saw blades (and respectively narrower teeth) will reduce kerf sizes. However, before making adjustments to machine centers, a mill manager must understand the potential tradeoffs between additional costs, capability of equipment, and the dollar value or recovery gained.

Sawing variation is influenced by machine type and sawing method (7,14). Any decrease in sawing variation may lead to a potential decrease in target size. Typically, machines with low within-board sawing variation have fences and/or horizontal feed rolls and small-diameter circular or sash gang saws. Machines with preset or single shifting saws have been shown to result in the lowest between-board variations (7). Single and double arbor gang saws had the lowest sawing variation. Total sawing variation, by headrig type in ascending order, is as follows: chipping, band, quad band, scragg, twin band, and finally the circular headrig (7). Total sawing variation by resaw type, in ascending order, is as follows: double arbor gang, single arbor gang, sash gang, circular linebar, twin band, vertical arbor gang, band linebar, horizontal band, and quad band resaw (7). Sawing variation between each type of machine center may be dependent on the saw kerf sizes. Generally, the large circular, scragg, and chipping headrigs had larger kerf sizes than the quad and twin band headrigs (14). A mill manager must balance thinner saw kerfs with a respective increase in sawing variation.

In addition to machine center factors, highly variable wood characteristics can affect lumber sawing variation (12). Factors that should be considered when trying to reduce sawing variability include: grain/fiber direction, bond strength between fibers, planes of wood, wood density of species, density variation across the stem, density variation within growth rings, knots in the wood, compression wood, tension wood, wood extractives, growth stresses in the trees, drying stresses, moisture content, and temperature level (12). Therefore, it is difficult to compare sawing capabilities between sawmills because of the large amount of external influences resulting from typical variability found in wood.

Wane allowance is a very important consideration when determining the maximum amount of lumber recovered from a log. Cutting at a lower wane allowance will significantly decrease lumber recovery (8). Large retailers, like Home Depot, allow their customers to pick through units of lumber. Typically, the customers will select lumber with the least amount of wane. Thus, these retailers have requested wane-free lumber to ensure they are able to sell the entire units of product. Sawmills are not always paid a premium for selling wane-free lumber (8).

A comparison method has been used to determine how well a mill is able to perform compared to other mills with similar machine centers. Comparison analysis by region in the United States showed that average headrig saw kerfs ranged from 0.186 to 0.266-inches (5). Within each region, the standard deviation for headrig saw kerf ranged between 0.043 and 0.081-inches (5). Thus, a reduction of the kerf sizes may be possible by following examples of more accurately run sawmills, as long as similar log species and diameters are used. Green target sizes for nominal 2-inch dimension lumber ranged from an average of 1.731 to 1.841 inches. Within region variation for target size ranged between 0.051 and 0.107-inches (5). The wide range of target sizes between the mills in each region may be partially due to the species type, type of machine centers, and the product produced. Typically, more accurate sawmills use quality control or size control programs.

Terry Brown, a professor at Oregon State University, noted that when discussing the benefits of a lumber size control program, a question often arises: “How much is a small change in kerf or target size worth anyway (4)?”. Three approaches for estimating potential lumber recovery are available: a mill test, sawmill simulation, and an analytical approach (6). Mill tests are difficult to perform, since log variation may require an extremely large sample to produce meaningful results. This method is discouraged because it is difficult to accurately estimate potential lumber recovery using different logs on each trial. Analytical approaches have proven successful, but can be very time consuming because of the data collection and manual calculations required for each variable change (6). Simulation studies may be the best way to determine additional lumber recovery because computers can quickly and accurately calculate recovery from logs using large sawing algorithms. Simulation software programs perform calculations using the same set of log data as many times as the variables are changed.

Simulation models can be very effective tools to aid in decision-making (1). For mill operations, simulation can reduce the possibility of making costly physical changes to a mill that may cause adverse effects (14). Simulations enable a sawmill to avoid costly, production-disrupting test runs and can identify advance effects resulting from changing kerf or target sizes (14). Computer simulation models enable a manager to predict the optimum or maximum recovery; however, they do not generally include external factors (log species, grade of lumber produced, etc), which could limit the potential for maximizing recovery (14). Many mills use simulation programs in automated sawmill control systems (1). Logs are scanned and the information is used by a log breakdown simulation program to determine the optimal cutting pattern and control the machine centers for log breakdown (14).

A 1993 report, described the capability of Monte Carlo simulation software to determine size reduction potential in a sawmill (3), but did not quantify the potential lumber recovery and value added. Best opening face (BOF) type systems have long been in use in small-diameter log sawing operations. This program is a computer simulation model that determines the optimal position of the first saw-line (14). The position of the first saw-line cut determines the maximum lumber recovery of the log, as all other saw cuts are based off the first one. Many of the primary log breakdown simulation programs have been developed using this concept. Several primary log breakdown simulation programs are available to sawmills including Maxi View® [Maxi Mill® Corporation, Albany, OR], LogMaster ™ [INOVEC, Eugene, OR], SETGEN ™ and SAWSIM® by [HALCO Software Systems Ltd, Vancouver, B.C.], Log Optimizer [Perceptron, Plymouth, MI], and RT^3-Real Shape for Real Trees [Porter Engineering, Richmond, B.C.] (17). Each of these simulation programs uses optical scanning and log breakdown models to simulate the maximum lumber recovery from a log. Differences between these programs vary depending on the application, but each could be used for running simulation studies. These programs have been shown to dramatically increase recovery by minimizing human error in the system. Specific sawing parameters can be set in the simulation programs to match what is currently run or could be run in the sawmill.

