SOME IMPLICATIONS OF REMANUFACTURING HARDWOOD LUMBER

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ABSTRACT

Research on several hundred well-manufactured 1 and 2A Common red oak boards shows that better edging and/or trimming or division-based remanufacturing can produce boards of higher grade and value. Division-based remanufacturing divides a board into as many as four smaller boards. The UGRS computer program (3,4) grades digitized boards, examines their remanufacturing potential, remanufactures to the highest valued solutions greater than the original board values, and displays the size, defect location, and grade of new boards for UGRS analysis. An example analysis of the effects of such remanufacturing for a simple, gang-rip-first, rough-mill cutting bill is included. Whether boards can be remanufactured profitably depends on the relative prices among the lumber grades and the costs assigned to remanufacturing. All software used in this research is available free of charge.

The first two sentences of paragraph 8 in the 1998 National Hardwood Lumber Association (NHLA) rule book (5) state: "Lumber should be properly manufactured of good, average width and lengths. It should be edged and trimmed carefully to produce the best possible appearance while conserving the usable product of the log." This dichotomy presents interesting questions for the person going from the log in a sawmill to rough-dimension parts in a furniture rough mill. Until now, it has not been possible to accurately quantify the effects of remanufacturing on secondary processing yields.

The edging and trimming method reduces the amount of material available for end products while increasing the cost to the lumber user. The lumber user, in turn, supposedly benefits from an increased ease of manufacture, less handling, and less waste. At today's prices, the cost of lumber is high relative to other manufacturing costs. Perhaps the lumber consumer should explore the possibility that the costs of processing the lower grades, particularly when gang-ripping-first is used, are more than offset by increases in rough-dimension yields. The first question we will explore is what are the effects of remanufacturing on the size and value of the remanufactured boards? The second is what is the effect of remanufacturing on clear-2-face rough dimension yields?

THE STUDY

Edging and/or trimming and division-based remanufacturing was used on 1C and 2AC 6-foot and longer boards in our 1998 red oak data bank (1). Division-based remanufacturing divides a board into as many as four smaller boards. These are well-manufactured boards that are typical of the grades when normal NHLA procedures are used: 80 percent of the 1 Common and 90 percent of the 2A Common had grading cutting areas as percentages of their surface measures in the normal range for their grades: 66-2/3 to 83-1/3 percent for 1 Common (with greater than 2 ft. surface measure), and 50 to 66-2/3 percent for 2A Common. For those readers unfamiliar with the NHLA rules, we have included an overview of these rules in **Table 1**. When the maximum number of grading cuttings allowed by NHLA were considered, we found that about half of the 1 Common and 2A Common boards had grading cutting area percentages of surface measures typical of the next higher grade (1 Common to FAS and 2A Common to 1 Common). These boards did not grade at the next higher grade due to other grading considerations, such as amount of wane, pith, or defect size. It is also important to note that board size is a key element when comparing grades. **Table 1** lists the minimum size boards acceptable for each grade. There were 5,345 board feet (BF) of 1 Common (883 boards) and 4,377 BF of 2A Common (784 boards).

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Forest Prod. J. 50(2):79-89.

TABLE 1. — Hardwood lumber grades standard inspection.[a]

	FAS	F1F	Selects	#1 Com	#2A & 2B	#3A Com	#3B Com	FAS limits	
Minimum size board	6″ by 8′	Same as FAS for species being graded	4″ by 6′	3″ by 4′		3″ by 4′	3″ by 4′	Pith = SM in inches	Wane in FASIFACE FAS limitations applies to better face.
Minimum size cutting	4″ by 5′ 3″ by 7′			4″ by 2′ 3″ by 3′	3″ by 2′	3″ by 2′	Not less than 1-1/2″ wide containing 36 in.^{2}	Wane = 1/2 length	# 1 Common side: 1/3W by 1/2L, widest wane added together. Length can be on both edges.
Basic yield	SM[b] × 10 83-1/3%	BETTER FACE TO GRADE FAS		SM × 8 66-2/3%	SM × 6 50%	SM × 4 33-1/3%	SM × 3 25%	Knot = 1/3 SM	Wane in selects
Formula to determine no. of cuts	$\frac{SM}{4}$ (4 max.)	POOR FACE TO GRADE #1 COMMON		$\frac{SM+1}{3}$ (5 max.)	$\frac{SM}{2}$ (7 max.)	Unlimited	Unlimited sound cuttings	Warp = entire board must be flat enough to S2S or S.S.T.	Pcs. 6″ & wider FAS limitations applies to better face. # 1 Common side: 1/3W by 1/2L, widest wane added together. Length can be on both edges.
SM needed to take extra cutting	6 to 15′ SM			3 to 10′ SM	2 to 7′ SM				
Extra yield needed for extra cutting	SM × 11 91-2/3%			SM × 9 75%	SM × 8 66-2/3%			Splits = not to excede 2 SM or 12″ whichever is greater. Splits shall diverge 1″ in 12″.	Pcs. 4″ by 5″ wide 1/3W or 1/2L applies to both faces. Add widest wane together, add total length of wane from both edges.
Special yields	97% Rule 2 cuts full width any length. Pcs. 6″ and wider with 6 to 12′ SM; SM × 11.64 for yield	97% Rule - on better face	2′ + 3′ SM to be 100% clear or SM × 11 in one cutting on better face 97% Rule	1′ SM - 100% 2′ SM - SM × 9	1′ SM, SM × 8; #2A Com - clear face cuttings; #2B Com - sound cuttings	#2A Com - better face and reverse side of cuttings sound; will also qualify for 3A Com		First Lineal Foot Rule: Applies to both ends of board. 10 contain not over 25%, unsound wood	

[a] Reproduced by permission of National Hardwood Lumber Assoc., Memphis, TN. This chart summarizes the main requirements for the standard grades. For complete information, consult the appropriate section of the NHLA Rule Book.

