Forintek Canada Corp.
Western Division
2665 East Mall
Vancouver, BC
V6T 1W5

General Revenue Project No. 4546

Final Report 2005/06

Benefits of Including Surface Defect Information in Edger and Trimmer Optimization

by

Laszlo Orbay
Research Scientist
Sawmilling Group, Manufacturing

March 2006

Forintek Canada Corp. would like to thank its industry members, Natural Resources Canada (Canadian Forest Service), and the Provinces of British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, Nova Scotia, New Brunswick, as well as Newfoundland and Labrador, for their guidance and financial support for this research.

Notice

This report is an internal Forintek Canada Corp. (Forintek) document, for release only to Forintek members and supporters. This distribution does not constitute publication. The report is not to be copied for, or circulated to, persons or parties other than Forintek members and supporters, except with the prior permission of Forintek. Also, this report is not to be cited, in whole or in part, unless prior permission is secured from Forintek.

Neither Forintek, nor its members, nor any other persons acting on its behalf, make any warranty, express or implied, or assume any legal responsibility or liability for the completeness of any information, apparatus, product or process disclosed, or represent that the use of the disclosed information would not infringe upon privately owned rights. Any reference in this report to any specific commercial product, process or service by trade name, trademark, manufacturer or otherwise does not constitute or imply its endorsement by Forintek or any of its members.

Abstract

The objective of this project was to quantify the lumber value recovery up-lift that is achievable by adding surface defect detection to board profile scanning in sawmill edger optimization. Optimized profile edging solutions of 194 spruce-pine-fir sample boards were compared to optimized edging solutions that took into account surface defects as well as the geometric shape of the board. The edger optimization improvement was found to be marginal. Data analysis showed a benefit of only \$0.13 per m^3 of processed logs, an equivalent of \$237.11 per shift. The findings of this report are mill specific. The value recovery figures were collected in a mill with given log supply, machinery and market orientation. A more significant up-lift in value recovery would likely be obtained for higher valued products produced from larger logs typically processed in coastal sawmills.

Acknowledgements

Forintek Canada Corp. would like to acknowledge Tolko's Lignum Sawmill for its support and cooperation throughout the project. In particular, the assistance of Mr. Barry McKinney, QC Supervisor, and his team in organizing the mill test and grading lumber pieces was invaluable.

The suggestions of Mr. Daniel Ethier, AUTOLOG and Mr. Don Starr, Weyerhaeuser Canada Ltd. regarding the design of project activities were also helpful. Thank you.

Table of Contents

List of Tables

List of Figures

1 Objectives

The objective of this project was to quantify the lumber value recovery up-lift that is achievable by adding surface defect detection to board profile scanning in edger optimization in sawmills.

2 Introduction

Recent improvements in image processing promise surface detection techniques that are capable of identifying and classifying lumber grade-determining defects on rough, green board surfaces. Surface defects like knots, stain, rot, bark and pitch pockets, honeycomb, etc., are natural wood characteristics that affect lumber grade. Their size and location have an effect on lumber value and can be influenced by sawing decisions in the sawmill. One of these decisions is board edging. Though edger optimizers are available and currently widely used in the industry, they take into account only the geometric shape of the board, hence, surface defects are not included in the optimization process. The resulting question is as follows: Can the performance of edger optimizers in sawmills be improved by including surface defect information in the optimization process?

3 Staff

Laszlo Orbay	Research Scientist, Sawmilling Group, Manufacturing Department
Anthony Barbosa	Technologist, Sawmilling Group, Manufacturing Department
John White	Technologist, Sawmilling Group, Manufacturing Department
Roy Abbott	Technologist, Building Systems
Vit Mlcoch	Technologist, Lumber Drying Group, Manufacturing Department
Al Matsala	Carpenter, Building Services.

4 Study Methods

One hundred and ninety-four un-edged spruce-pine-fir boards were scanned by a CAE Newnes Transverse Edger Optimizer at a BC Interior sawmill. The technology, the log supply and the market orientation of this sawmill represented a typical B.C. Interior sawmill operation. Depending on their location in the parent log (either in the center cant or in the flitches), the boards had wane, part wane or square edges. Sample boards were identified with numbers, profile-scanned, and the edging solutions from the optimizer were downloaded. Downloaded parameters included positioning pin distances from the feed line and saw positions. The example in Figure 1 shows 4.049 and 3.397 inches as the positioning pin distances from the feed line and -2.990 and 2.990 inches as the saw positions relative to the feed line.

