

# A comparison of two roughmill cutting models

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## Abstract

A comparison of lumber yield using the Automated Lumber Processing System (ALPS) Cutting Program and the Optimal Furniture Cutting Program (OFCP) was conducted on eight cutting bills. No. 1 Common grade hard maple data files were compiled using a board database collected and used by the USDA Forest Service's Forest Products Laboratory to develop standard hardwood lumber yield tables. The ALPS Cutting Program processed three furniture cutting bills, three kitchen cabinet cutting bills, and two "other" cutting bills with a board database of 343 boards containing 2,180 board feet. The ALPS Cutting Program was used to determine the maximum yield by selecting the number of parts cut for each cutting bill. The OFCP was used on the same cutting bills to generate the optimal yield of lumber that can be obtained by applying conventional roughmill technology. The results showed that by using ALPS and the ALPS Cutting Program, yield increases of 12.6 to 22.9 percent can be realized.

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National hardwood lumber production between 1967 and 1986 has averaged 6.7 billion board feet (BBF). The majority of this volume of lumber goes into the manufacture of furniture, cabinets, and dimension parts in the United States. Although the production level of hardwood lumber has fluctuated little, the value of that production has risen significantly. Costs for hardwood lumber production in 1986 increased to 317 percent of the 1967 producer price index (10). Over this same period, the processing of hardwood lumber in the roughmill has not changed substantially from current crosscut-and-rip cutting methods.

The objective of this study is to determine and compare the yield of hardwood dimension parts from 4/4 No. 1 Common hard maple lumber as predicted by two different roughmill cutting models: The Automated Lumber Processing System (ALPS) Cutting Program (7) and the Optimal Furniture Cutting Program (OFCP) (4).

The OFCP is a linear program computer model that computes the total yield and the least cost combination of hardwood lumber required to produce a given cutting bill by crosscut-and-rip cutting methods. In contrast, the ALPS cutting program places cutting bill pieces around user-identified board defects and then employs a system capable of making blind cuts by starting and stopping at any point on the board surface, producing a "cookie cut" appearance.

The conventional means of maximizing the yield of dimension parts from hardwood lumber is based primarily on: 1) conventional roughmill crosscut-and-rip operations; 2) operator efficiency; 3) grade of lumber processed; and 4) the cutting bill.

In a roughmill, an operator converts hardwood lumber into dimension parts that will be subsequently glued, machined, and finished into usable parts for the furniture or cabinet industries. It is at the roughmill, with the initial crosscut or rip operation, that the maximum yield will be determined (3).

The three lumber grades most commonly used in the furniture and cabinet industries are: 1) Firsts and Seconds (FAS); 2) No. 1 Common; and 3) No. 2 Common. The National Hardwood Lumber Grading Association specifies that these grades must possess minimum clear surface areas of 83-1/3 percent, 66-2/3 percent, and 50 percent, respectively. Therefore, if a manufacturer increases the lumber grade used from No. 2 Common to No. 1 Common,

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TABLE 1. — Example of ALPS Cutting Program output.

Lower corner coord.	Upper corner coord.	Type	Face
( .00:6.75)	( 16.25:7.25)	1	0
( 18.25:7.00)	( 43.75:7.25)	1	0
( 35.75: .00)	( 66.75: .25)	1	0
( 66.75: .00)	( 73.25:3.50)	1	0
( 73.25: .00)	(106.25: .75)	1	0
( 84.25:7.00)	(106.25:7.25)	1	0
(103.00:4.50)	(106.25:7.00)	1	0

Total board area = 770.31 in.<sup>2</sup>  
 Total cutting area = 538.50 in.<sup>2</sup>  
 Percent of board area utilized = -69.91  
 Percent of clear area utilized = 78.45  
 Total value returned = 26,803<sup>a</sup>  
 Inches that must be cut = 329.25

Defect information for the board	
Defect type no. 1	83.88 in. <sup>2</sup>
Defect type no. 2	.00 in. <sup>2</sup>
Defect type no. 3	.00 in. <sup>2</sup>
Defect type no. 4	.00 in. <sup>2</sup>
Defect type no. 5	.00 in. <sup>2</sup>
Defect type no. 6	.00 in. <sup>2</sup>
Defect type no. 7	.00 in. <sup>2</sup>
Defect type no. 8	.00 in. <sup>2</sup>
Defect type no. 9	.00 in. <sup>2</sup>
Other defect types	.00 in. <sup>2</sup>
<b>Total</b>	<b>83.88 in.<sup>2</sup></b>

Lower X	Lower Y	Upper X	Upper Y
.00	.25	56.75	3.25
.00	3.25	56.75	6.25
56.75	4.25	100.75	7.00
73.25	.75	101.25	3.50

Number of cuttings placed = 4.

