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Furniture Rough Mill Costs Evaluated by Computer Simulation

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Abstract

A crosscut-first furniture rough mill was simulated to evaluate processing and raw material costs on an individual part basis. Distributions representing the real-world characteristics of lumber, equipment feed speeds, and processing requirements are programed into the simulation. Costs of parts from a specific cutting bill are given, and effects of lumber input costs are discussed. GASP IV (A Combined Continuous/Discrete FORTRAN-based Simulation Language) was used.

NOTE

The computer program described in this publication is available on request with the understanding that the U.S. Department of Agriculture cannot assure its accuracy, completeness, reliability, or suitability for any other purpose than that reported. The recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a Government-produced computer program. For cost information, please write: Northeastern Forest Experiment Station, Forestry Sciences Laboratory, P.O. Box 152, Princeton, West Virginia 24740.

Introduction

Traditional cost accounting methods are inadequate for comparing different production sequences. Traditionally, costs are evaluated in a furniture rough mill by product line or production run. For example, a quantity of lumber is fed into the rough mill in a day's production run. This lumber is converted into rough cut-to-size parts. The cost of this conversion is usually calculated by adding the cost of the lumber to the costs associated with the overall operation of the rough mill, such as wages, utility costs, and some percentage of the plant overhead. In this way, a gross estimate of the part costs is obtained by dividing the total costs by the quantity of parts produced. This method is sufficient for cost accounting purposes, however, it does not provide the accurate individual part costing that is necessary to compare different production sequences.

To compare one sequence with another, costs per part are needed. Production costs of individual parts enable rough mill designers and users to compare various types of rough mill configurations. Determining these costs can present very complex problems, especially where random events or elements have important effects on production. Converting rough lumber into furniture parts by crosscutting first is a case in point. Because of the random occurrence of defects in rough lumber, it is usually not possible to predict exactly how much time it will take to complete each step in the manufacturing process. Other elements also make it difficult to predict processing time and cost: the desired output will change from order to order, workers do not always work at the same speed, the capabilities of various machines differ, production rules can have unexpected effects on output, and different grades of lumber will also affect output.

The production costs in a crosscut-first furniture rough mill can be analyzed by computer simulation. The technique is a radical departure from the traditional cost control methods in the furniture industry. By using the computer to simulate the production sequences, we can measure part costs and, in particular, determine the value of each part as it passes through the rough mill.

The Problem

Determining actual costs of production for individual furniture parts presents a three-part task: First, develop the model of an existing rough mill to include all operations from the lumber breakdown hoist through the crosscut saws to the final machining-to-width on ripsaws; second, identify and measure important parameters within the rough mill that affect the cost of the furniture part being produced; third, establish the incremental cost of processing individual parts at each step in the production sequence.

Our approach to this task is to consider each part separately and assign costs on the basis of the amount of processing it actually receives. The cost of each step in the production sequence is a factor in a furniture part's cost only if the part receives processing at that step. By accumulating the processing received and the associated costs at each step in the production process, a cost for each finished part can be accurately determined.