Edging solutions were mainly one-piece solutions but in the case of larger boards two-piece solutions (splitting the piece longitudinally) were possible. The boards were then removed from the processing line, before the actual edging took place, and were shipped to Forintek's Western Laboratory for grading.

The majority of lumber produced in the Interior of B.C. goes to the standard dimensional US lumber market. Therefore, lumber pieces were graded by grading rules outlined in Paragraph 114 a to e of the NLGA grading rules.

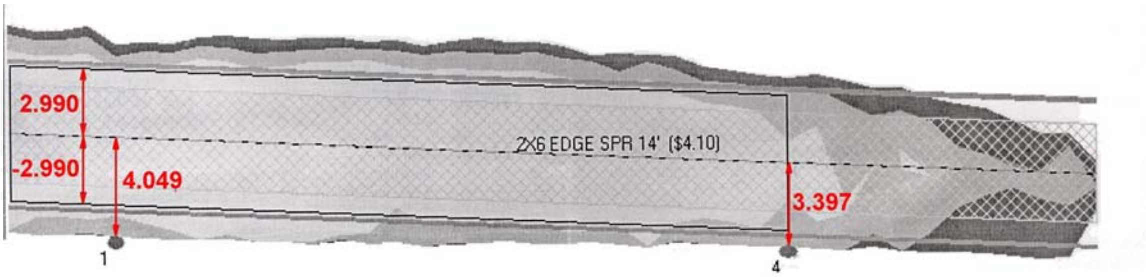

Figure 1: Parameters determining lumber location within the parent board.

A special grading table equipped with laser lines and positioning pins was set up to assist with visual lumber grading (Figure 2). The positioning pins were used to orient the board in accordance with the edging solution determined by the optimizer (i.e., the pins were used to adjust skew and offset). Laser lines were then projected on the board surface to show the grader the location of the sawlines in the optimized solution and the piece was then visually graded. The grade and value of these lumber pieces represented the base-case of what is currently done in most BC interior mills, and in this report are referred to as the profile optimized lumber solutions.

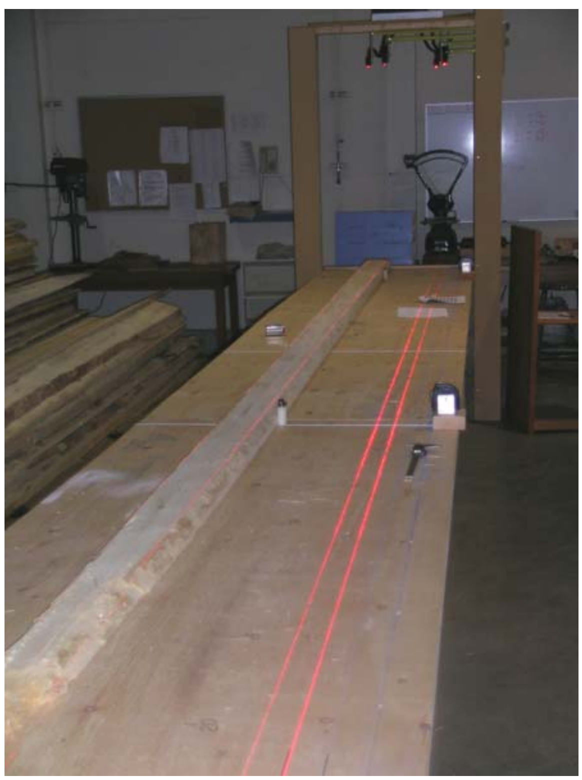

Figure 2: Grading table.

Next, the grader manually determined the best edging decision by taking into account both the profile and surface characteristics of each piece. These solutions were referred to us the profile/defect optimized lumber solutions and were considered to represent the best edging decision possible (i.e., the "perfect" solution) because the human eye can detect many surface features that are not detectable by machine vision systems.

At the planning phase of the project, a third method of optimizing edging decisions was also considered. This method was intended to take into account only those surface defects that are visible by currently available machine vision systems. Since machine vision systems cannot see surface defects as well as human eyes, (see Figure 3), the intention was to see what proportion of the potential "perfect" up-lift could be achieved by automated machine vision grading systems. Thus, the completion of this third method was planned only if the up-lift in lumber value recovery achievable by "perfect" profile/defect optimization was large enough to make further investigation logical.