[b] SM = surface measure.

The UGRS program (3,4) grades boards whose length, width, and defect types and sizes have been digitized. It remanufactures lumber by either edging and/or trimming or dividing a board into as many as four smaller boards, provided that the total value is at least 1 cent more than the original and the method produces at least one higher grade board. Through assignment of fixed cost and/or processing costs it is possible to specify any margin greater than 1 cent. UGRS determines and retains the largest increase in value.

Because the remanufacturing solution is value based, two lumber price files were used: one that is included with UGRS (Price File A) and another that reflects kiln-dried prices in April 1998 (Price File B). The values (in dollars) of 1,000 board feet (MBF) were:

Grade	Price File A	Price File B
	------- ($/MBF) -------	
FAS	1,110	1,450
F1F	1,100	1,425
Selects	1,090	1,405
1 Common	700	1,050
2A Common	400	815
3A Common	335	680

The relative values of the Common grades in comparison to the Selects and better grades differ greatly between Price File A and Price File B. In Price File A, FAS is nearly three times as expensive as 2A Common; 1 Common is nearly twice as expensive as 2A Common; and the prices of FAS, F1F, and Selects are similar. Price File B had higher prices but the cost of FAS, FIF, and Selects lumber is less than twice that of 2A Common, and the price of 1 Common is only 25 percent higher than that of 2A Common.

The results of edging and/or trimming and division-based remanufacturing using Price File A are illustrated in **Figures 1** through **3**. The board in **Figure 1** contains 13 BF and grades out to 1 Common with a value of $9.10. If edging and/or trimming are used, the best solution is shown in **Figure 2**. By trimming 40 inches from the right end, the board is converted to 10 BF of FAS with a value of $11.10. We ignore remanufacturing costs in this example. If division-based remanufacturing is used, the best solution is shown in **Figure 3**. Three boards will be produced with a total value of

$13.49 obtained as follows: Board 1 is 5 BF of FAS with a value of $5.55; board 2 is 2 BF of 1 Common with a value of $1.40; and board 3 is 6 BF of Selects with a value of $6.54. Three estimates of remanufacturing costs were used:

Costs	File 1	File 2	File 3
Fixed per board	1 cent	10 cents	30 cents
Per linear foot of sawkerf	1/2 cent	2 cents	5 cents

In effect, remanufacturing costs are a charge below which no remanufacturing will be done. That is, there will be no remanufacturing unless the value of the new board(s) minus the remanufacturing costs exceeds that of the original board by at least 1 cent. A 10-foot-long board that is ripped to two boards would have a remanufacturing cost of 6 cents when Cost File 1 is used, 30 cents when Cost File 2 is used, and 80 cents when Cost File 3 is used. Fewer solutions are found as the cost of remanufacturing is increased.

Three lumber inputs were used in a gang-rip-first rough mill: 1) the well-manufactured 1 Common and 2A Common 6-foot and longer 4/4 kiln-dried lumber from the 1998 red oak data bank; 2) higher grade lumber from edging and/or trimming; and 3) lumber resulting from either the edging and/or trimming method or division-based remanufacturing, whichever had the highest net value (combination method). In the combination method, when the values for edging and/or trimming are the same as for the division-based remanufacturing, the edging and trimming solution is retained as it is typical of the lumber preparation of well-run sawmills. The division-based procedure will become commonplace when scanning and automated processing reach their potential. Net value is the value of the new board(s) less remanufacturing costs.

The data-bank lumber was the input for remanufacturing with the edging and/or trimming and combination methods. To better simulate sawmill output, boards that could not be remanufactured due to defect location or insufficient quality were added. This procedure minimizes the impact of remanufacturing, but represents a more realistic condition.

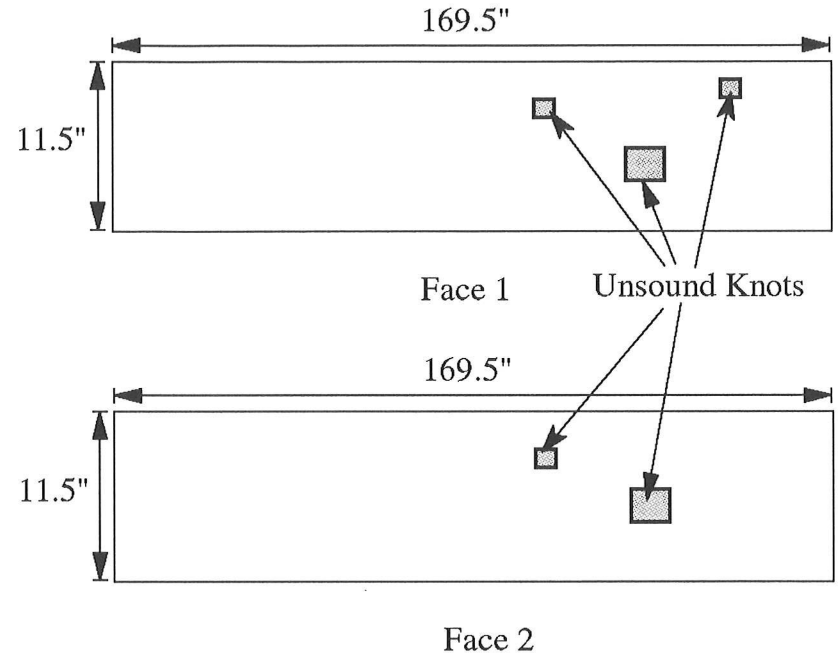

Figure 1.—Sample board for remanufacturing (not to scale): 13 BF of 1 Common.