Few articles have been published on the concept of using primary log simulation software to determine the economic benefits resulting from incremental target size and kerf reductions (2,8,9). This may be explained in two ways. First, those that have simulation equipment do their own studies, but do not publish them. Second, mills using a real time simulation program cannot afford to stop production and simulate changes in machine centers to conduct simulation trials (2).

While size control programs are valuable, there is limited data on quantifiable lumber recovery and dollar gains from their efforts. The objective for this study was to quantify the dollar value and lumber recovery as target size and saw kerf were incrementally reduced in a sawmill using computer simulation methods.

MATERIALS AND METHODOLOGY

Data Collection

A set of random mill run log data from the Georgia Pacific small log sawmill in Philomath, Oregon was obtained from Maxi Mill Inc (Albany, OR). The log data set was split into two diameter ranges (7 to 15 inches and 12 to 22 inches) with random length logs (8 to 24 feet). The 7 to 15-inch diameter log set represents logs processed at an average small log sawmill and the 12 to 22-inch diameter log set represents logs processed at an average medium log sawmill (1). Small log and medium log sets consisting of 500 and 441 Douglas-fir (*Pseudotsuga menziesii*) logs, respectively, were simulated on MaxiView ™, a real-time, dollar optimization software program for simulating sawmill primary log processing systems. The simulation program was set to use a single set of lumber prices (Table 1) for all the simulation runs in an effort to control the scope of the project. These prices were selected to represent an average price between the high and low market periods for standard and better grades of lumber (1). The prices were set to ensure a premium for wider boards, which will force wider lumber to be cut from a log. The price per length was not varied in an effort to reduce the number of variables as well as to determine the additional lumber recovery on per foot basis.

Table 1. Assumed values of lumber of varying lengths and widths ($/MBF)

Nominal Dimension (inches)	Length (ft)						
	8	10	12	14	16	18	20
2 x 4	320	320	320	320	320	320	320
2 x 6	335	335	335	335	335	335	335
2 x 8	345	345	345	345	345	345	345
2 x 10	355	355	355	355	355	355	355
2 x 12	360	360	360	360	360	360	360

Source: Terry Brown, Professor, Oregon State University, Corvallis, OR.

Three sawing parameters (green target size, wane allowance, and saw kerf) were varied on the two different sets of log data to reflect the range of parameters currently being used in the industry (1). The green target size parameter was adjusted to simulate green Douglas-fir lumber (1.60 to 1.65-inches), and southern pine lumber or glulam stock (1.70 to1.75-inches) (Table 2) (1). These target size values were based on industry experience (Terry Brown, personal communication).

Table 2. Green target lumber thicknesses (in.) evaluated using MaxiView ^{TM}.

Green Lumber	Dry Lumber/ glulam stock
1.65	1.75
1.64	1.74
1.63	1.73
1.62	1.72
1.61	1.71
1.60	1.70

Source: Terry Brown, Oregon State University

Two wane allowance values, 5 and 35 percent, were used in the simulation (1). The 5 percent wane allowance represents mills cutting wane-free lumber for specific customers like Home Depot (1), while the 35 percent wane allowance value represents the maximum wane allowance allowed by the West Coast Lumber grading rules (1/3 thickness and 1/3 length) plus the wane removed from the planer (1,20).

The saw kerf parameter, a representation of four machine center (headrig, board edger, rotary gang, and resaw) kerf sizes, was varied between 0.125 inches and 0.185 inches in 0.01-inch increments (Table 3) (1). Kerf sizes for each machine were reduced at the same rate to reduce the number of simulation runs required. The range of kerf sizes was representative of current industry practice. The MaxiView ^{TM} simulation program calculated the cutting pattern using all four machine centers during each run (19).

Table 3. Machine center kerf thickness values (inches) evaluated using MaxiView ™

Machine Center	Kerf Set #						
	1	2	3	4	5	6	7
Headrig	0.185	0.175	0.165	0.155	0.145	0.135	0.125
Board Edger	0.195	0.185	0.175	0.165	0.155	0.145	0.135
Rotary Gang	0.150	0.140	0.130	0.120	0.110	0.100	0.090
Resaw	0.185	0.175	0.165	0.155	0.145	0.135	0.125

Source: Terry Brown, Oregon State University

The simulation program was run on a PC computer. A simulation run was performed each time a parameter or log set changed. Thus, 336 simulation runs of 500 logs each were performed to examine all individual and multivariable changes.

Total simulation runs = # log sets * # Target sizes * # wane allowances * # kerf size sets

= 2 * 12 * 2 * 7

= 336 runs

Each simulation run took an average of 5 to 7 minutes, for a total running time of approximately 34 hours.

Data Analysis

Small-end diameter and log length distribution plots were constructed to classify the logs used in the simulation for each set of mill run log data using Microsoft Excel. Three outputs (cubic log scale, lumber nominal board feet, and dollar value) were collected from each simulation run for each log placed in a raw data fil. Lumber recovery factor (LRF) was calculated from each simulation run by dividing board feet of lumber by cubic feet of log. Two tables, each representing a different log mix, were constructed with the dollar and LRF values from each simulation run.