Rough Mill Model

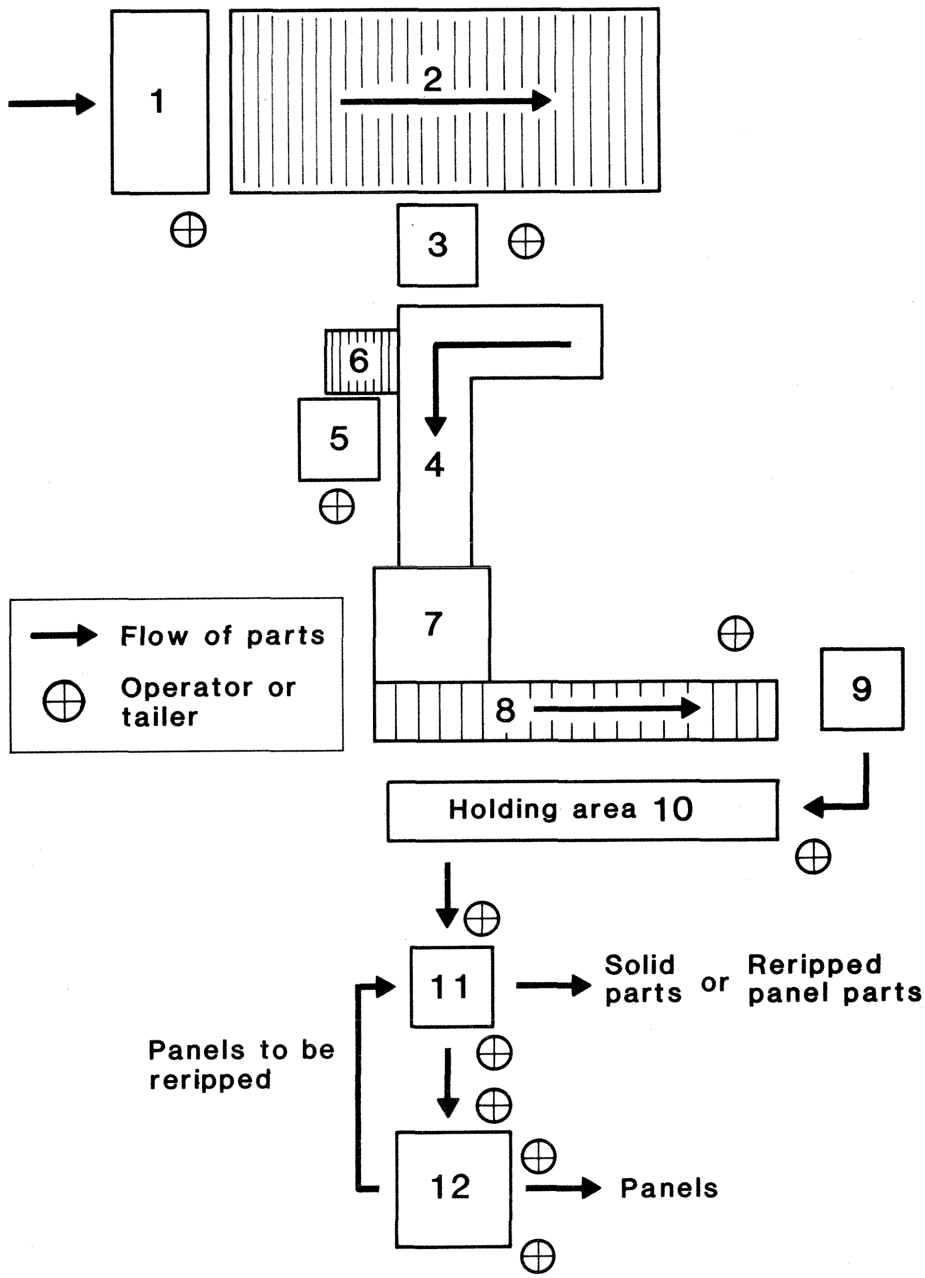
Evaluating production sequences in an existing rough mill has several advantages. Production figures from the existing mill provide benchmarks for evaluating the simulated production performance. Production parameters such as machine capability, feed speeds, sawing rates, and personnel availability are well established in an existing mill. Simulation involves describing the mill in a mathematical model that incorporates the production parameters and manipulating this model experimentally.

The model includes all production steps in an operating furniture rough mill. However, not every part goes through every production step. For example, only those parts containing visible defects such as knots, wane, or excessive cup go through the defect ripsaw. Other parts that contain no defects skip this processing step and do not incur any of its cost. These are important factors that affect the costs of production and must be accounted for.

Our crosscut-first furniture rough mill uses the following sequence of operations (Fig. 1): (The number in parentheses refers to the machine associated with each production step.)

- Lumber infeed—Rough, kiln-dried, graded lumber in random widths and in random lengths up to 16 feet starts into the mill on a tilted breakdown hoist (1).
- Conveyor—The lumber is unstacked one layer at a time onto a cross conveyor (2).
- Crosscut saws—Worker removes board from cross conveyor, inspects it to determine optimal parts lengths based on the current cutting bill in front of him, makes a trim cut on the leading edge of the board, and makes necessary cuts to produce cut-to-length random-width parts on the crosscut saw (3).
- Conveyor—As the parts are crosscut, they drop onto a conveyor (4) that takes them past the defect ripsaw to the planer.
- Defect ripsaw—Worker inspects each part, removes parts that have defects that can be removed by ripping, feeds ripsaw (5), and alines all other parts on the planer infeed belt.

Figure 1.—Flow chart of operations in a crosscut-first furniture rough mill.



- Offbearer conveyor—Automatically tailing ripsaw, the conveyor (6) returns parts to planer infeed belt.

- Planer—The planer or facer and planer (7) skip planes the boards on both sides to a standard thickness.

- Conveyor—From the tail of the planer, the parts move up a conveyor (8) to the sorting station.

- Sorting station—Worker removes parts from conveyor and stacks them on pallets by length at the sorting station (9).

- Holding area—After parts are sorted onto pallets according to length, they are placed in a holding area (10) until the rough mill foreman schedules their entry into the next processing step. Wages of the worker who handles pallets between sort and rip operations are divided between these two processing steps.

- Ripsaw—Worker feeds the random-width parts one at a time into the straight line ripsaw (11). One of these four multiple processing operations is performed:

  - Rip to remove defects, followed by rip to specific width for part with a finished width less than or equal to some minimum width

  - Rip to remove defects, followed by rip to produce glue line edge on both sides of random-width parts scheduled for gluing

  - Panel matching and/or sizing by laying up panels from random-width parts and ripping panel to specific width

  - Rip glued-up panels back to some specified width part.

- Offbearer station—Worker tails the ripsaw, moves edgings out of the way, and stacks the cut-to-length and width parts on pallets for further processing. Because the ripsaws perform up to four different types of processing, the next step in the production sequence depends on the type of processing being performed.

- Materials handler—Worker moves parts pallets from ripsaw area either to panel gluing area or to further processing beyond the scope of the rough mill model.