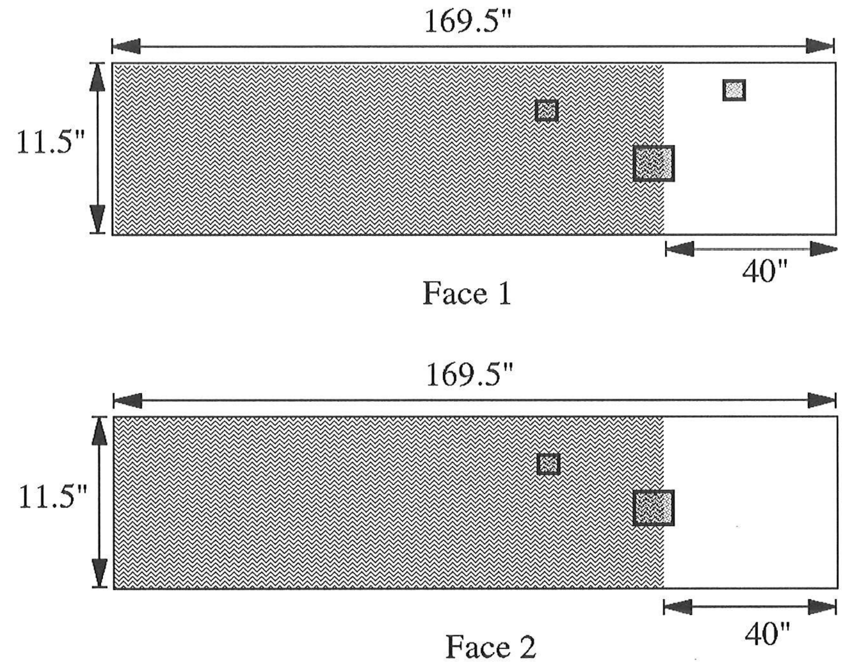

Figure 2. — Edging and/or trimming remanufacturing solution: 10 BF of FAS.

The ROMI-RIP Version 2.0 gang-rip-first rough-mill simulator (6) was used to develop clear-2-face yields and values from the remanufactured data sets. To simplify comparisons, we ran a cutting bill with many short lengths and narrow widths and several sizes of glued-up panels (**Table 2**). We also used an arbor with fixed saw spacings and the capability to feed boards for optimum yield. This procedure assured that 2A Common alone could be used to satisfy the needs of the cutting bill. This is not a study of arbor design or cutting bill complexity. Comparisons of easy and difficult cutting bills processed with all-spacings-moveable and fixed-spacings-best-feed arbors can be made using straight and mixed 1 and 2A Common lumber but without remanufacturing

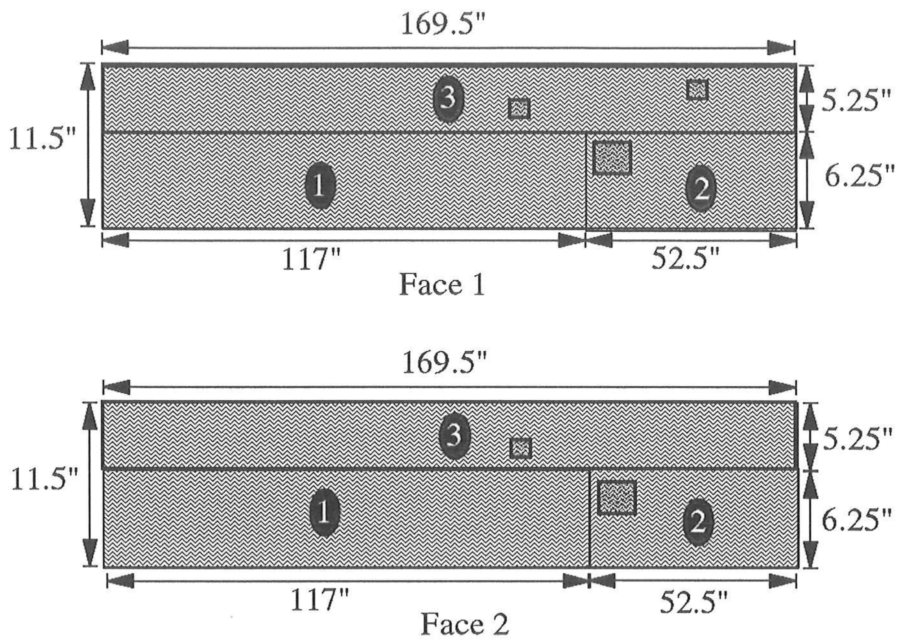

Figure 3. — Division-based remanufacturing solution producing: Board 1, FAS (5 BF); Board 2, 1 Common (2 BF); Board 3, Selects (6 BF).

TABLE 2. — Cutting bill for ROMI-RIP rough-mill simulations.