The data files, consisting of individual LRF values for each log, were used to test for statistically significant differences between the outputs of each simulation run. An ANOVA test was used to test the statistical significance of each treatment (parameters) and block (log data set) for LRF and dollar value (21). For the differences found, the Duncan's Multiple Range test and paired T-test analyses were used to test for the significance. All statistical analyses were performed using Statgraphics.

The total and average lumber recovery (nominal board feet), dollar value, and LRF value were calculated for each incremental change in the simulation parameters (kerf, wane and target size). A series of matrices were constructed with the simulated actual lumber recovery, LRF, and relative dollar value. Average dollar value and lumber recovery factor gains were converted into percent gains. A summary table was constructed to represent the percentage change in dollar value or lumber recovery based on 0.01-inch reductions in kerf and target sizes. Calculations were made to determine at what additional price wane-free (5% wane allowance) lumber must be sold to balance the expected loss in recovery.

RESULTS AND DISCUSSION

Input Data:

Several log diameter versus log length distributions were developed to characterize the two log files used in this study (Figures 1 and 2). These figures demonstrated that the log mixes were typical of those found at small and medium log sawmills. Log diameters for each population generally had a normal distribution (Figure 3). Additional analyses of the input data for the simulation can be found in Appendix A.

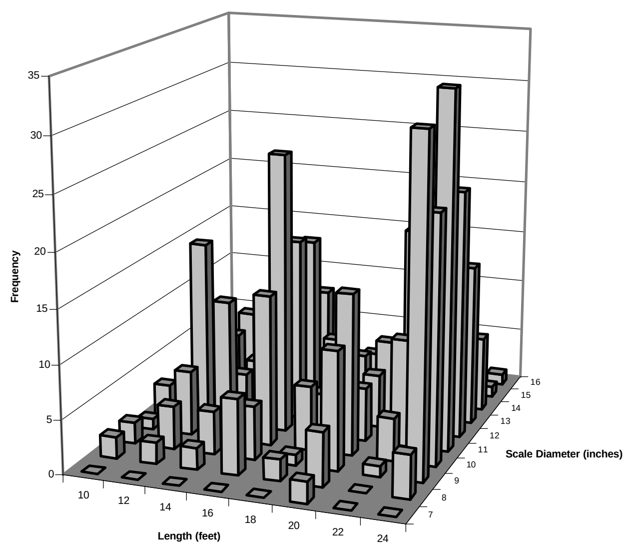


Figure 1. Histogram: log diameter versus length for the small log set (Appendix A-2)

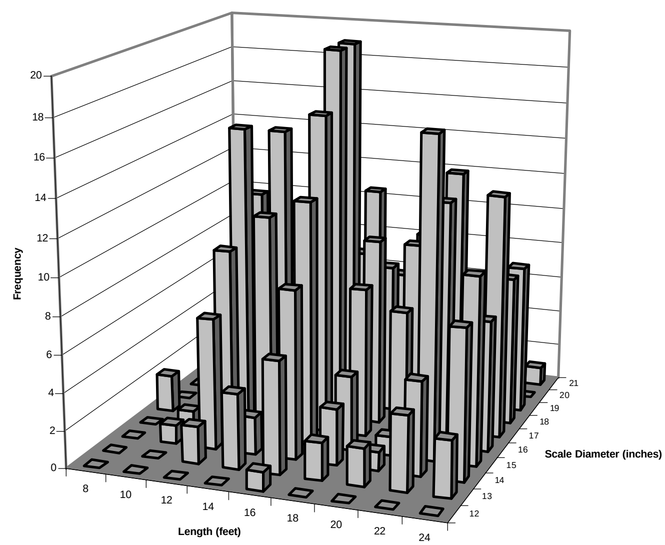
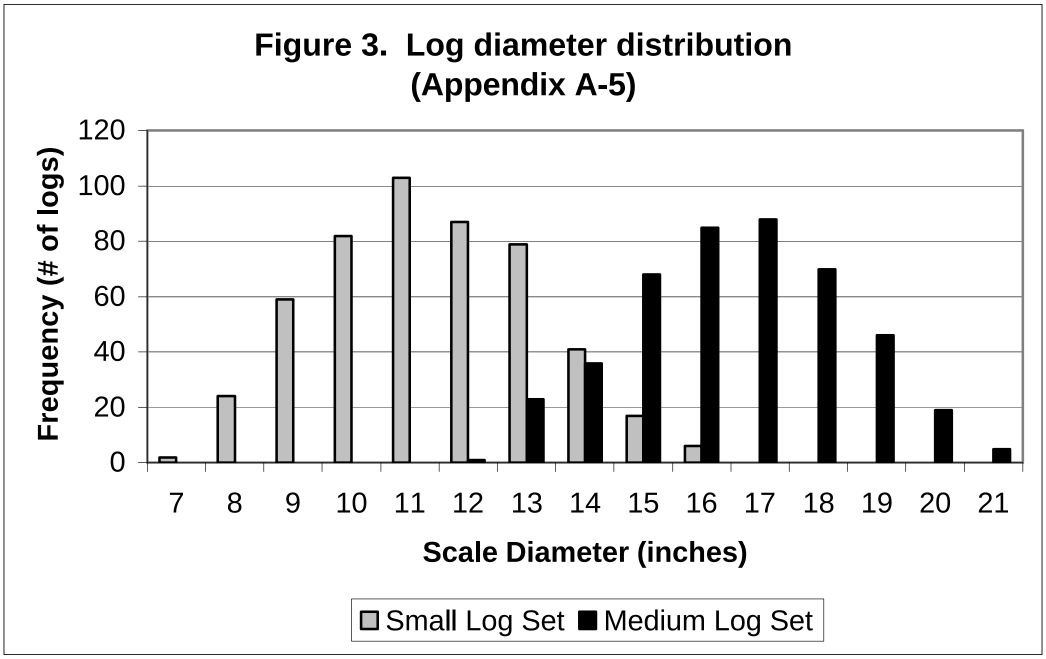