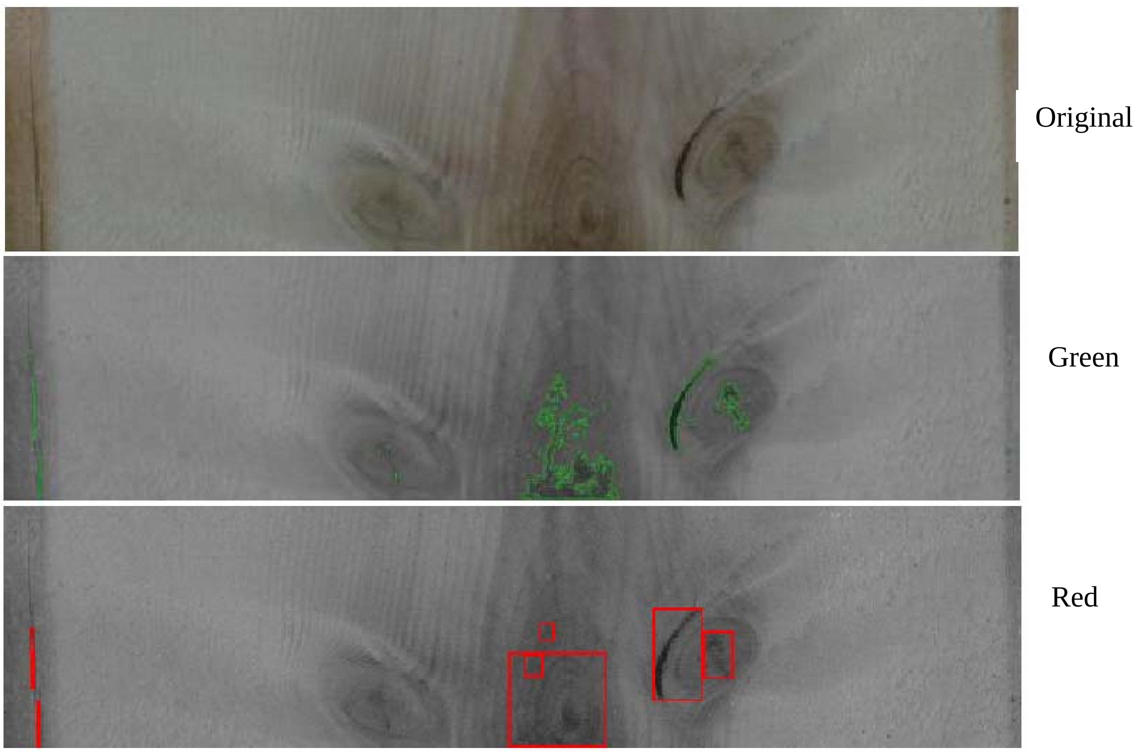

Figure 3: Pictures of original board surface, the images of defects developed (green) by the machine vision system and the final size and location envelopes (red) generated by machine vision system. (The images were generated by Hema Electronic Gmbh.)

5 Results

Out of the 194 sample boards that were processed by the edger optimizer, 86 pieces required no edging (i.e. the optimization solution indicated that only trimming the length was required). These pieces were judged by quality control personnel as not being realistic candidates for recovery improvement. However their piece counts was taken into account when the overall benefits were calculated (Appendix 3). Among the remaining 108 boards, there was only one piece that made two-piece edging solution: board #22. All the others had one-piece solutions, and thus the total number of pieces to be graded was 109. Their grades, causes of downgrading and piece values are listed in Appendix 1.

Lumber prices for each grade and size combination and the corresponding piece values used in value recovery calculations are shown in Appendix 2. The total value of profile-optimized lumber recovered from the 194 sample boards was $866.66 (Appendix 1).

There were only 3 boards out of 108 in which incorporating surface defect information resulted in better edging/trimming decisions. For board #53, the profile/defect optimization resulted in 4 inch-wide edging (2x4-20, grade #1) as opposed to the profile optimization solution of 6 inch-wide edging (2x6-18, grade Economy). This allowed the recovery of a longer, narrower piece and a resulting higher grade and lumber value (See Figure 4 and Table 1). This optimization was achieved by detecting the bark pocket that was edged out from the profile/defect-optimized lumber. The value recovery uplift was $5.89 - $3.55 = $2.34.