Part width	Part length	Quantity
- - - - - - - - - (in.) - - - - - - - - -		
Glued-up panels		
4.5000	78.8750	30
4.5000	11.8750	125
6.2500	28.3750	30
17.6250	54.0000	26
20.6250	19.8750	125
22.5000	25.6250	26
Solid parts		
1.5000	15.0000	240
1.5000	23.0000	1,550
1.5000	57.3750	250
1.8750	44.6250	300
2.6250	22.8750	100
2.6250	57.3750	215
3.8750	14.6250	105
3.8750	61.7500	44
4.2500	15.8750	125
4.2500	32.0000	44

(2). Copies of the software used in that study are also available.

Results

Remanufacturing

Remanufacturing by edging and/or trimming amounts to making a large board smaller to increase its grade and, therefore, its value. Division-based remanufacturing amounts to making two or more smaller boards with at least one of the smaller boards being of higher grade and the total value of all smaller boards being greater than the original board. However, descriptions of specific results are not as straightforward because of interactions among factors such as the price of various grades, the cost of remanufacturing, and the length and width distribution for various lumber grades.

The 1 Common input was 883 boards totaling 5,345 BF valued at $3,742 using Price File A and $5,612 using Price File B (**Table 3**). For 2A Common, the input was 784 boards totaling 4,377 board feet and valued at $1,751 for Price File A and $3,566 for Price File B. Not surprisingly, when remanufacturing costs were low (as in A-1 and B-1), the greatest amount of lumber was remanufactured for the greatest increase in value. As costs increased to 30 cents per board and 5 cents per foot of sawing (A-3 and B-3), there were important decreases in the amount of material that could be remanufactured. As a result, the percentage increase in total value from the processing is less.

The relationship among prices of various grades of lumber at the time of remanufacturing can greatly affect profitability. When prices are relatively close, as in Price File B, there is less remanufacturing and the increase in value of this work is much less. This is true regardless of the remanufacturing costs.

For the lumber prices and remanufacturing costs used in this study, the percentage of lumber input that was remanufactured ranged from 52.6 to 80.6 percent for 1 Common and 53.9 to 92.4 percent for 2A Common (**Table 4**). The increase in value of output lumber ranged from 7.4 percent to 21.7 percent for 1 Common and 6.6 percent to 50.1 percent for 2A Common (**Table 3**).

Let's examine the remanufacturing process in greater detail. Some boards can be remanufactured only by edging and/or trimming and others only by division. In general, edging and/or trimming works best when defects are on the edges or ends of the boards, e.g., (wane or end splits). Division-based remanufacturing works best when defects are located near the center of the board; this is often the case with pith. For other boards, both methods produce acceptable results. Recall that when the dollar values are equal, edging and/or trimming results are retained as the best solution because this is what a well-run sawmill can do today. Otherwise, the best solution is the remanufacturing result with the highest net dollar value.

A summary of the number of "best" results is given in **Table 4**. When the price spread among the lower grades was relatively wide (Price File A), edging and/or trimming produced more of the best solutions, though the differences were not great at the higher remanufacturing costs. When the price differential among the lower grades was relatively small (Price File B), division-based remanufacturing became important.

The sole output of edging and/or trimming was boards of higher grades. For 1 Common boards, this meant remanufacturing to Selects, F1F, or FAS. The 2A Common would be improved to 1 Common or higher. For division-based remanufacturing, at least one of the new boards had to be of a higher grade. The others could be 3A Common and better. The value of new boards minus the costs of remanufacturing had to exceed the value of the original board by at least 1 cent.

The grade distributions from the best remanufacturing solutions are shown in **Table 5**. In addition to Selects and F1F boards, there was a considerable amount of FAS lumber made from 1 Common boards. Except for board dimensions, Selects and F1F have about the same quality (FAS on the better face, 1 Common on the poorer face). A surprising number of Selects and FIF boards were produced from 2A Common.

An examination of the number of boards and board feet produced by grade shows that individual boards from edging and/or trimming had a larger volume on average (**Table 5**). There was more total board footage produced by division-based remanufacturing for all price and cost combinations. However, to obtain the higher grades, some lower-grade boards, including 3A Common, were produced. When the price range among the grades was wide (Price File A), there was a greater opportunity to find higher-valued solutions. An important factor when grade prices differ greatly is that smaller boards of higher grade and value can be found within the larger boards. Along with other smaller boards of lower grade, a larger overall net value increase can result. This works well for division-based remanufacturing.

The lumber from remanufacturing was regraded with UGRS to determine the maximum percentage of the surface that could be found in the maximum allowable number of grading cuttings. The surface measure of the new boards was noted. As shown in **Table 6**, the nonremanufactured boards (last two columns) always were smaller on average than the data bank boards from which they came (top row). The remanufactured boards also were slightly lower in quality, as they were the remanufacturing residuals. Where there was relatively little remanufacturing (Price File B and Cost File 3), the data sets contained more of the original 1 Common or 2A Common boards.

The 1 Common boards resulting from the combination method of remanufacturing 1 Common had a lower average surface measure but a higher quality than the 1 Common boards from either the edging and/or trimming method or combination method of remanufacture for 2A Common. In the first case, the new 1 Common boards are a byproduct of remanufacturing to a higher grade

TABLE 3. — Effect of lumber prices and remanufacturing costs on output lumber values (1C = 883 boards; 2AC = 784 boards).