Figure 2. Histogram: log diameter versus length for medium log set (Appendix A-4)



Output From Simulation:

Large quantities of value, lumber, and LRF data were obtained from the simulation runs and placed in tables for the initial analysis. In Appendix B, Table B-1 represents all the raw data output from the 336 simulation runs including the total, average, and standard deviation values for Lumber, LRF, and Values for each individual simulation run. Table 4 provided an example of the tables in Appendix B and displays only the total lumber value output for the simulation runs with the wane allowance parameter set to 5%. As expected, the total output value (which is what the simulation program optimized on) increased as the kerf or target size was reduced. Tables for total dollar value, lumber recovery factor, and total lumber volume for 5 and 35% wane allowances can be found in Appendix B.

Table 4. Total lumber value ($) versus mill kerf and target size reduction (5% wane allowance) for large and small log sets

		Kerf Set	1	2	3	4	5	6	7
		Headrig	0.185	0.175	0.165	0.155	0.145	0.135	0.125
		Board Edger	0.195	0.185	0.175	0.165	0.155	0.145	0.135
		Gang	0.15	0.14	0.13	0.12	0.11	0.1	0.09
		Resaw	0.185	0.175	0.165	0.155	0.145	0.135	0.125
Log Set	Target Size	Reduction	0	0.01	0.02	0.03	0.04	0.05	0.06
Small Log Set (Green Target)	1.60	0.05	25693	25864	26033	26202	26367	26529	26751
	1.61	0.04	25570	25718	25903	26060	26237	26389	26561
	1.62	0.03	25401	25555	25703	25879	26049	26206	26379
	1.63	0.02	25248	25389	25538	25697	25870	26036	26208
	1.64	0.01	25079	25237	25380	25519	25689	25853	26024
	1.65	0.00	24899	25069	25226	25369	25508	25676	25832
Small Log Set (Dry Target)	1.70	0.05	24123	24268	24412	24560	24703	24841	24995
	1.71	0.04	23969	24109	24253	24405	24552	24690	24837
	1.72	0.03	23811	23952	24091	24249	24395	24537	24678
	1.73	0.02	23663	23807	23943	24083	24241	24385	24522
	1.74	0.01	23495	23650	23793	23924	24082	24225	24375
	1.75	0.00	23348	23482	23634	23776	23919	24066	24211
Medium Log Set (Green Target)	1.60	0.05	48232	48534	48855	49172	49498	49813	50138
	1.61	0.04	47930	48231	48526	48833	49155	49479	49805
	1.62	0.03	47621	47916	48223	48517	48826	49142	49456
	1.63	0.02	47317	47618	47900	48217	48517	48814	49134
	1.64	0.01	47028	47310	47599	47890	48211	48506	48814
	1.65	0.00	46729	47008	47296	47589	47879	48202	48489
Medium Log Set (Dry Target)	1.70	0.05	45265	45542	45813	46097	46381	46670	46974
	1.71	0.04	44982	45248	45540	45805	46083	46364	46661
	1.72	0.03	44694	44966	45239	45526	45802	46076	46348
	1.73	0.02	44432	44692	44957	45235	45513	45795	46062
	1.74	0.01	44152	44423	44682	44953	45224	45494	45786
	1.75	0.00	43879	44143	44412	44669	44949	45219	45484

Source: Appendix B-2

Tests for Significance:

The first step in determining the quality of the data output from the MaxiView32 program was to test for statistically significant differences. The percent changes between each of the simulation runs with the base cases (5% wane allowance, 0.0-inch kerf and target size reductions) were calculated. An ANOVA was used to test for statistically significant differences between the small and medium log sets for all 336-simulation runs (Table 5). Due to the limitations of our statistical software, analysis on more than three crosses between treatments was not possible. For this analysis, total comparisons, single factor and paired comparison statistical analyses were performed (full analysis can be found in Appendix C).

Table 5. Treatments, classes, and degrees of freedom for statistical analysis of logs analyzed using a sawmill simulation program.

	Treatment	Number of Classes	Degrees of Freedom
A	Log Diameter	2 (1 = small, 2 = medium)	1
B	Green versus Dry Target Size	2 (1 = green, 2 = dry)	1
C	Kerf Change	7 (1 = 0.0-inch reduction, 2 = 0.01-inch reduction, etc)	6
D	Target Size	6 (1 = 0.0-inch reduction, 2 = 0.01-inch reduction, etc)	5
E	Wane Allowance	2 (1 = 5% wane allowance, 2 = 35% wane allowance	1

Source: Appendix C-1

Table 6, displays the overall ANOVA table output from this analysis. Based on the low p-values from the ANOVA table (below 0.0001), each of the treatments or simulation input variable changes could be considered statistically significant. The analysis in Appendix C demonstrates that each single factor and individual simulation runs differed significantly from the others.