Table 1: Quantifying the benefits of surface defect detection in edger optimization.

Board ID	Profile optimization					Profile and surface defect optimization					Up lift, $
	Resulting lumber			Grade	Piece value, $	Resulting lumber			Grade	Piece value, $	
	T	W	L			T	W	L			
53	2	6	18	Econ	3.55	2	4	20	#1	5.89	2.34
61	2	6	20	Econ	3.94	2	6	8	#3 (Piece1)	2.29	
						2	6	10	#2 (Piece2)	3.76	
Total value of two pieces recovered from board# 61:										6.05	2.11
103	Reject piece with volume of 6 board feet – Saving of post-trimming operation:										0.15
										Total:	**4.60**

In the case of board #61, detecting and trimming the knots in the two-foot board segment between the eight and ten feet mark helped to produce a piece of 2x6-10, grade #2 and another piece of 2x6-8, grade #3, as opposed to 2x6-20, grade Economy (See Figure 5 and Table 1). The value recovery up-lift was $6.05 - $3.94 = $2.11. Notice that to achieve this value recovery up-lift, the edging decisions of profile and profile/defect optimizations were the same and a trimmer with defect surface detection capabilities was assumed.

In the case of board #103, the fiber volume of the board was overestimated because the profile scanning system could not differentiate between fiber and bark. In other words, the bark was scanned as being fiber. Thus a “reject” piece of board was unnecessarily entered into the post-trimming operation. Had this board been rejected, the cost of post-trimming could have been saved. Assuming a $25/MFBM cost of post-trimming operation, rejecting this board with an estimated volume of six board feet could have saved $0.15 per board.

The overall up-lift was $4.60, or 0.53% (i.e., $4.60 / $866.66 = 0.53%). In terms of the number of boards, 3 out of 194 pieces resulted in higher value recovery, which is 3 / 194 = 1.55%. Calculations in Appendix 3 show that the $4.60 per sample lumber value recovery up-lift converts to a profile/defect optimization benefit of $237.11/shift or $0.13/m^3 of processed log.

When interpreting the results of this study, it is important to remember that the results are mill specific. The benefits achievable with surface defect detection are heavily dependent on the sawmill’s particular log supply, product mix and proprietary grading rules (i.e., the sizes and grades of lumber the sawmill produces). In this study the smaller logs processed by the mill that supplied the un-edged sample boards resulted in pieces with fewer edging solutions than would have been possible if the boards were wider. Thus, the potential up-lift from surface defect detection was less than might have been the case for mills processing larger logs.

The original intention of this project was to quantify what proportion of the benefits of "perfect" defect detection can be realized by automated machine vision systems. Due to the fact that the "perfect" defect detection showed marginal potential benefits, this planned phase of the study was not implemented.