- Panel gluing infeed—Worker inspects parts, loads parts over glue applicator, alines parts in bed of panel gluing machine (12), and activates gluing machine.

- Panel gluing offbearer—Worker removes panels from gluing machine and stacks them on pallets.

- Materials handler—Worker moves parts on pallets from panel gluing operation to ripsaw or on to further processing beyond the scope of the rough mill model.

Parts that leave the ripsaw or panel gluing operation for further processing in the furniture mill have been cut to final rough part size; that is, to some specified length and width. All major defects have been removed and those defects that remain fall within the limits allowable for each part grade.

Rough Mill Simulation

In determining part costs, an accurate description of the mechanics of production is only one part of the solution. Everything else that affects the way the mill is operated must also be considered. These items are the inputs to the computer program, and how adequately they are identified and defined directly affects the value of our results. As a minimum, we have identified the following as critical inputs: cutting orders, raw material characteristics for various grades of lumber, instructions for operating the system, cost information including lumber costs, and wages of production personnel. These are the parameters that directly affect the production cost of furniture parts.

Cutting Orders

A cutting order, as opposed to a cutting bill, is the complete list of parts that a furniture manufacturer wants from a particular production run. Thus, while a crosscut saw operator is working to fulfill a cutting bill of up to 10 length-width combinations, that cutting bill is a part of a larger cutting order.

A typical furniture rough mill may process up to 200 part sizes in a single cutting order. The cutting order used here has 90 individual part lengths with 145 total length-width combinations for the finished rough part sizes for a variety of furniture items including chairs, tables, and cabinets. Input from the cutting order includes the length, width, thickness, and number of board feet for each part size.

The cutting order calls for 90 different lengths to be crosscut. Machine operators can handle no more than 10 at one time (the computer allows any number up to 10 to be used, although many mills would use fewer than 10). How are the lengths chosen? There are two criteria: priority value and absolute difference in length.

Priority value. Because any one of 10 lengths can be crosscut at any given time, a priority value is assigned by the furniture manufacturer's production scheduling division to each part size. This value determines when the part will be listed as one of the 10 "active" lengths. As the volume requirement for a particular part is satisfied, that part is replaced on the active cutting bill by the next part length in priority order until the requirements for all part sizes have been satisfied.

Absolute difference in length. This criterion is used in combination with priority ordering of parts to determine the entry of lengths on the cutting bill. The absolute difference between a length entering and any length already being cut must be at least 2 inches. This 2-inch difference was needed to enable crosscut saw operators and sorting personnel to differentiate one part size from another quickly. This restriction would be unnecessary in a rough mill where parts are sorted by an optical scanner or mechanical sorter. Also, the practical lower limit for crosscut saw operators may be the width between stops, about 1/2 inch, which is considerably less than the 2-inch restriction required in this model. Regardless of the size difference chosen, the restriction is a necessary production parameter.

Table 1 illustrates the information in the simulation input instructions for the 10 lengths with the highest priority in the cutting order. While Table 1 does not show all of the part lengths in the cutting order, it does show the longest and shortest lengths in the particular cutting order used. All of the other 80 part lengths fall within the range 76.75 to 14.5 inches. The 10 part lengths in Table 1 make up the cutting bill given to the crosscut saw operators at the start of the production run.

Raw Material Characteristics

A description of the lumber and estimates of the part yield after each step in the manufacturing sequence are needed as input to the simulation program. This information was obtained by on-site study at an existing crosscut-first rough mill. From observations at this rough mill and from yield studies available at the Forestry Sciences Laboratory in Princeton, West Virginia, I compiled the following types of lumber input information to describe the lumber entering the system and to calculate the amount of material left after each operation:

- Statistics describing the normally distributed lengths and widths of Selects and No. 1 and 2 Common grades of red oak lumber (Table 2)

Table 1. Typical cutting bill—first 10 lengths in the partial cutting order listed by priority

Priority	Length	Volume required
	Inches	*Board feet*
1 (lowest)	14.500	4,482
2	35.625	2,059
3	41.000	8,863
4	43.000	4,910
5	43.875	1,492
6	48.250	1,703
7	49.875	926
8	53.250	4,307
9	68.750	1,118
10 (highest)	76.750	550

Table 2. Parameters used to describe distributions of board sizes by grade (parameters in inches)[a]

Grade	Mean	Minimum	Maximum	Standard deviation
		LENGTH		
Select	192	72	200	44.66
1 Common	144	48	200	44.66
2 Common	118	47	200	44.66
		WIDTH		
Select	5.35	4	11	1.31
1 Common	5.31	3	8	1.26
2 Common	5.31	3	8	1.26

[a] Based on a sample of boards entering existing rough mill at breakdown hoist. These values are input as variables in model and can be altered to meet user's needs.