Table 6. ANOVA Table.

Analysis of Variance for Chg Value - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Log Class	0.0248395	1	0.0248395	140.71	0.0000
B:Mill Type	0.0566426	1	0.0566426	320.87	0.0000
C:Kerf Set	25.4524	6	4.24206	24030.86	0.0000
D:Target Size	20.1376	5	4.02753	22815.53	0.0000
E:Wane Allowance	0.0203787	1	0.0203787	115.44	0.0000
RESIDUAL	27.8429	157727	0.000176526		
TOTAL (CORRECTED)	73.5292	157741			

All F-ratios are based on the residual mean square error.

Source: Appendix C-2

Calculation and Summary of Data:

One of the first steps in the analysis was to convert the total value and LRF output values into percent changes based on the base case for each mill type. Table 7, displays the percent change in total lumber value versus mill and kerf size reductions for 5% wane allowance.

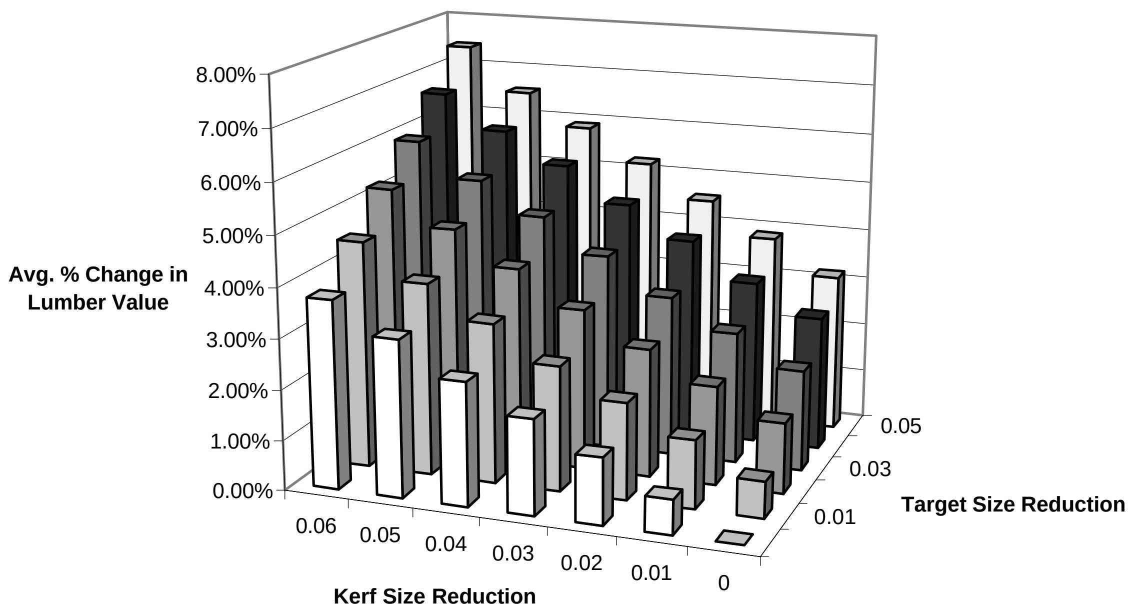
Table 7. Percentage change of total lumber value ($) versus mill kerf and target size reduction (5% wane)

		Kerf Set	1	2	3	4	5	6	7
		Headrig	0.185	0.175	0.165	0.155	0.145	0.135	0.125
		Board Edger	0.195	0.185	0.175	0.165	0.155	0.145	0.135
		Gang	0.15	0.14	0.13	0.12	0.11	0.1	0.09
		Resaw	0.185	0.175	0.165	0.155	0.145	0.135	0.125
Log Set	Target Size	Reduction	0	0.01	0.02	0.03	0.04	0.05	0.06
Small Log Set (Green Target)	1.60	0.05	3.19%	3.88%	4.55%	5.23%	5.89%	6.55%	7.44%
	1.61	0.04	2.70%	3.29%	4.03%	4.66%	5.37%	5.98%	6.67%
	1.62	0.03	2.01%	2.63%	3.23%	3.94%	4.62%	5.25%	5.94%
	1.63	0.02	1.40%	1.97%	2.57%	3.21%	3.90%	4.57%	5.26%
	1.64	0.01	0.72%	1.36%	1.93%	2.49%	3.17%	3.83%	4.52%
	1.65	0.00	0.00%	0.68%	1.31%	1.89%	2.44%	3.12%	3.75%
Small Log Set (Dry Target)	1.70	0.05	3.32%	3.94%	4.56%	5.19%	5.80%	6.40%	7.06%
	1.71	0.04	2.66%	3.26%	3.88%	4.53%	5.16%	5.75%	6.38%
	1.72	0.03	1.98%	2.59%	3.19%	3.86%	4.49%	5.09%	5.70%
	1.73	0.02	1.35%	1.97%	2.55%	3.15%	3.83%	4.44%	5.03%
	1.74	0.01	0.63%	1.30%	1.91%	2.47%	3.15%	3.76%	4.40%
	1.75	0.00	0.00%	0.57%	1.22%	1.84%	2.45%	3.08%	3.70%
Medium Log Set (Green Target)	1.60	0.05	3.22%	3.86%	4.55%	5.23%	5.93%	6.60%	7.29%
	1.61	0.04	2.57%	3.21%	3.85%	4.50%	5.19%	5.88%	6.58%
	1.62	0.03	1.91%	2.54%	3.20%	3.83%	4.49%	5.16%	5.84%
	1.63	0.02	1.26%	1.90%	2.50%	3.18%	3.83%	4.46%	5.15%
	1.64	0.01	0.64%	1.24%	1.86%	2.49%	3.17%	3.80%	4.46%
	1.65	0.00	0.00%	0.60%	1.21%	1.84%	2.46%	3.15%	3.77%
Medium Log Set (Dry Target)	1.70	0.05	3.16%	3.79%	4.41%	5.05%	5.70%	6.36%	7.05%
	1.71	0.04	2.52%	3.12%	3.79%	4.39%	5.02%	5.66%	6.34%
	1.72	0.03	1.86%	2.48%	3.10%	3.75%	4.38%	5.01%	5.63%
	1.73	0.02	1.26%	1.85%	2.46%	3.09%	3.72%	4.37%	4.98%
	1.74	0.01	0.62%	1.24%	1.83%	2.45%	3.07%	3.68%	4.35%
	1.75	0.00	0.00%	0.60%	1.21%	1.80%	2.44%	3.05%	3.66%