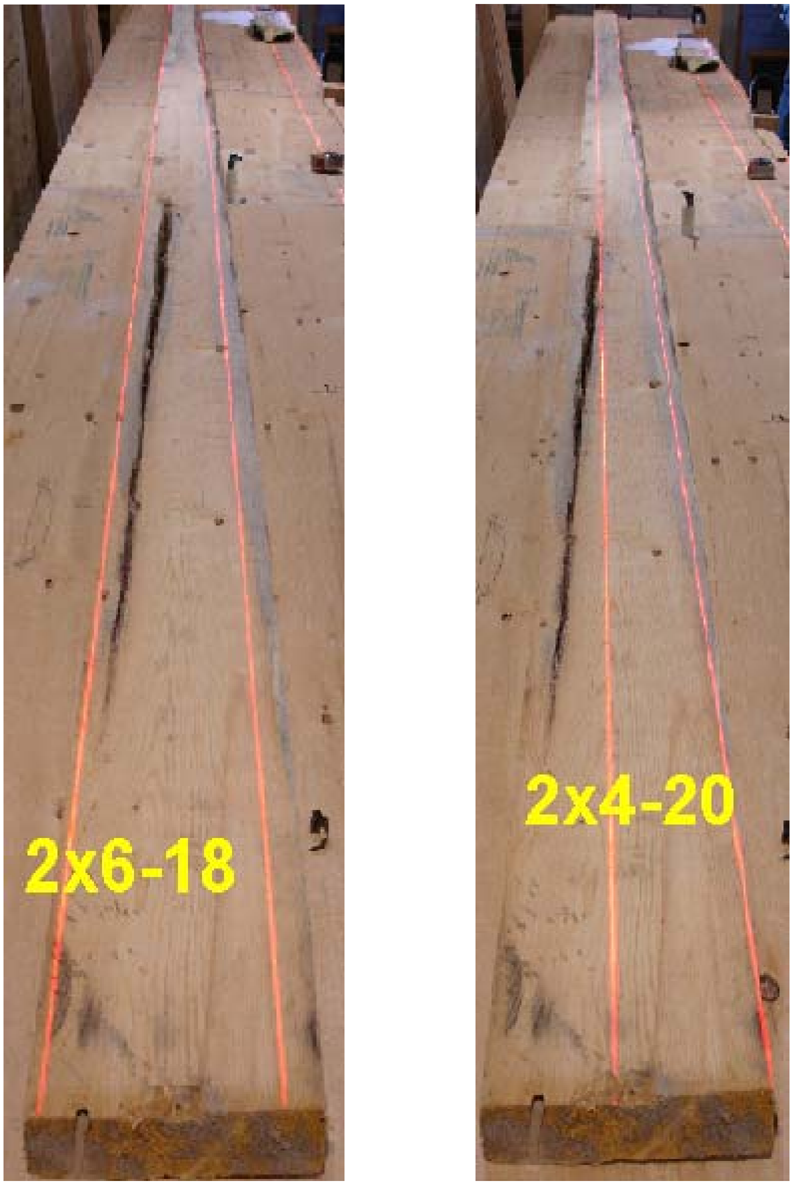

Figure 4: ***Board #53 and its two projected edging solutions: profile edged lumber on the left and profile/defect on the right.***

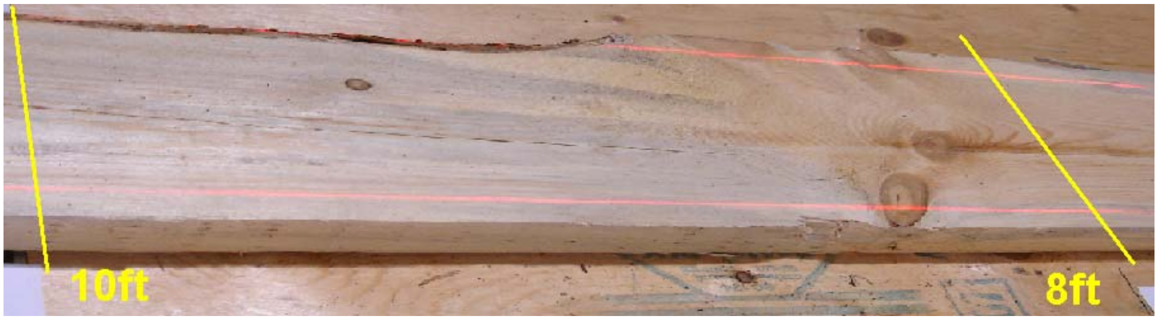

Figure 5: ***Board #61 - Cutting out a knotty two-foot segment resulted in higher lumber value recovery.***

Tables 2 to 4 are included to summarize the overall characteristics of the sample boards and their impact on the limitations of potential benefits of surface defect scanning. Table 2 shows proportions of lumber by dimension, Table 3 lists grade proportions and Table 4 lists the causes of downgrading.

Table 2: ***Proportions of resulting lumber by dimension.***

Dimension	Number of pieces	Proportion, %
Reject	1	0.9
2x3	1	0.9
2x4	63	57.8
2x6	40	36.7
2x8	4	3.7
Total:	109	100.0

Table 3: ***Grade proportions of resulting lumber.***

Grade	Number of pieces	Proportion, %
Select Structural	46	42.2
#1	7	6.4
#2	38	34.9
#3	13	11.9
#4	4	3.7
Reject	1	0.9
Total:	109	100.0

Table 4: ***Causes of downgrading and their proportions.***

Causes	Number of boards with the cause	Proportions, %
Skip	2	1.8
Decay (Rot)	3	2.8
Shake	3	2.8
Slope of grain	4	3.7
Knot	11	10.1
Wane	39	35.8
No downgrading	47	43.1
Total:	109	100.0

The proportion of the larger sizes, 2x6 and 2x8, in which the feasible set of edging decisions is higher, was about 40%. The proportion of the highest select structural grade (when no edging decision of higher value recovery is possible) was 42.2%. This imposes a limitation on the profitable application of profile/surface edger optimization because there is no room for grade improvement in the case of boards of the highest grade. It should be noted that even if there had been more flexibility in the edging solutions, the proportion of boards where surface defects could improve piece value was only about 21% (23/109).