Table 3. Distribution of crosscuts made versus number of parts produced

Number of crosscuts made	Number of parts produced per board						
	1	2	3	4	5	6	8
3	0.25[a]	0.75	—	—	—	—	—
4	—	0.28	0.72	—	—	—	—
5	—	0.08	0.48	0.44	—	—	—
6	—	0.07	0.22	0.64	0.07	—	—
7	—	—	0.29	0.14	0.43	0.14	—
8	—	—	0.10	0.50	0.20	0.20	—
9	—	—	—	—	—	0.33	0.67

[a] Interpreted as follows: 25 percent of the time when three crosscuts are made on a board, only one part is produced out of that board.

- Parameters describing the normally distributed board thickness, in inches, for 4/4-inch-thick lumber entering the rough mill. These are:

Mean	*Minimum*	*Maximum*	*Standard deviation*
1.088	0.835	1.440	0.123

- Frequency distribution of crosscuts made in comparison with the number of parts produced from each board (Table 3)
- Frequency of parts processed at defecting ripsaw (Table 4).

Table 4. Frequency of processing alternatives at defecting ripsaw

Percent of boards arriving at ripsaw	Action taken
30	Bypass defect ripsaw
50	Split to remove cup
20	Defect ripped out
100	

Table 5. Machine characteristics used as variable input[a]

Equipment or operation	Length	Rate or time	Comments
	Feet		
Breakdown hoist			Release rate controlled by operator
Cross conveyor	77	25.00	Feet per minute
Crosscut saw	8	6.25	Board feet per minute
Conveyor times to defecting ripsaw:			Expressed in minutes
from saw 1		0.40	
saw 2		0.72	
saw 3		1.04	
saw 4		1.26	
saw 5		0.74	
saw 6		0.95	
saw 7		1.15	
saw 8		1.36	
Defecting ripsaw	6	130.00	Feet per minute
Offbearer conveyor	5	70.00	Feet per minute
Conveyor time to planer from ripsaw:		0.40	Minutes
Planer	8	90.00	Feet per minute
Conveyor time to sort from planer:		0.4	Minutes

[a] These values reflect the characteristics of the existing mill used as an example. Minor changes to the program can be made for different layouts and equipment by altering these variables.

Equipment Operating Instructions

Operating instructions and information needed to regulate the simulation program include equipment speeds, belt speeds, travel distances, processing rates for each piece of equipment, and time delays for setting up machinery between cutting bills. The information on processing rates for ripsaws and gluing machines and the time delays are built into the model; the other machine characteristics for conveyors, crosscut and defect ripsaws, and planers are input as variables each time the program is run. These variable operating instructions are summarized in Table 5.

Rough mill processing begins when lumber is moved from the breakdown hoist to the cross-conveyor. This operation is handled by the first crosscut saw operator and is scheduled whenever the cross-conveyor becomes less than 50 percent full. The operator then moves lumber onto the conveyor until it is over 95 percent full; that is, the entire length of the conveyor is covered with boards, single thickness, lying side-by-side for at least 95 percent of its overall length. The 50 and 95 percent figures are used to determine when lumber is off-loaded, both in the actual mill and in the simulation program.

The crosscut saw operators pull boards off the cross-conveyor and cut parts to length at the specified processing rate. The program is flexible: up to eight crosscut saws may be operating at the same time.

In the simulated mill, the material from four of the crosscut saws is conveyed past a defecting ripsaw to a skip-planer. The material from the other four crosscut saws is conveyed separately to another defecting ripsaw and planer. The feed speeds for the belt conveyors are different for these two lines, but the processing rates for ripsaws and planers are the same. The belt conveyor tailing both planers goes directly to the sorting station.

Production Cost Information

In addition to the physical characteristics of lumber input and the equipment operating instructions, two types of costs are defined as input to the simulation program. These are the cost of lumber input to the mill and the cost of labor involved with equipment operation.

It is important to note that this is a study of production costs and not of prices. The price of a part will include such items as factory overhead, selling costs, administrative costs, general expenses, and profit. These are not included in the calculation of production costs. Our primary concern was to allocate direct labor and lumber costs to the individual parts as they pass through the various manufacturing steps.

Lumber costs contain two components: purchase price and cost of handling. Purchase price will, of course, vary with grade and species. The cost of handling is a fixed cost per board foot that estimates the cost of regrading, stacking, drying, and handling before entry into the rough mill. The actual rough mill simulated uses a prior handling cost of $43 per M bm (thousand board feet).

Rough mill labor costs, based on machining time, are assigned to individual parts. If it takes twice as much ripping and crosscutting time to produce a part, that part is assigned twice as much labor costs. These costs include an hourly wage cost, an estimate of fringe benefit costs (expressed as a percentage of the hourly wage) and any applicable bonus for incentive work. All of these costs are combined for each operation and may therefore reflect the cost of more than one worker. In fact, the labor costs for the material handlers described in the model are divided between the sorting and ripsaw stations. The labor costs for the individual machining operations shown in Table 6 represent 1980 practice.

Table 6. Combined labor costs, by type of operation

Operation	Rate[a]	Comments
	$/hour	
Breakdown hoist	5.30	
Cutoff saw	5.64	
Defect ripsaw	5.35	
Sort	5.21	Includes materials handler
Ripsaw	14.06	Includes materials handler and offbearer
Gluing	27.81	Includes materials handler and operators

[a] Includes hourly wage cost, estimated fringe benefit cost, and (for ripsaw and gluing) an estimate of bonus for incentive work.