Source: Appendix D-1

As the sawmilling parameters changed from the base case (0.0-inch target and kerf size reduction), the percentage change in value recovered increased substantially. According to Terry Brown, a professor at Oregon State University, any change in sawmilling parameters that will result in a 0.5% change in total revenue output can be recognized. Therefore, there could be substantial impacts to mill profitability if a mill operated with smaller target or kerf sizes. Appendix D consists of tables similar to Table 7 that display the percent changes of LRF and dollar value with respect to the individual and composite changes in the three sawmill parameters (wane allowance, target and kerf size). Figure 4, which is a visual representation of the upper part of Table 7, demonstrates the predictable stepwise increase.

Figure 4. Percentage change of lumber value versus kerf and target size reductions (Appendix D, Figure D-1) (5 % wane allowance in Small Log mill)



One possible reason for this predictable stair step is because the simulation program fits the optimal cutting solution within a 3-D representation of the logs consisting of a series of ovals 6-inches to 2-feet apart. Because we specified the simulation program to cut specified cants widths (i.e. 4, 6, 8, 10, and 12-inch), increases occur incrementally once wider cants can be cut. According to MaxiMill Corporation, the stair step would go away if a random cant size was specified. The price table used in the simulation input also contributed to the stepwise increases, due to it being a random length and preferred width price table.

Sometimes mill managers only want to make one parameter change to a mill at a time. Table 9 and Figures 5, 6, and 7 are summaries of the percentage changes in value for each individual sawmill parameter change by log set and mill type (similar tables and figures can be found in Appendix E). Clearly, a 0.01-inch reduction in kerf or target size for either the small or medium log mill will result in at least a 0.60% increase in recovery or value. Thus, if a mill can recognize at least a 0.05% increase, then a 0.01-inch reduction in kerf or target size is significant. It is interesting to note that with either a 0.01-inch size reduction in kerf or target, the log mix type (small or medium), target type (green or dry), and wane allowance (5% or 35%) has little or no effect on the % increase. This occurs because a 0.01-inch reduction had a much larger effect on the % change than log mix type, target type, or wane allowance parameters.

Table 9. Percentage value increase vs. changes in target and kerf size, wane, and mill type

			Small Log Set		Medium Log	
Sawmill Parameter	Wane	Measure	Green Target	Dry Target	Green Target	Dry Target
Target Size Reduction (0.01-inch)	5%	Average	0.65%	0.65%	0.65%	0.63%
		Stdev	0.07%	0.03%	0.02%	0.02%
		2-Stdev	0.15%	0.06%	0.05%	0.04%
	35%	Average	0.61%	0.63%	0.64%	0.62%
		Stdev	0.08%	0.05%	0.07%	0.03%
		2-Stdev	0.16%	0.09%	0.15%	0.05%
Kerf Size Reduction (0.01-inch)	5%	Average	0.63%	0.60%	0.63%	0.61%
		Stdev	0.06%	0.03%	0.02%	0.02%
		2-Stdev	0.11%	0.06%	0.05%	0.04%
	35%	Average	0.61%	0.60%	0.63%	0.61%
		Stdev	0.07%	0.04%	0.07%	0.02%
		2-Stdev	0.13%	0.08%	0.15%	0.05%
Wane Allowance (5-35%)		Average	8.52%	8.69%	5.62%	5.69%
		Stdev	0.11%	0.07%	0.06%	0.03%
		2-Stdev	0.22%	0.13%	0.12%	0.06%

Source: (Appendix E-1)

A change in wane allowance from 5 to 35% is extremely significant. Value increased over 8.5% with the small log set, while an increase of over 5.6% was found with the medium log set. Therefore, it is very critical for a mill to sell wane free lumber at a much higher price (8.5 or 5.6 %) to compensate for the loss in recovery. With an overall average selling price of $325/MBF, a loss in value or recovery of 8.5% is approximately equal to a loss of $25MBF (5.6% equates to $17.5/MBF). Lumber sales people need to recognize the potential loss in recovery when they sell the wane free lumber versus lumber at the maximum wane allowance. In Figures 5, 6, and 7, a dashed line was drawn at the level of an average recognizable percentage change in a sawmill. Error bars, showing a 95 % confidence interval, were also inserted for each of the percentage gains. Using these graphs, we can see that at any level a mill is operating (small or medium log mix, 5-35 % wane allowance, and dry or wet target sizes), a 0.01-inch change in kerf or target size can be significant.