<sup>a</sup>Comparative weighting of parts produced.

the corresponding clear area for grading purposes would increase approximately 16 percent. This relationship also holds true for increasing the lumber grade from No. 1 Common to FAS. SELECTS and FAS 1 face lumber grades are also used in the industry, but they are graded from the poor face and contain elements of both No. 1 Common and FAS.

For a company to minimize its roughmill costs, it must maximize lumber yield while using the least total cost combination of grade lumber and labor. The relationship between the price structure of lumber grades and yield tends to complicate a manufacturer's efforts in maintaining low roughmill lumber costs. For example, the September 24, 1988 prices (2) for 4/4 hard maple lumber were \$.490/BF for FAS grade lumber, \$.385/BF for No. 1 Common grade lumber and \$.200/BF for No. 2 Common grade lumber. A furniture manufacturer would have to pay an additional \$.105/BF to change from No. 1 Common lumber to FAS lumber. This represents a 27.3 percent increase in costs for an additional 16 percent of clear surface area. Similarly, a change from No. 1 Common lumber to No. 2 Common lumber would reduce lumber costs by \$.185/BF. This change represents a 48.1 percent cost reduction with only a 16 percent reduction in the available clear surface area. This nonlinear relationship between price of lumber

grades and yield is created by the lumber grade supply and demand forces working in the marketplace.

It is commonly believed that the way to increase the yield of longer length parts is to use a higher grade of lumber, such as FAS grade. Because manufacturers believe No. 2 Common lumber produces only short parts, the prices of the higher grades of lumber have increased at a greater rate as compared to No. 2 Common lumber. Gatchell (1) suggests that lumber prices have been set by our current level of technology and that plants locked into the crosscut first approach have little opportunity to modify their processing sequence to increase yield. Therefore, manufacturers have little choice but to pay the increasing prices of the higher grades of lumber.

McMillin et al. (7) describe a trend toward automating the roughmill operation, which would dramatically change the level of technology currently employed. ALPS is proposed to eliminate all human judgment in processing hardwood lumber. Lumber would be scanned by optical image analyzers to identify defects and then be automatically processed using a wood cutting laser or another device allowing blind cuts. Klinkhachorn and Franklin (5) have recently developed an ALPS Cutting Program that uses a computer model to locate pieces from a given cutting bill around user-identified defective areas. The ALPS Cutting Program has high potential for increasing the total yield of hardwood lumber cut with a laser. This potential is derived from a woodcutting laser's ability to make blind cuts by starting and stopping at any point on the board surface, producing a "cookie cut" appearance. Yields will also increase through a reduction in the kerf width to approximately .025 inch. By employing a woodcutting laser system as proposed by ALPS, hardwood lumber yield should be dramatically improved.

### Methods and materials

The yield and value of 4/4 No. 1 Common hard maple lumber was determined for two different cutting models. The conventional crosscut-and-rip method was tested using the OFCP (4) model, which uses the standard yield tables published in the Forest Products Laboratory Research Paper 81 (8). The "cookie cut" method of cutting is represented by the ALPS Cutting Program model. The board data used in this study are the same as those used to develop the standard yield tables (8). These board data files contain the size of the board and the size and location of all defects on both surfaces. Using identical boards will provide a direct and reliable comparison of the two cutting models.

Eight different cutting bills were developed and used for testing the two cutting methods. Each of the eight cutting bills were processed with the same board file to determine the yield of parts from the lumber cut. The ALPS Cutting Program selected the number and sizes of dimension parts cut from the board data file. The selected number and sizes of parts were then used as the cutting bills to be processed by the OFCP. The OFCP was constrained to calculate yield for only No. 1 Common hard maple lumber. No adjustments to actual plant yields were made in calculating the yield using the OFCP. Comparisons were made between yields and value of lumber required to produce the eight cutting bills using the two cutting models.

## ALPS Cutting Program

The ALPS Cutting Program developed by Klinkhachorn and Franklin (5) is a heuristic, rule-based computer model that uses the position of defects to compute an efficient cutting strategy based on a given cutting bill. The placement algorithm used by this program was chosen from five different algorithms tested and described by Klinkhachorn et al. (6). The program accepts user-created board and cutting bill data from separate files and outputs the graphical results to the user's color monitor or printer. Table 1 provides an example of the ALPS Cutting Program's output. The algorithm employs a set of logically applied rules that approximate the thought process of humans, but gives consistently better results. For the board file, the program accepts defect data in user-identified units of resolution on an X-Y coordinate basis. The user can identify the type of defect entered and the side of the board on which the defect is located. The cutting bill file is constructed by entering part lengths and widths, the number of parts to be cut, and a weighting factor that places priorities on the pieces to be cut. The dollar value of the dimension parts cut is related to the length of those

TABLE 2. — Examples of a furniture cutting bill and a kitchen cabinet cutting bill.