Table 7. Average cost of processing, by type of process

Process	$/part	$/bd ft
Breakdown hoist	0.011	0.002
Cutoff saw	0.023	0.022
Defecting ripsaw	0.009	0.016
Sort	0.028	0.041
Rip—solid parts	0.020	0.072
Rip—glue line edge	0.087	0.110
Rip—panel matching/sizing	0.108	0.030
Rip—panels to parts	0.018	0.056
Gluing panels	0.162	0.044

The Output

Our computer simulation results are processing costs, production cost of parts, and yields of parts as they flow through the system. We can determine the cost of each individual part and then group these parts in any way desired. Results can be determined as a function of part length, part width, part quality, or any combination. It is most useful to sum up the data in terms of part length because part length is related to part cost.

Any change in rough mill design or inputs will show clearly in these costs. Although, for simplicity, we talk in terms of averages, it is important to remember that these results are from individual part costs and are not the same as numbers calculated by dividing total plant costs by total number of parts produced.

Processing Costs

Processing costs are determined at each point where there is labor or material input. Starting with the breakdown hoist and ending with the final rip-to-size, the cost of each processing step on the individual parts is calculated. These costs are summarized in Table 7.

Parts that are the same size and that require the same machining operations have the same processing costs. It is important to note that the cost of an individual processing step such as one rip or one crosscut is directly related to machine or processing time and is a function of part length or width. Thus, if a part requires one rip and one crosscut, the processing cost is the same whether the lumber input is FAS (First and Seconds) or 2 Common. On the average it will take more operations to process the lower grades because of the need to remove or work around more defects. But the price differential among grades is such that using the lower grades may be cost effective.

Processing cost at the breakdown hoist is a function of the wage of the operator and the speed of the lumber conveyor. This is the only exception to the rule that processing costs are similar for all grades of lumber input. On the average, it costs about one cent to offload a board from the breakdown hoist onto the cross conveyor. This cost per board is the same regardless of the grade of lumber, but better grade boards contain more board feet of usable lumber. The processing cost of this operation, per board foot of lumber input, is obtained by dividing the constant cost per board by the board foot volume of the piece being processed. The average board foot volume per board for the three grades of lumber input is as follows:

Grade	*Average volume/ board input*
Select	7.317 board feet
1 Common	5.678 board feet
2 Common	4.752 board feet

Thus, for 2 Common grade lumber, the average cost of the breakdown operation is $0.0024 per board foot; for 1 Common grade lumber it is $0.0020; and for Select grade lumber, $0.0015.

Cost of Processing Parts— Through Sort Operation

After the cost of each processing step has been determined, the cost of processing an individual part

Table 8. Average cost of processing, by part length, through the sort operation for random-width parts

Part length	$/part	$/bd ft	Part length	$/part	$/bd ft
Inches			*Inches*		
14.500	0.134	0.145	25.875	0.094	0.102
14.624	0.131	0.142	26.750	0.095	0.104
15.125	0.128	0.139	27.000	0.094	0.104
15.250	0.125	0.135	29.000	0.087	0.096
15.375	0.125	0.135	29.875	0.089	0.097
15.500	0.124	0.135	30.000	0.089	0.098
15.625	0.125	0.135	31.000	0.087	0.097
15.750	0.122	0.133	31.250	0.087	0.094
16.000	0.124	0.133	31.375	0.085	0.093
16.250	0.122	0.132	32.000	0.085	0.093
16.365	0.125	0.133	32.500	0.084	0.093
16.750	0.117	0.128	33.000	0.082	0.090
16.875	0.122	0.132	33.125	0.086	0.095
17.000	0.125	0.134	33.750	0.083	0.092
17.125	0.124	0.135	34.375	0.084	0.092
17.500	0.117	0.127	35.000	0.080	0.089
17.625	0.115	0.125	35.625	0.085	0.095
17.750	0.116	0.126	36.375	0.080	0.088
17.875	0.118	0.129	36.500	0.079	0.088
18.000	0.111	0.123	36.750	0.083	0.091
18.500	0.115	0.125	36.875	0.078	0.087
18.750	0.111	0.123	38.375	0.083	0.091
18.875	0.111	0.122	39.250	0.075	0.085
19.000	0.110	0.119	39.875	0.076	0.083
19.125	0.110	0.118	40.500	0.075	0.083
19.375	0.110	0.119	41.000	0.077	0.085
19.500	0.112	0.122	42.500	0.077	0.085
19.625	0.110	0.121	43.000	0.077	0.085
19.875	0.105	0.120	43.375	0.075	0.082
20.000	0.112	0.123	43.875	0.078	0.087
20.750	0.098	0.110	44.375	0.077	0.081
21.250	0.105	0.113	44.625	0.073	0.080
22.000	0.103	0.113	44.750	0.071	0.080
22.375	0.108	0.116	48.250	0.075	0.083
22.625	0.099	0.108	49.250	0.070	0.079
22.750	0.106	0.117	49.500	0.073	0.080
23.000	0.100	0.109	49.875	0.076	0.084
23.500	0.100	0.110	51.000	0.076	0.083
24.000	0.095	0.105	51.250	0.071	0.079
24.125	0.094	0.102	53.000	0.070	0.078
24.500	0.099	0.108	53.250	0.071	0.080
24.750	0.099	0.109	55.500	0.069	0.078
24.875	0.096	0.106	59.000	0.070	0.078
25.000	0.093	0.102	68.750	0.066	0.075
25.750	0.095	0.105	76.750	0.064	0.072