Figure 5. Percent increase in lumber value vs reduction in kerf or target size by mill type size
(2-Sigma Error bars also included)
Source: Appendix E, Figure E1

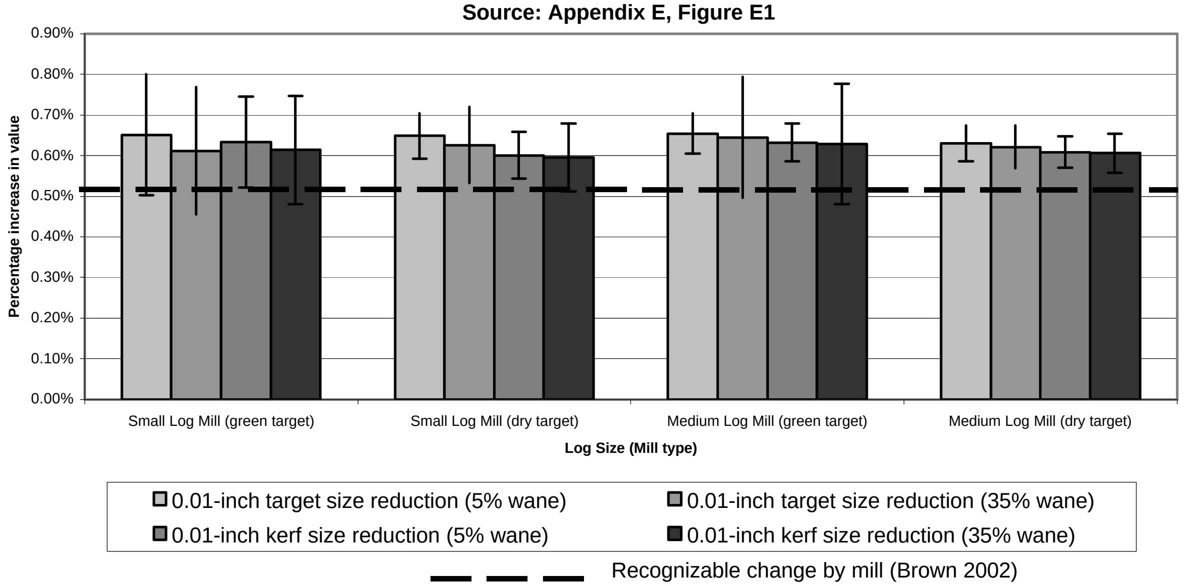


Figure 6. Percent increase in LRF vs reduction in kerf or target size by mill type and green or dry target size (2-Sigma Error bars also included)
Source: Appendix E, Figure E-2