No. of pieces cut	Length	Width	Weighting value
	(in.)		
<b>Furniture cutting bill no. 1<sup>a</sup></b>			
294	73.50	2.50	13,505.630
81	48.50	4.25	9,997.063
218	56.75	3.00	9,661.688
138	60.50	2.50	9,150.625
102	52.75	2.75	7,652.047
16	36.00	5.00	6,480.000
40	40.25	3.75	6,075.234
72	44.00	2.75	5,324.000
174	35.00	2.50	3,062.500
13	21.50	5.25	2,426.813
105	28.00	2.75	2,156.000
23	23.00	4.00	2,116.000
24	20.50	3.75	1,575.938
12	16.00	5.50	1,408.000
47	23.50	2.50	1,380.625
1	16.50	5.00	1,361.250
25	18.75	3.50	1,230.469
17	15.00	4.50	1,012.500
71	20.00	2.50	1,000.000
49	14.00	3.75	735.000
<b>Kitchen cabinet cutting bill no. 1<sup>b</sup></b>			
405	64.50	2.50	10,400.630
166	52.50	3.25	8,967.813
168	57.50	2.50	8,265.625
134	46.50	3.25	7,027.313
54	36.00	4.25	5,508.000
167	42.00	2.50	4,410.000
117	36.00	2.50	3,240.000
6	23.00	6.00	3,174.000
94	32.00	2.50	2,560.000
21	22.50	4.25	2,151.563
70	28.50	2.50	2,030.625
12	18.00	4.25	1,377.000
133	22.50	2.50	1,265.625
9	15.00	4.25	956.250
88	19.50	2.50	950.625
26	16.50	3.25	884.812
8	18.75	2.50	878.906
20	17.25	2.50	743.906
44	16.00	2.50	640.000
81	14.25	2.50	507.656

<sup>a</sup> ALPS yield = 66.4 percent; ALPS volume processed = 2,180 BF; OFCP yield = 43.5 percent; OFCP volume processed = 3,232 BF.

<sup>b</sup> ALPS yield = 67.0 percent; ALPS volume processed = 2,180 BF; OFCP yield = 54.3 percent; OFCP volume processed = 2,687 BF.

parts (2,9). Therefore, the ALPS Cutting Program's weighting factors can be used to emphasize longer parts.

## ALPS board file

The ALPS board file was compiled by the ALPS Cutting Program from a file supplied by the USDA Forest Products Laboratory. This file consists of 343, 4/4 No. 1 Common hard maple boards containing 2,180 BF. These data files are the same data used to develop the standard hardwood yield tables (8). The size of the board was entered along with the location of the defects. The defect location was specified by an X-Y coordinate system to the closest 0.250 inch such that the lower left corner and upper right corner of each defect were identified.

## ALPS cutting bill file

The following eight cutting bills were created. Part sizes are based on actual sizes cut in furniture and kitchen cabinet industries. Cutting priorities were set based on a weighting factor of length squared  $\times$  width.

Three cutting bills requiring a wide range of lengths and widths were selected from furniture manufacturers.:

1. Furniture cutting bill no. 1 consists of 20 parts with lengths from 14.00 to 73.50 inches, and widths from 2.50 to 5.50 inches (Table 2).

2. Furniture cutting bill no. 2 consists of 20 parts with lengths from 14.00 to 80.00 inches, and widths from 2.00 to 5.00 inches.

3. Furniture cutting bill no. 3 consists of 20 parts with lengths from 15.25 to 72.50 inches, and widths from 1.75 to 6.00 inches.

Three cutting bills requiring a wide range of lengths but uniform widths were selected from kitchen cabinet manufacturers.:

1. Kitchen cabinet cutting bill no. 1 consists of 20 parts with lengths from 14.25 to 64.50 inches, and four different widths from 2.50 to 6.00 inches (Table 2).

2. Kitchen cabinet cutting bill no. 2 consists of 20 parts with lengths from 14.00 to 80.00 inches, and two different widths of 1.75 and 3.25 inches.

3. Kitchen cabinet cutting bill no. 3 consists of 20 parts with lengths from 14.00 to 80.00 inches, and five different widths from 1.50 to 4.50 inches.

One cutting bill was selected that consisted of 24 parts with short lengths between 15.00 and 40.00 inches in 5-inch increments. For each of the six lengths, parts were cut in 4 widths: 2.00, 3.00, 4.00, and 5.00 inches.