					Remanufactured output				Not remanufactured		Total value	
Grade	Input	Value	Price file	Cost file	No. of BF	Value	Remanufacturing cost	Net value	No. of BF	Value	Net remanufacturing Non remanufacturing	Percent increase
	(BF)	($)			(BF)	($)	($)	($)	(BF)	($)	($)	(%)
1C	5,345	3,742	A	1	3,841	3,855	27	3,828	1,037	726	4,554	21.7
	5,345	3,742	A	2	3,506	3,510	116	3,394	1,489	1,042	4,436	18.5
	5,345	3,742	A	3	2,945	2,977	271	2,706	2,152	1,506	4,212	12.6
	5,345	5,612	B	1	3,352	4,298	19	4,279	1,883	1,977	6,256	11.5
	5,345	5,612	B	2	3,194	4,130	98	4,032	2,033	2,135	6,167	9.9
	5,345	5,612	B	3	2,714	3,558	191	3,367	2,531	2,658	6,025	7.4
2AC	4,377	1,751	A	1	3,287	2,518	23	2,495	332	133	2,628	50.1
	4,377	1,751	A	2	3,227	2,459	127	2,332	451	180	2,512	43.5
	4,377	1,751	A	3	2,867	2,201	268	1,933	935	374	2,307	31.8
	4,377	3,566	B	1	2,788	2,956	16	2,940	1,305	1,063	4,003	12.3
	4,377	3,566	B	2	2,643	2,822	85	2,737	1,462	1,191	3,928	10.2
	4,377	3,566	B	3	2,155	2,325	164	2,161	2,015	1,641	3,802	6.6

TABLE 4. — *Influence of lumber price and remanufacturing cost on type of remanufacturing that produces the highest valued solutions.*

Grade and amount	Price file	Cost file	Type of remanufacturing[a]	No. of best solutions	No. of BF processed	Percent of input
					(BF)	(%)
	A	1	E/T	377	2,053	38.4
			Division	277	2,255	42.2
			Total	654	4,308	80.6
		2	E/T	276	1,675	31.3
			Division	266	2,181	40.8
			Total	542	3,856	72.1
		3	E/T	231	1,454	27.2
1 Common,			Division	213	1,739	32.5
883 boards,			Total	444	3,193	59.7
5,345 BF						
	B	1	E/T	162	1,017	19.0
			Division	307	2,445	45.7
			Total	469	3,462	64.7
		2	E/T	167	1,063	19.9
			Division	283	2,249	42.1
			Total	450	3,312	62.0
		3	E/T	146	975	18.2
			Division	225	1,839	34.4
			Total	371	2,814	52.6
	A	1	E/T	359	1,807	41.3
			Division	337	2,238	51.1
			Total	696	4,045	92.4
		2	E/T	349	1,777	40.6
			Division	323	2,149	49.1
			Total	672	3,926	89.7
		3	E/T	294	1,596	36.5
2A Common,			Division	274	1,846	42.2
784 boards,			Total	568	3,442	78.7
4,377 BF						
	B	1	E/T	169	894	20.4
			Division	334	2,178	49.8
			Total	503	3,072	70.2
		2	E/T	168	904	20.7
			Division	304	2,011	45.9
			Total	472	2,915	66.6
		3	E/T	138	776	17.7
			Division	229	1,586	36.2
			Total	367	2,362	53.9

[a] E/T = edging and/or trimming; Division = division-based remanufacturing.

(1 Common input); in the second case, the new 1 Common may well be the objective of the remanufacturing (2A Common input).

ROMI-RIP ROUGH-MILL SIMULATIONS

It is important to understand the basic differences between the remanufacturing results given earlier and the rough-mill simulation results presented here. Previously, we analyzed the "best" solutions by the edging and/or trimming and the combination method for the entire runs on the 6-foot and longer boards from the data bank. For the rough-mill simulations, we analyzed only the amount of randomly selected lumber from remanufacturing that was needed to satisfy a cutting bill. Further, in the rough-mill simulations, the edging and/or trimming solutions were used whether or not they are superior to any possible division-based remanufacturing solutions. This procedure simulates the output of a conventional sawmill that emphasizes grade output over volume output. The combination method used here is similar to that described previously in that the highest net dollar value solution is retained, and, where the division-based and edging and/or trimming solutions are equal, the latter solution is retained.

Recall that the data-bank boards that could not be remanufactured were added to the remanufactured results before the rough-mill simulations were run to better estimate sawmill output. As remanufacturing costs increase, the number of remanufacturing solutions decreases (**Table 3**). One result is that ROMI-RIP data files become more like those from the original data bank. There was relatively little remanufacturing when Price File B and Cost File 3 were used; these data sets contained mostly original 1 Common or 2A Common boards.

ROMI-RIP continues to draw boards from data files until all of the parts and panels in the cutting bill are produced. The number of boards and board feet are a measure of the size and quality of the input raw material. ROMI-RIP draws more boards of lower quality or smaller size to meet cutting bill requirements. Although, all of the boards in a data file will not be used, each board in the original data set has an equal chance of being selected because of randomization. We will examine the remanufacturing variables that give the largest and smallest increases in total value for the 1 Common and 2A Common input lumber grades (**Table 3**). For both 1 Common and 2A Common input lumber, the largest total value increase was obtained with Price File A and Cost File 1 (A-1); the smallest was obtained with Price File B and Cost File 3 (B-3).