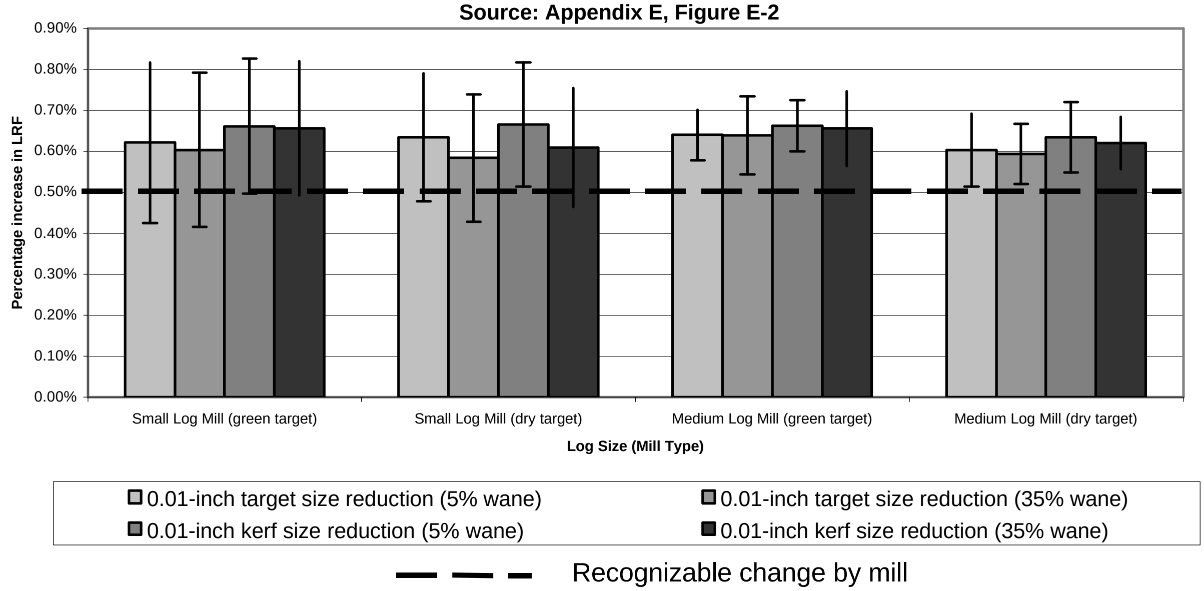
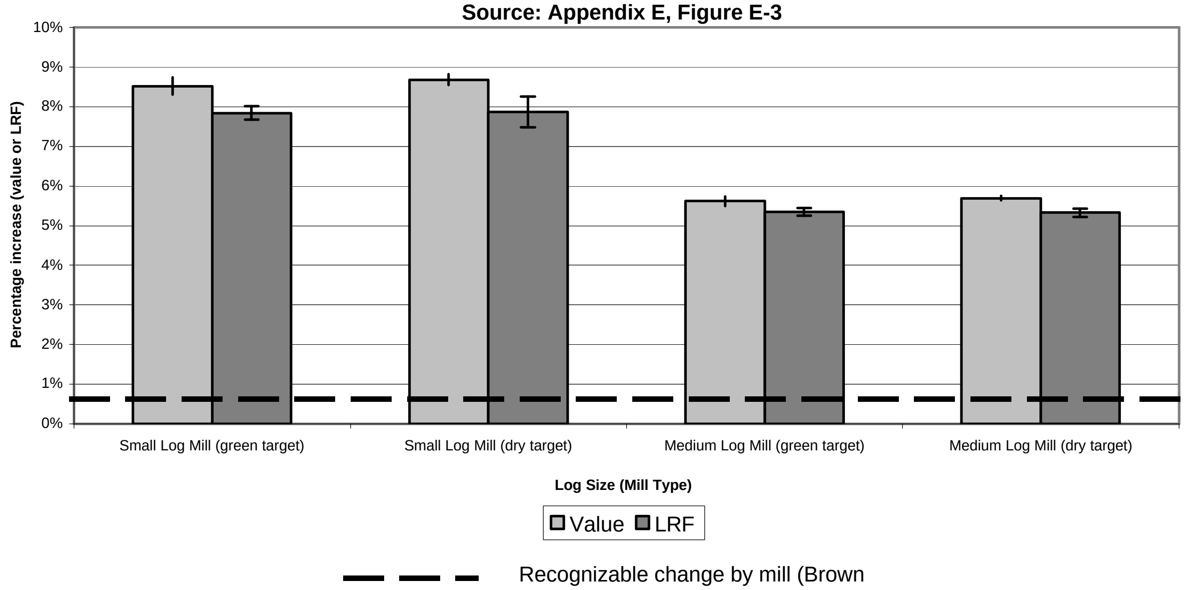


Figure 7. Percentage increase in value and LRF vs decrease in wane allowance from 35 to 5 % for large and small log data sets (2-Sigma Error bars also included)
Source: Appendix E, Figure E-3



A final part of analysis quantified the effects of a 0.6% increase in recovery at the mill production level. Table 10 shows the production parameters of an average small and medium log sawmill. These calculations used an average value for all the lumber sold of $325 per thousand board feet and assumed 250 days of production per year. Interestingly, an average small log sawmill will achieve an increase in revenue of almost $244,000, while the large log mill may see an increase of $390,000. Expensive raw material (logs) and low lumber sales price causes sawmills to operate at a very low profit margin. The low profit margins make the increases in revenue become much more substantial as long as the cost to implement the size reductions is not too expensive.

Table 10. Additional revenue generated by a 0.6% change in value of lumber from small and large log mills.

Production Parameters	Small Log Mill	Medium Log Mill
$ Value per MBF	$ 325	$ 325
Production MBF/Day	500	800
No Days in Production	250	250
% Increase in Production	0.60%	0.60%
Production Output		
Gross Production (MBF/yr)	125,000	200,000
Additional Production (MBF/yr)	750	1,200
Revenue Generated		
Gross Revenue	$ 40,625,000	$ 65,000,000
Typical Profit		
Additional Revenue	**$ 243,750**	**$ 390,000**

Source: Appendix E-3

CONCLUSIONS

This project showed the substantial benefits of monitoring sawmilling practices at a higher level. It is up to sawmill operation managers to determine what level of optimization is most profitable. This project showed a significant (approximately 0.6%) improvement in lumber recovery with each incremental decrease in kerf and target size. Recovery losses from producing wane free lumber are not necessarily compensated with a higher selling price. It is essential for sawmill managers and lumber sales people to understand the implications of running a sawmill at different sawing parameters. The dollar value associated with changes in wane allowance, size control and kerf in the sawmill can help to keep a mill operating at a profit during tougher economic periods.

Sawmill managers, quality control employees, equipment manufacturers, lumber sales people, and many others associated with sawmilling practices can use the results from this project. Sawmill managers can use this information to determine if operating at higher optimization levels is worth the additional revenue. This study may also be used as an incentive for quality control people to identify areas for improving sawmill operations. Equipment manufactures may be able to use this information as a marketing tool, as equipment can be built to improve sawing accuracy and reduce target and kerf sizes. Lumber marketing people can use this data to assess the additional cost of producing wane free lumber so prices may be set to compensate for the loss in recovery.

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