can be found by summing the costs of all processing steps it goes through. Recall that the typical rough mill processes parts in two stages: up through the sort operation, and then all subsequent operations. In the first stage, the width of each part depends on the width of the board from which it was cut. However, the length of the part is fixed once it has passed the crosscut step. To summarize the cost of parts at the end of the first stage, the processing costs for parts of each length were collected and averaged. The cutting order used in the simulation contained 90 different part lengths. Excluding the value of raw material input, the typical costs of processing these 90 lengths through the sort operation are shown in Table 8.

The cost per board foot for processing parts through the sort operation is inversely related to the length of the part. This appears unreasonable at first, but a 14-inch part contains only one-half the board foot volume of a 28-inch part if both are the same width. So, it must take more processing to obtain the same volume of 14-inch parts as 28-inch parts.

Figure 2 illustrates the relationship between the cost per board foot and the length of the part in inches. Regression analysis of the costs per board foot shown in Table 8 defines the relationship between cost (Y) and length of part (x) as follows:

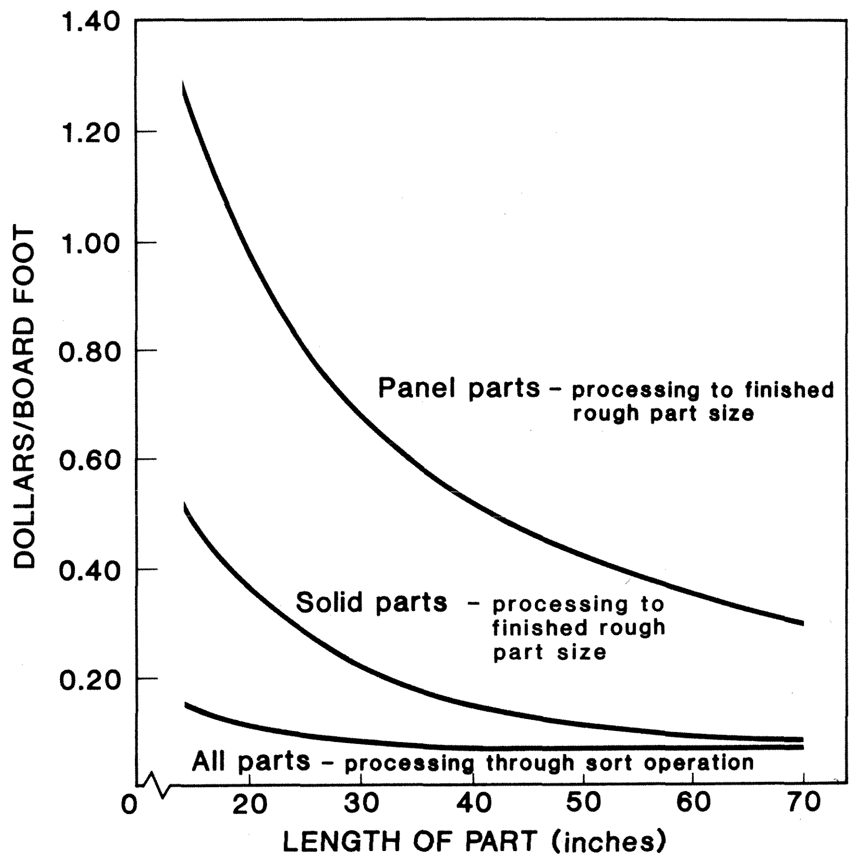
$$Y = 0.0551 + 1.2691 \left(\frac{1}{x}\right)$$
$$R^2 = 0.98$$

Over the range of part lengths tested in this study, the part processing costs per board foot are estimable within very close tolerances. The standard deviation resulting from the regression analysis is 0.0024, or less than three-tenths of a cent per board foot.

Cost of Processing Parts—From Sort to Finished Rough Part Size

In the second stage of the typical rough mill, parts are cut to specific lengths and widths. Part costs in this stage may be separated into three distinct groups: solid, glued-up panel, and reripped panel parts. The cutting order used in the simulation of the rough mill contains a total of 145 different length and width combinations. Twenty-eight of these are solid parts; 114 are panel parts. Typical costs per board foot for processing these parts are shown in Tables 9 and 10. These represent the average costs for parts of a particular length and width within the specified group.

Figure 2.—Processing costs in relation to length of part.