The results of ROMI-RIP rough-mill simulation runs by grade are given in **Table 7** and summarized for all grades in **Table 8**. Only the primary gang-ripping yields are shown. These are rough dimension parts that are produced by crosscutting full-width, gang-ripped

TABLE 5. — Summary of output lumber by grade from best remanufacturing solutions.

Grade and amount	Price file	Cost file	Remanufacturing method[a]	FAS		F1F		Selects		1C		2A		3A		
				No. of boards	No. of BF	No. of boards	No. of BF	No. of boards	No. of BF	No. of boards	No. of BF	No. of boards	No. of BF	No. of boards	No. of BF	Total BF
					(BF)		(BF)		(BF)		(BF)		(BF)		------ (BF) -------	
	A	1	E/T	45	316	97	621	235	786	--	--	--	--	--	--	1,723
			Division	42	260	52	281	248	836	183	550	39	83	45	108	2,118
			Total	87	576	149	902	483	1,622	183	550	39	83	45	108	3,841
		2	E/T	42	298	89	581	145	564	--	--	--	--	--	--	1,443
			Division	40	240	56	313	228	809	171	524	39	83	38	94	2,063
			Total	82	538	145	894	373	1,373	171	524	39	83	38	94	3,506
		3	E/T	45	314	81	540	105	420	--	--	--	--	--	--	1,274
1C,			Division	41	249	46	262	170	622	133	415	34	69	22	54	1,671
833 boards,			Total	86	563	127	802	275	1,042	133	415	34	69	22	54	2,945
5,345 BF																
	B	1	E/T	30	200	64	421	68	293	--	--	--	--	--	--	914
			Division	50	294	70	388	233	822	155	516	119	305	45	113	2,438
			Total	80	494	134	809	301	1,115	155	516	119	305	45	113	3,352
		2	E/T	35	228	69	455	63	271	--	--	--	--	--	--	954
			Division	49	299	68	374	207	732	142	471	110	280	34	84	2,240
			Total	84	527	137	829	270	1,003	142	471	110	280	34	84	3,194
		3	E/T	33	220	61	438	52	225	--	--	--	--	--	--	883
			Division	48	289	62	342	147	550	124	414	71	180	21	56	1,831
			Total	81	509	123	780	199	775	124	414	71	180	21	56	2,714
	A	1	E/T	--	--	35	176	149	443	175	678	--	--	--	--	1,297
			Division	--	--	19	91	174	503	212	648	114	269	185	479	1,990
			Total	--	--	54	267	322	946	387	1,326	114	269	185	479	3,287
		2	E/T	--	--	32	167	141	428	176	705	--	--	--	--	1,300
			Division	--	--	19	89	162	477	200	625	102	251	187	485	1,927
			Total	--	--	51	256	303	905	376	1,330	102	251	187	485	3,227
		3	E/T	--	--	32	169	111	351	151	678	--	--	--	--	1,198
2AC,			Division	--	--	19	94	142	418	170	556	76	191	152	410	1,669
784 boards,			Total	--	--	51	263	253	769	321	1,234	76	191	152	410	2,867
4,377 BF																
	B	1	E/T	--	--	22	114	90	277	57	300	--	--	--	--	691
			Division	--	--	17	84	144	440	205	652	168	498	168	423	2,097
			Total	--	--	39	198	234	717	262	952	168	498	168	423	2,788
		2	E/T	--	--	22	114	83	256	63	339	--	--	--	--	709
			Division	--	--	17	84	138	424	181	594	156	458	145	374	1,934
			Total	--	--	39	198	221	680	244	933	156	458	145	374	2,643
		3	E/T	--	--	17	90	66	212	55	318	--	--	--	--	620
			Division	--	--	18	88	105	344	131	466	123	373	98	264	1,535
			Total	--	--	35	178	171	556	186	784	123	373	98	264	2,155

[a] E/T = edging and/or trimming; Division = division-based remanufacturing.

strips. The additional yield from salvage was less than 2 percent.

It is important to understand what is contained under each lumber-grade heading in **Table 7**. Consider the grades that are produced from the 1 Common lumber input. With edging and/or trimming, a large 1 Common will not be processed to a smaller 1 Common board. Therefore, the 1 Common boards shown for edging and/or trimming are non-remanufactured boards drawn by ROMI-RIP from the randomized 1 Common sample. For the combination method, the 1 Common boards are a combination of both smaller 1 Common from division-based remanufacturing and non-remanufactured 1 Common boards. Similarly, the 2A Common boards for edging and/or trimming 2A Common input lumber are nonremanufactured boards. For the combination method, the 2A Common are a mixture of smaller 2A Common from division-based and nonremanufactured 2A Common boards.

It is interesting to note that the yield values for the same remanufactured grade generally are lower when the boards are remanufactured from 2A Common; that is, the primary yield of F1F from 1 Common was higher than the primary yield of the F1F from 2A Common and so on. Primary yield values become similar with 2A and 3A Common. At least part of the reason is shown in **Table 6**, which was developed using the UGRS program. The best measure of the quality of FAS and the Common grades is to determine the maximum percentage of surface measure in the maximum number of grading cuttings allowed by NHLA (5). This does not change the initial grade determined by UGRS but is a better predictor of utility. A grading cutting occurs on the poorer face of the FAS and Common boards, and defects on the opposite side of the cuttings must be taken into account. For F1F and Selects, this maximum has no meaning because each face is graded separately, and what is on one face has no effect on the grading cuttings of the other.