6 Conclusions and Recommendations

Due to the sample boards' characteristics (size, quality and surface defects) the potential benefits of including surface defect detection in edger optimization was found to be marginal in this test. The benefit was estimated as $0.13 per m^3 of processed logs, equivalent to $237.11 per shift for a mill processing 1,880 m^3 per shift. Thus, the application of machine vision systems for identifying rough green lumber surface defects in edging/trimming optimization is unlikely to be a profitable for typical B.C Interior sawmills. Because value up-lift is dependent on log size and product mix, a similar study investigating the benefits of surface defect detection in a coastal BC sawmill is recommended.

Appendix I

Board dimensions and grades

Board#	Recovered lumber				Cause of downgrading	Value, Can$/ Piece
	Thickness, in	Width, in	Length, ft	Grade		
1	2	4	16	Select		5.48
2	2	6	16	Select		6.88
9	2	6	14	Select		5.32
20	2	4	20	Select		6.21
23	2	6	12	Select		4.92
29	2	6	18	Select		7.63
30	2	6	10	Select		4.36
33	2	6	12	Select		4.92
38	2	6	20	Select		8.48
41	2	6	14	Select		5.32
48	2	4	8	Select		2.55
75	2	4	18	Select		5.59
83	2	6	10	Select		4.36
84	2	6	12	Select		4.92
93	2	4	16	Select		5.48
97	2	4	16	Select		5.48
101	2	4	14	Select		4.59
102	2	6	16	Select		6.88
104	2	4	20	Select		6.21
108	2	6	16	Select		6.88
110	2	6	10	Select		4.36
112	2	4	14	Select		4.59
114	2	4	16	Select		5.48
116	2	4	12	Select		3.61
117	2	4	16	Select		5.48
120	2	4	8	Select		2.55
121	2	4	16	Select		5.48
133	2	4	18	Select		5.59
141	2	4	18	Select		5.59
146	2	6	20	Select		8.48
147	2	4	16	Select		5.48
152	2	6	8	Select		3.3
153	2	4	16	Select		5.48
158	2	4	14	Select		4.59
160	2	4	14	Select		4.59
163	2	6	16	Select		6.88
169	2	4	8	Select		2.55
172	2	4	16	Select		5.48
174	2	4	16	Select		5.48
176	2	4	8	Select		2.55
185	2	4	16	Select		5.48
187	2	4	14	Select		4.59
189	2	4	16	Select		5.48
190	2	6	14	Select		5.32
192	2	4	10	Select		3.11
194	2	4	16	Select		5.48
24	2	8	10	#1	Decay/Rot	5.89
49	2	4	10	#1	Knot	2.95
106	2	4	8	#1	Knot	2.42
115	2	4	12	#1	Knot	3.42
150	2	4	10	#1	Knot	2.95
171	2	4	14	#1	Wane	4.37
181	2	4	18	#1	Wane	5.3