The remaining group is reripped panel parts. These receive the most processing and consequently have the highest processing cost. Two of the three reripped parts are the same length, 14.5 inches; the third part is 15.125 inches in length. The average cost per board foot for processing these 4/4-inch-thick parts is as follows:

Length (in)	*Width (in)*	*Cost ($/bd ft)*
14.5	2.6875	1.66
14.5	3.000	1.58
15.125	3.000	1.65

Costs per board foot through the second stage of the rough mill are also inversely related to the length of the part, as shown in Figure 2. Equations relating the cost per board foot (Y) to the length of the part (x) in inches are as follows: for solid parts, $Y = -0.0481 + 8.2014 \left(\frac{1}{x}\right)$ $R^2 = 0.97$; for panel parts, $Y = 0.0454 + 18.6648 \left(\frac{1}{x}\right)$ $R^2 = 0.98$. The standard deviation of the estimated cost per board foot for solid parts is 0.03; for panel parts it is 0.05. These equations may be used to predict the processing cost of finished rough parts between 14.5 and 76.75 inches in length.

The difference between the processing costs of solid and panel parts is the result of additional processing required to produce a finished-to-size panel part. However, when the costs are separated by degree of processing, the relationship between cost per board foot and part length is consistent and estimable within close tolerances for both solid and panel parts. The cutting order did not contain enough different reripped panel part lengths for a regression analysis based on part length. However, the same relationship between cost per board foot and part length would be expected for these parts.

Table 9. Average processing costs for 4/4-inch thick solid parts, by length

Length	Width	Cost
----- *Inches* -----		*$/bd ft*
14.500	1.0000	0.59
14.500	0.1250	0.51
14.500	1.3750	0.55
14.500	1.7500	0.51
14.500	1.1875	0.55
14.500	2.0000	0.52
14.500	2.3750	0.51
14.625	2.6250	0.50
15.250	2.6250	0.46
15.375	2.5000	0.48
16.000	2.8750	0.44
16.250	2.5000	0.43
17.125	1.7500	0.43
19.375	0.5625	0.44
19.625	2.3750	0.33
22.375	1.7500	0.29
22.750	2.0000	0.30
23.500	2.2500	0.28
24.125	1.1250	0.27
32.500	2.0000	0.19
32.500	2.2500	0.20
36.500	2.2500	0.15
36.750	2.5000	0.17
44.625	2.2500	0.14
49.250	2.1250	0.13
49.500	2.5000	0.13
51.000	2.2500	0.14
68.750	2.3750	0.10

Table 10. Average processing costs for 4/4-inch-thick panel parts, by length

Length	Width	Cost	Length	Width	Cost
----- *Inches* -----		*$/bd ft*	----- *Inches* -----		*$/bd ft*
14.500	17.4375	1.41	24.813	14.5625	0.81
14.500	19.1250	1.29	24.875	23.3125	0.70
14.500	20.7500	1.29	25.000	14.6250	0.84
14.500	21.1250	1.19	25.750	16.7500	0.80
14.500	22.0000	1.33	25.750	21.5625	0.75
14.500	22.1250	1.32	25.875	24.3125	0.82
14.500	22.1250	1.48	26.750	17.7500	0.73
14.500	23.2500	1.38	27.000	20.9375	0.72
14.500	23.3125	1.42	29.000	15.0000	0.67
14.500	23.4375	1.30	29.000	22.1250	0.66
14.500	23.5625	1.38	29.875	22.1250	0.63
14.500	23.6250	1.30	29.875	23.4375	0.65
14.500	24.0000	1.32	30.000	25.5000	0.65
14.500	24.2500	1.36	30.000	25.7500	0.65
14.500	24.3125	1.40	31.000	21.9375	0.62
15.375	19.8750	1.27	31.250	22.0000	0.64
15.500	20.1250	1.27	31.375	17.0625	0.65
15.625	24.3125	1.22	31.375	22.0000	0.62
15.750	22.1250	1.31	32.000	21.5625	0.61
16.250	20.4375	1.13	32.500	23.3125	0.67
16.250	23.1875	1.17	33.000	23.3125	0.57
16.375	22.1250	1.34	33.125	17.5000	0.60
16.750	19.5625	1.14	33.750	21.9375	0.60
16.750	24.1875	1.11	34.375	17.0625	0.56
16.875	17.6250	1.19	35.000	23.3125	0.56
17.000	23.8750	1.12	35.625	16.2500	0.61
17.500	24.3125	1.06	35.625	19.0000	0.57
17.625	21.7500	1.07	36.375	16.7500	0.56
17.750	23.3125	1.07	36.750	16.8750	0.56
17.875	19.5625	1.09	36.875	20.7500	0.49
18.000	23.3125	1.11	38.375	16.7500	0.53
18.500	20.7500	1.11	39.250	23.4375	0.54
18.750	22.1250	0.99	39.875	24.3125	0.51
18.875	18.7500	1.07	40.500	21.5625	0.54
18.875	20.2500	1.06	40.500	22.0000	0.47
18.875	20.3125	0.98	40.500	23.6250	0.47
18.875	21.0625	1.02	41.000	15.5000	0.49
19.000	21.6875	1.04	41.000	20.1250	0.50
19.125	24.3125	0.99	41.000	31.0000	0.50
19.375	24.4375	1.03	42.500	14.0000	0.51
19.500	16.8750	0.99	43.000	21.3750	0.49
19.625	22.6250	1.04	43.000	27.7500	0.48
19.875	22.1250	0.94	43.375	14.8750	0.50
20.000	13.1250	1.03	43.875	15.3750	0.51
20.750	23.3125	0.79	43.875	21.9375	0.46
21.250	18.0000	0.93	44.375	22.1250	0.46
22.000	18.4375	0.88	44.750	16.2500	0.48
22.000	20.4375	0.85	48.250	13.5000	0.47
22.000	21.5625	0.92	49.500	20.1250	0.45
22.000	23.3125	0.84	49.875	13.5000	0.44
22.000	24.1875	0.85	51.250	14.1250	0.45
22.625	21.1875	0.77	53.000	17.5000	0.40
23.000	13.3750	0.92	53.250	17.7500	0.44
23.500	21.9375	0.76	55.500	24.1875	0.41
23.500	22.1250	0.81	59.000	21.5625	0.39
24.000	13.5000	0.92	76.750	22.1250	0.29
24.500	17.8125	0.84	76.750	22.9375	0.31