One cutting bill was selected that consisted of 27 parts with long lengths between 40.00 and 80.00 inches in 5-inch increments. For each of the nine lengths, parts were cut in 3 widths: 2.00, 3.00 and 4.00 inches.

## Results

The results of the study are displayed in Tables 3 and 4. Table 3 displays a comparison of the yield obtained and the required lumber volume for the ALPS Cutting Program and the OFCP. Yield differences from 12.6 percent to 22.9 percent above the standard yield tables (represented by the OFCP) were obtained using the ALPS Cutting Program. Table 4 shows the dollar value of the savings that resulted from the ALPS Program compared to

TABLE 3. — Comparison of yield and volume using the ALPS Cutting Program and the OFCP.

	ALPS		OFCP		Difference
	Yield (%)	Volume (BF)	Yield (%)	Volume (BF)	
<b>Furniture cutting bills</b>					
No. 1	66.4	2,180			
No. 2	67.0	2,180			
No. 3	70.0	2,180			
<b>Kitchen cabinet cutting bills</b>					
No. 1	67.0	2,180	54.3	2,687	12.7
No. 2	70.9	2,180	54.8	2,752	16.6
No. 3	70.6	2,180	54.2	2,832	16.4
Short length cutting bill	69.6	2,180	53.4	2,846	16.2
Long length cutting bill	60.2	2,180	45.5	2,857	14.7

the OFCP. The range of possible lumber savings is between \$184 and \$405 per cutting bill. These savings are based on the lumber price of \$.385/BF (2) and the difference in lumber requirements between the ALPS Cutting Program and the OFCP. For example, the volume of lumber required to cut furniture cutting bill no. 1 was 3,232 BF for the OFCP, and 2,180 BF for the ALPS Cutting Program. The value of the lumber saved by using the ALPS Cutting Program was  $(3,232 - 2,180) \times \$.385/\text{BF} = \$405$ .

### Conclusion and discussion

A comparison of yields from the ALPS Cutting Program and conventional methods for processing eight cutting bills shows that yield increases of 12.6 to 22.9 percent, with an average of 15.9 percent, are possible by using the ALPS Cutting Program. The volume of lumber required to produce the same cutting bill would thus be substantially reduced (Tables 3 and 4), thereby creating potential cost savings if the ALPS Cutting Program could be used commercially.

The extent to which a yield difference is possible depends on the size of the parts in the cutting bill. For this study, the ALPS Cutting Program determined the number of each part size to be included in the cutting bill by processing a large number of part sizes with a limited number of boards. When the board file was exhausted, the parts that had been selected became the cutting bill processed with the OFCP. An examination of the volume of different parts from the eight cutting bills reveals that the ALPS Cutting Program algorithm tends to first select part sizes that are long and narrow and, secondly, parts that are short and narrow. This occurs because the algorithm selects only one part size, based on the greatest total weighting factor, to place in each clear area of a board. For a given length within a clear area, there seems to be a greater chance for selecting more narrow part sizes rather than few wide part sizes.

The extent to which cost savings are realized depends on both the increase in yield and the cost of the lumber used. The standard yield tables are applicable to all grades and species of wood except black walnut and red alder, which have their own individual yield tables. Processing any No. 1 Common grade of lumber of most species, except those stated, will result in yield increases similar

TABLE 4. — Lumber volume and value saved using the ALPS Cutting Program.

	Lumber saved <sup>a</sup> (BF)	Value saved (\$)
<b>Furniture cutting bills</b>		
No. 1	1,052	406
No. 2	666	256
No. 3	479	184
<b>Kitchen cabinet cutting bills</b>		
No. 1	507	196
No. 2	572	220
No. 3	652	251
Short length cutting bill	666	256
Long length cutting bill	677	261

<sup>a</sup> Difference between ALPS and OFCP.

to the No. 1 Common hard maple boards used in this study. As the cost of lumber increases, so do the potential cost savings. For example, by using red oak lumber at a cost of \$.645/BF (2) to process furniture cutting bill no. 1, the cost savings would have been \$679 as compared to \$405 when using the lower cost hard maple species.

### Additional research needs

This study investigated yield differences only in cutting bills with a large number of different sized parts using No. 1 Common lumber. Further yield comparisons using FAS and No. 2 Common lumber grades and smaller cutting bills need to be completed in a manner similar to this study. One advantage of using an ALPS Cutting Program is that large numbers of part sizes can be processed (7). This is due to the elimination of human judgment in cutting a board. In a conventional roughmill, represented by the OFCP, only five to seven part sizes can practically be cut at one time.

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