Recall that edging and/or trimming produces a single board that is smaller than the lower grade board from which it came. Also, recall that the division-based remanufacturing part of the combination method produces at least two or more smaller boards and that only one of these must be of a higher grade. Also, FAS and FIF can come only from the larger lower grade boards as the FAS and F1F minimum dimensions for kiln-dried boards are 5-3/4 inches by 8 feet. From 1 Common, the second board will be a small Selects or poorer board.

The higher yields of the F1F and Selects from 1 Common input may reflect some of the reasoning just described. However, for these grades, it is more likely that boards in these grades from 2A Common just made the grade. From 1 Common, a different set of conditions comes into play. No. 1 Common may contain a better face that just fails to meet the minimum requirements for FAS. This could be due to such factors as insufficient surface area in the grading cuttings in combination with the board's surface measure or downgrading defects such as knots or splits in the first foot of the board. Perhaps there is too much wane. Simple edging and/or trimming might easily produce F1F or Selects boards from 1 Common.

Another example is excessive pith on the better face of a 1 Common board. Division-based remanufacturing might well remove enough of this defect to allow an upgrade. If the 1 Common or poorer face in these examples also can be improved sufficiently, an FAS board could result. The final board(s) will be the result of the interactions of initial board quality, relative prices among the grades, and remanufacturing costs.

Let us view **Table 8** from the point of view of a lumber consumer. Considering only lumber prices, the cutting bill can be satisfied with 3,007 BF of No. 1 Common valued at $2,105 (Price File A) or $3,157 (Price File B). If this 1 Common is purchased after being remanufactured, the lumber cost using Price File A values will be increased from 20.3 to 28.0 percent depending on remanufacturing costs. When Price File B prices are used, the increase is from 11.0 to 13.9 percent depending on remanufacturing costs. Remember, there is much less remanufacturing done with Price File B values. While the yield from the combined grades from remanufacturing are about the same as the original 1 Common boards from which they came, the number of boards usually is greater, particularly when both edging and/or trimming and division-based

TABLE 6. — Average surface measure (SM) and grading surface area for edging and/or trimming and combination methods of remanufacturing for selected price and cost files.

Method	FAS		F1F		Selects		1C		2AC		3AC		Non-remanufactured	
	Avg. SM	Avg. max. grading area	Avg. SM	Avg. max. grading area	Avg. SM	Avg. max. grading area	Avg. SM	Avg. max. grading area	Avg. SM	Avg. max. grading area	Avg. SM	Avg. max. grading area	Avg. SM	Avg. max. grading area
Data bank	7.7	94.5	7.3	--	3.6	--	6.0	82.8	5.6	66.7	4.2	45.8	--	--
No. 1 Common														
E/T-A1	7.9	96.0	6.7	--	4.1	--	--	--	--	--	--	--	5.6	81.3
E/T-B3	8.0	95.4	7.1	--	4.6	--	--	--	--	--	--	--	5.6	81.3
Comb.-A1	6.6	92.8	6.1	--	3.4	--	3.0	83.0	2.1	72.9	2.4	50.4	4.5	80.8
Comb.-B3	6.3	92.9	6.3	--	3.9	--	3.3	82.4	2.5	67.9	2.7	48.2	4.9	80.7
No. 2A Common														
E/T-A1	--	--	5.2	--	3.3	--	4.8	79.3	--	--	--	--	5.2	64.0
E/T-B3	--	--	5.5	--	3.4	--	5.9	77.4	--	--	--	--	5.4	65.0
Comb.-A1	--	--	4.9	--	2.9	--	3.4	80.1	2.4	64.2	2.6	50.9	3.8	64.4
Comb.-A2	--	--	5.2	--	3.2	--	4.2	77.7	3.0	63.6	2.7	48.0	4.8	63.9

TABLE 7. — Cost and amount of remanufactured lumber used to meet needs of rough-mill cutting bill.

Input grade	Remanufacturing method	Price cost file	FAS				F1F				Selects			
			No. of BF	Cost	No. of boards	Primary yield	No. of BF	Cost	No. of boards	Primary yield	No. of BF	Cost	No. of boards	Primary yield
			(BF)	($)		(BF)	(BF)	($)		(BF)	(BF)	($)		(BF)
1C	None	A-1												
1C	None	B-3												
1C	E/T[a]	A-1	324	360	38	73.95	424	466	56	67.63	348	379	78	68.46
1C	E/T	B-3	298	432	35	71.28	438	624	57	66.40	166	233	34	68.64
1C	Combination	A-1	396	440	55	74.52	477	525	70	67.91	664	724	161	68.89
1C	Combination	B-3	338	490	54	75.73	417	594	66	70.25	445	625	112	67.10
2AC	None	A-1												
2AC	None	B-3												
2AC	E/T	A-1					244	268	42	60.84	546	595	138	60.45
2AC	E/T	B-3					149	212	23	63.09	254	357	63	60.33
2AC	E/T	A-1					228	250	39	63.09	745	812	211	61.72
2AC	E/T	B-3					163	232	29	60.11	494	694	133	61.88
Input grade	Remanufacturing method	Price cost file	1 Common				2A Common				3A Common			
			No. of BF	Cost	No. of boards	Primary yield	No. of BF	Cost	No. of boards	Primary yield	No. of BF	Cost	No. of boards	Primary yield
			(BF)	($)		(BF)	(BF)	($)		(BF)	(BF)	($)		(BF)
1C	None	A-1	3,007		487	65.41								
1C	None	B-3	3,007		487	65.41								
1C	E/T	A-1	1,896	1,327	333	63.61								
1C	E/T	B-3	2,110	2,216	365	64.42								
1C	Combination	A-1	1,395	976	299	61.74	40	76	19	53.14	37.7	13	14	41.30
1C	Combination	B-3	1,697	1,782	360	62.10	100	82	41	54.32	35	24	14	39.29
2AC	None	A-1					3,530		621	55.39				
2AC	None	B-3					3,530		621	55.39				
2AC	E/T	A-1					1,684	674	318	52.19				
2AC	E/T	B-3					2,493	2,032	451	53.92				
2AC	E/T	A-1					992	397	249	51.41	366	123	128	40.29
2AC	E/T	B-3					2,034	1,658	454	52.17	217	148	81	41.04