Part Yields and Final Production Costs

Along with processing costs, part yields are included in the final output from simulation of a typical rough mill. Part yields provide the needed measure of the cost of material lost in processing. As noted earlier, the production cost of an individual part is made up of processing costs, which account for the direct labor involved, and material costs. However, the cost of material lost in production must be considered when production costs are calculated, in addition to the cost of material left in the part.

Part yields are used to adjust the cost of material in a part to reflect the allocation of costs of material lost in processing. For example, if the value of lumber input is $200 per M bm and the final yield of the furniture parts is 48 percent, then the material cost for 480 board feet of parts produced from 1 M bm of lumber is $200. The material cost per board foot is obtained by dividing the cost of lumber input by the board feet of parts, or in this example, $200 ÷ 480 = $0.42 per board foot.

Part yields differ slightly depending on the type of processing received in the rough mill:

Type of processing	*Average yield (in percent) from 2 Common lumber*
Solid parts	44
Panel parts	49
Reripped panel parts	48

Thus, solid part material costs are higher and panel part material costs are slightly lower than the material cost for reripped panel parts. Again, using the value of $200 per M bm for lumber input, solid part material costs would be $0.45 per board foot while panel part material costs would be $0.41 per board foot.

Finally, the dollar cost per board foot for processing is added to the material cost per board foot to get the total production cost for each part. For example, a 14.5- by 1.0-inch solid part has an average processing cost per board foot of $0.59. If the lumber used for cutting this part is valued at $200 per M bm or $0.45 per board foot after adjusting for part yield, the cost of producing this part would be $0.59 + $0.45 or $1.04 per board foot.

Summary

The production sequence in a conventional crosscut-first rough mill is reproduced by computer simulation and tested against a well-run conventional rough mill. Benchmark costs of rough mill processing are established for the typical mill. Overall part production costs are obtained by combining material and processing costs. The program used can easily be modified through changes in input variables and minor internal changes to reflect the operating characteristics of any conventional crosscut-first rough mill.

Processing costs are a function of time in the machine; given an operating rate for a processing step, the amount of time that a part spends in the step can be determined. This time depends on the size of the part.

At the ripsaw four operations are possible. The operating rates differ for each of the four, so four separate processing costs must be considered at this step.

Processing costs are independent of grade of lumber input: the same time is required to rip a part of a given length from a Select grade board as from a 2 Common grade board. Parts that are the same size and require the same machining operations have the same processing costs, regardless of the grade of lumber they are made from.

Processing costs per board foot is inversely related to part length because a short part contains less volume than a long part. Thus, more processing of short parts is required to produce the same total volume as a long part.

Overall part production costs, combining material costs with processing costs, can be calculated using the part yields in the model to allocate the cost of material lost in processing. These costs are not the final selling or transfer price of parts; rather, they are costs of a specific production process and are intended for use in making comparisons with cost of parts from other processes.

This study was the first step in developing the methodology for determining production costs on an individual part basis. We have an accurate model. The next step is to develop a general model that will make comparisons with any mill design.

Anderson, R. Bruce. **Furniture rough mill costs evaluated by computer simulation.** Res. Pap. NE-518. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 11 p.

A crosscut-first furniture rough mill was simulated to evaluate processing and raw material costs on an individual part basis. Distributions representing the real-world characteristics of lumber, equipment feed speeds, and processing requirements are programed into the simulation. Costs of parts from a specific cutting bill are given, and effects of lumber input costs are discussed. GASP IV (A Combined Continuous/Discrete FORTRAN-based Simulation Language) was used.

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Keywords: Processing costs; computer program; FORTRAN: GASP IV; rough flat dimension

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