Board#	Recovered lumber				Cause of downgrading	Value, Can$/ Piece
	Thickness, in	Width, in	Length, ft	Grade		
7	2	6	20	#2	Knot	7.29
10	2	6	12	#2	Wane	4.2
14	2	4	20	#2	Shake	5.42
22	2	4	10	#2	Wane	2.71
22	2	4	20	#2	Wane	5.42
36	2	4	18	#2	Shake	4.87
51	2	6	10	#2	Wane	3.76
59	2	6	16	#2	Wane	5.93
62	2	4	16	#2	Knots	4.84
63	2	4	18	#2	Wane	4.87
67	2	4	14	#2	Wane	4.04
71	2	4	10	#2	Wane	2.71
72	2	6	10	#2	Wane	3.76
73	2	8	12	#2	Shake	6.79
87	2	6	16	#2	Wane	5.93
88	2	4	10	#2	Wane	2.71
89	2	6	16	#2	Knot	5.93
96	2	6	8	#2	Wane	2.82
107	2	4	14	#2	Wane	4.04
109	2	6	12	#2	Wane	4.2
113	2	4	16	#2	Wane	4.84
118	2	4	10	#2	Knot	2.71
130	2	6	12	#2	Skip	4.2
134	2	4	12	#2	Wane	3.13
137	2	4	12	#2	Wane	3.13
143	2	6	12	#2	Wane	4.2
145	2	4	16	#2	Wane	4.84
151	2	4	12	#2	Wane	3.13
157	2	4	12	#2	Wane	3.13
167	2	4	14	#2	Wane	4.04
168	2	4	14	#2	Wane	4.04
173	2	6	16	#2	Slope of grain	5.93
175	2	4	12	#2	Knot	3.13
178	2	4	20	#2	Wane	5.42
179	2	6	10	#2	Wane	3.76
182	2	4	12	#2	Knots	3.13
183	2	6	12	#2	Wane	4.2
193	2	6	12	#2	Skip	4.2
40	2	6	8	#3	Wane	2.29
44	2	4	14	#3	Wane	3.18
54	2	4	12	#3	Wane	2.72
55	2	6	8	#3	Wane	2.29
64	2	4	12	#3	Wane	2.72
92	2	8	14	#3	Grain	6.02
94	2	4	18	#3	Slope of grain	4.09
98	2	6	20	#3	Decay/Rot	5.73
105	2	4	8	#3	Wane	1.82
129	2	4	8	#3	Wane	1.82
131	2	4	14	#3	Decay/Rot	3.18
132	2	6	8	#3	Wane	2.29
139	2	6	12	#3	Slope of grain	3.44
53	2	6	18	Econ	Wane	3.55
61	2	6	20	Econ	Knot	3.94
161	2	3	8	Econ	Wane	0.82
188	2	6	12	Econ	Wane	2.36

Board#	Recovered lumber				Cause of downgrading	Value, Can$/ Piece
	Thickness, in	Width, in	Length, ft	Grade		
103				Reject		
Total lumber value, $:						**482.47**

The approximate value* of the 86 boards sent directly to the trimmer is: $384.19
The total value of profile-optimized lumber recovered from the 194 sample boards: $866.66

* Note: Calculated by using the average value of boards with “EDGE” decisions: $482.47/108=$4.47.

Appendix II

Lumber prices and piece values used in the study.

Source: Lumber Price Guide of Random Lengths, May 20, 2005.

Grade: Export/MSR2400, CAN$/Mfbm

Dimension	feet						
	8	10	12	14	16	18	20
2x4	550	538	523	564	585	538	538

Grade: SelectStr., CAN$ / Mfbm

Dimension	feet						
	8	10	12	14	16	18	20
2x4	478	466	452	492	514	466	466
2x6	412	436	410	380	430	424	424
2x8	466	466	484	448	460	466	466
2x10	442	442	556	526	478	472	472
2x12	532	532	544	460	538	532	532

Grade: #1, CAN$ / Mfbm

Dimension	feet						
	8	10	12	14	16	18	20
2x4	454	442	428	468	490	442	442
2x6	388	412	386	356	406	400	400
2x8	442	442	460	424	436	442	442
2x10	418	418	532	502	454	448	448
2x12	508	508	520	436	514	508	508

Grade: #2, CAN$ / Mfbm

Dimension	feet						
	8	10	12	14	16	18	20
2x4	418	406	392	432	454	406	406
2x6	352	376	350	320	370	364	364
2x8	406	406	424	388	400	406	406
2x10	382	382	496	466	418	412	412
2x12	472	472	484	400	478	472	472

Grade: Utility / #3, CAN$ / Mfbm

Dimension	feet						
	8	10	12	14	16	18	20
2x4	340	340	340	340	340	340	340
2x6	287	287	287	287	287	287	287
2x8	323	323	323	323	323	323	323
2x10	299	299	299	299	299	299	299
2x12	311	311	311	311	311	311	311

Grade: Economy / #4, CAN$ / Mfbm

Dimension	feet						
	8	10	12	14	16	18	20
2x3	204	204	204	204	204	204	204
2x4	200	200	200	200	200	200	200
2x6	197	197	197	197	197	197	197
2x8	190	190	190	190	190	190	190
2x10	194	194	194	194	194	194	194
2x12	197	197	197	197	197	197	197