TABLE 8. — Effects of remanufacturing on lumber requirements and costs to satisfy needs of a simple gang-rip-first, rough-mill cutting bill.

Input grade	Remanufacturing method	Price/cost file	No. of BF	No. of boards	Primary yields	Total cost	Increase in cost of lumber
			(BF)		(BF)	($)	(%)
1C	None	A-1	3,007	487	65.41	2,105	
1C	None	B-3	3,007	487	65.41	3,157	
1C	E/T[a]	A-1	2,993	505	65.86	2,532	20.3
1C	E/T	B-3	3,011	491	65.62	3,505	11.0
1C	Combination	A-1	3,010	618	65.61	2,694	28.0
1C	Combination	B-3	3,032	647	64.95	3,697	13.9
2AC	None	A-1	3,530	621	55.39	1,412	
2AC	None	B-3	3,530	621	55.39	2,877	
2AC	E/T	A-1	3,526	682	55.48	2,273	61.0
2AC	E/T	B-3	3,550	633	55.20	3,288	14.3
2AC	Combination	A-1	3,556	903	55.20	2,420	71.4
2AC	Combination	B-3	3,613	854	54.40	3,472	20.7

[a] E/T = edging and/or trimming.

remanufacturing are used. In addition, the costs of handling and processing may be higher.

What are the rough-mill lumber costs of meeting the cutting bill needs from standard lumber without remanufacturing and from boards subjected to remanufacturing? The amount of 1 Common lumber required was always less than 2A Common but the lumber costs always were greater (**Table 8**). The percentage increase in costs of remanufactured lumber from 2A Common was much more than the increases from 1 Common. This means that there was more remanufacturing to relatively higher value from the 2A Common. When remanufacturing costs were small (Cost File 1) and price differences among the grades were large (Price File A), the increase in total lumber cost was 61 percent for edging and/or trimming and 71.4 percent for combination remanufacturing from 2A Common. When the lumber price differences were smaller (Price File B) and remanufacturing costs higher (Cost File 3), the increase in lumber costs was much smaller (14.3 percent from edging and/or trimming to 20.7 percent for the combination method).

Discussion

This work was done on a large set of digitized boards (1). These straight boards were collected by several people from several companies in several states over a period of several years. We believe they represent the quality of well-manufactured boards that have been available in the marketplace, that is, they have been "...edged and trimmed carefully to produce the best possible appearance while conserving the usable product of the log" (5). We underestimated the amount of remanufacturing that was possible. And with boards containing crook or side bend or with boards that are less well manufactured, the potential for remanufacturing should be even greater.

The amount of remanufacturing that can be done profitably depends on lumber market conditions and the costs assigned to the process. It is the price relationships among the grades that is most important. As the range of prices narrows, the ability to remanufacture profitably diminishes. Few people have any accurate knowledge of the manufacturing costs to be assigned.

Remanufacturing should become a more important factor as scanning and automated processing become more effective and commonplace, that is, unless the headrig is operated with scanning and computer control for grade recovery. Then, the largest board of the highest grade will be produced but, on average, the boards probably will be at the low end of the quality scale in each grade, because the software probably will emphasize the entry level of each grade.

Remanufacturing represents a definite advantage to the lumber producer but could have a negative influence on the lumber markets. One adverse effect is that the consumer will purchase smaller lumber at a higher cost, which would require more handling for less yield and might have a negative impact on throughput. Remanufacturing also may have a negative impact on the lumber grades themselves. A basis of the NHLA grades is that the entire range of quality within a grade is available. If the better boards are remanufactured, this assumption is no longer valid.

This paper is the first effort with new computer grading, remanufacturing, and rough-mill processing software. Our purpose was to examine the remanufacturing potential of 1 Common and 2A Common lumber that was well manufactured originally. The actual effects on the higher grades (Selects and better) will be less than shown here as we excluded the higher grades contained in the data bank in our rough-mill simulations. Further, for analytical purposes, we separated the 1 Common and 2A Common input from the subsequent remanufactured output. This would not occur in a rough mill.

The reader can gain much from independent study of the tables. Of greater importance, the reader can obtain the software used to conduct this study and develop different comparisons from the ones reported here. For the first time, it is possible to accurately grade and remanufacture lumber from digitized data while taking into account the relationship among lumber grades and the costs of processing to rough-dimension parts in gang-rip-first or crosscut-first rough mills. For a copy of the 1998 red oak data bank, UGRS and/or ROMI RIP software, contact the Northeastern Research Station, Forestry Sciences Laboratory, 241 Mercer Springs Road, Princeton, WV 24740; (304) 431-2700.

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