Grade: Stud, CAN$ / Mfbm

Dimension	feet						
	8	10	12	14	16	18	20
2x4	470	470	470	470	470	470	470

Piece values

Grade: Export/MSR2400, CAN$ / piece

Dimension	feet						
	8	10	12	14	16	18	20
2x4	2.93	3.58	4.19	5.26	6.24	6.45	7.17

Grade: SelectStr., CAN$ / piece

Dimension	feet						
	8	10	12	14	16	18	20
2x4	2.55	3.11	3.61	4.59	5.48	5.59	6.21
2x6	3.30	4.36	4.92	5.32	6.88	7.63	8.48
2x8	4.97	6.21	7.74	8.36	9.81	11.18	12.42
2x10	5.89	7.37	11.11	12.27	12.74	14.16	15.73
2x12	8.51	10.63	13.05	12.88	17.20	19.14	21.27

Grade: #1, CAN$ / piece

Dimension	feet						
	8	10	12	14	16	18	20
2x4	2.42	2.95	3.42	4.37	5.22	5.30	5.89
2x6	3.11	4.12	4.63	4.98	6.50	7.20	8.00
2x8	4.72	5.89	7.36	7.92	9.30	10.61	11.79
2x10	5.58	6.97	10.63	11.71	12.11	13.44	14.93
2x12	8.12	10.15	12.47	12.21	16.44	18.28	20.31

Grade: #2, CAN$ / piece

Dimension	feet						
	8	10	12	14	16	18	20
2x4	2.23	2.71	3.13	4.04	4.84	4.87	5.42
2x6	2.82	3.76	4.20	4.48	5.93	6.56	7.29
2x8	4.33	5.42	6.79	7.25	8.54	9.75	10.83
2x10	5.10	6.37	9.92	10.87	11.15	12.37	13.74
2x12	7.55	9.44	11.61	11.21	15.29	16.99	18.88

Grade: Utility / #3, CAN$ / piece

Dimension	feet						
	8	10	12	14	16	18	20
2x4	1.82	2.27	2.72	3.18	3.63	4.09	4.54
2x6	2.29	2.87	3.44	4.01	4.59	5.16	5.73
2x8	3.44	4.30	5.16	6.02	6.88	7.74	8.60
2x10	3.98	4.98	5.97	6.97	7.96	8.96	9.96
2x12	4.97	6.21	7.45	8.70	9.94	11.18	12.42

Grade: Economy / #4, CAN$ / piece

Dimension	feet						
	8	10	12	14	16	18	20
2x3	0.82	1.02	1.23	1.43	1.63	1.84	2.04
2x4	1.07	1.33	1.60	1.87	2.13	2.40	2.67
2x6	1.58	1.97	2.36	2.76	3.15	3.55	3.94
2x8	2.03	2.53	3.04	3.55	4.05	4.56	5.07
2x10	2.59	3.23	3.88	4.53	5.17	5.82	6.47
2x12	3.15	3.94	4.73	5.52	6.30	7.09	7.88

Grade: Stud, CAN$ / piece

Dimension	feet						
	8	10	12	14	16	18	20
2x4	2.51	2.51	2.51	2.51	2.51	2.51	2.51

Appendix III

Calculation of annual benefits that are achievable with profile/defect edger and trimmer optimization.

Assumptions about the production of the theoretical sawmill

(1)	Piece count / shift at the Edger Optimizer Scanner:	10,000
(2)	Volume of logs processed, m^3/shift:	1,880

Data resulted from the edger optimizer test

(3)	Total number of sample boards:	194
(4)	Value recovery uplift due to profile/defect optimization, $/sample:	4.60

Calculated data

(5) Sample board proportion over the piece count/shift at the optimized edger:

$$\frac{(3)}{(1)} = \frac{194}{10000} = \frac{1}{52} shift / sample$$

(6) Benefits of profile/defect optimization $ / shift:

$$\frac{1}{(5)} * (4) = 52 \frac{sample}{shift} * 4.60 \frac{\$}{sample} = 237.11 \frac{\$}{shift}$$

(7) Benefits of profile/defect optimization per m^3 of log processed, $ / m^3:

$$\frac{(6)}{(2)} = \frac{237.11 \frac{\$}{shift}}{1880 \frac{m3}{shift}} = 0.13 \frac{\$}{m3}$$