Hardwood lumber widths and grades used by the furniture and cabinet industries: Results of a 14-mill survey

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Abstract

Data on red oak lumber width, length, and grade were collected at 14 furniture and cabinet industry rough mills to identify relationships among these lumber attributes and the degree to which they differ from mill to mill. Also, this information is needed to formulate valid lumber size distributions that will improve the quality of the results obtained in mill and simulation-based studies of rough mill processing and product options. The width of the dry, 4/4 thickness, red oak lumber sample was significantly influenced by lumber grade, lumber length, and mill. The dominant lumber width class was 5.00to 6.75 inches (47 % of all boards). Boards in the FAS andFAS-1F grades were wider than those in the No. 1, No. 2A, and No. 3A Common grades, and these were wider than the Selects grade boards. There was significant variability in lumber size attributes between mills, supporting the contention that each mill must collect its own data on lumber size and quality characteristics for optimal decision making. Grade-based lumber size distribution charts are given that can be used to compose study samples when conducting rough mill research.

Secondary processors who have good knowledge of the lumber sizes, grades, and quality levels available for processing in their rough mill operation can plan production to optimize order completion schedules and product recovery. This knowledge can be used to:

- Decide which suppliers to use in a soft "buyer" market.
- Determine whether supplier-specific lumber-procurement specifications are required to eliminate higher proportions of suboptimal lumber received from a particular supplier.
- Determine the feasibility of purchasing lumber from a more distant supplier if its lumber is more appropriate to the mill's needs.
- Decide which lumber to load first into a dry kiln given current and anticipated orders.
- Decide which lumber packages to bring into the rough mill for processing when a large, rough, dry lumber inventory is available to choose from.
- Decide when and how to change the grade mix of lumber being purchased.
- Cost orders more precisely since product yield estimates will be more accurate.

A knowledge of the size and quality distribution of the dry lumber resource also would be useful in designing studies and performing valid processing simulations (Thomas et al. 1996, Buehlmann 1998, Mitchell 1999, Lamb 2000).

In addition, systematic surveys of hardwood lumber size and quality distributions that are being processed in secondary manufacturers' rough mills might help detect the degree to which changes in the hardwood resource and primary industry markets affect the availability of larger lumber and higher grade lumber. This is an issue that deeply concerns the wood products industry.

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For example, has the significant increase (Nolley 1994, Emanuel and Rhodes 2001) in the proportion of sawmills that export lumber reduced the size and grade distribution of lumber that is being delivered to secondary industry rough mills? Lacking a time-series analysis of the size and grade distribution of lumber input into secondary industry rough mills, we cannot answer this question.

Objectives

The primary objectives of this study were to derive an accurate estimate of the width distribution of red oak lumber for different lumber grades and lengths and to investigate the relationship between width and these other variables. Secondary objectives were to evaluate whether regional differences in red oak lumber size and grade are apparent and to describe the degree of variability between rough mills in the size and quality of the red oak lumber inputs. Such information can be used as a benchmarking tool by mills interested in optimizing lumber inputs for a given lumber grade mix.

Methods

Data collection

During the first half of 1996, supervisory personnel were contacted at rough mills in three regions: the West Virginia/western Virginia Appalachian region (WVA), the southern Virginia Appalachian region (SVA), and the North Carolina Piedmont region (NCP). Our mill contact list was comprised of rough mills that met the following three criteria: 1) willingness to participate with the USDA Forest Service as a research partner; 2) accessibility from Princeton, West Virginia; and 3) significant inventory and use of red oak lumber. We intended to survey five mills in each region but only four mills in WVA met all three criteria at the time of the study. Our final list of participating mills included three kitchen cabinet manufacturers, one stair-parts manufacturer, two dimension-parts manufacturers, and eight furniture manufacturers.

Individual studies were conducted during the spring and summer of 1996. Rough mills were contacted periodically to determine when they would be processing oak lumber. We chose red oak for this study because the primary lumber data bank used in lumber cutup studies consists of this species (Gatchell et al. 1998). A study crew comprised of three to four people collected data on lumber grade and size as lumber was input into the rough mill. Only 4/4-thickness, kiln-dried lumber was sampled.

At the beginning of each mill study, the lengths of the red oak lumber packages in the rough mill's dry inventory were surveyed to determine the length distribution of the red oak lumber available for processing at the mill that day. An effort was made to ensure that the lumber packages brought out of inventory for processing represented the length distribution available in the entire inventory. Due to part requirements and the logistics involved in making accessible certain stored lumber packages, the distribution of lumber lengths brought to the rough mill for processing usually deviated somewhat from the lumber length distribution in rough dry inventory. Also, on a given day, the length distribution of lumber packages in inventory can be affected by dry kiln space and drying priorities, kiln discharge schedule, and the prior week's production schedule. Lumber-length distributions in our studies are similar to those processed at the sample mills but are not statistically representative of either the individual mill's lumber lengths or the lengths utilized by the furniture and cabinet industries.

Lumber-grade distributions sampled at each mill are subject to some of the same bias factors that affect the distribution of lumber lengths in each sample population but generally to a lesser extent. Many furniture and cabinet industry rough mills (including those in our study) buy a portion of their lumber in mixed-grade packages using procurement specifications such as "1 Common lumber not to exceed 10 percent FAS & F1F and 15 percent 2A Common lumber." These packages typically contain grade distributions that parallel each rough mill's inputs. Such packages were targeted in our sampling at mills that use this type of procurement specification. For mills that tend to buy single-grade lumber packages, we attempted to sample a distribution of packages similar to the rough mill's overall distribution. For these mills, the same sampling bias issues exist for lumber grade as for lumber length.

Boards within packages were selected for sampling using systematic random sampling. After the first board on the bottom-outside edge of the package was marked as a sample board, every 10th board in the package was end-marked with crayon as a sample board throughout the package. Since board widths are random within most lumber packages (only packages with random-width lumber were sampled in this study), the width distribution of the sample board population was not biased.

The grading and measurement of the sample boards were conducted in the rough mill at the input conveyors. One member of the study team pulled the premarked sample boards from the input lumber stream at a convenient and safe location. One or two team members moved the sample boards from the collection pile onto the grading and measurement table and then returned them to the input stream after all measurements were taken. Team members also assisted in measuring board dimensions (length and width to the nearest 0.25 in.) and took turns tallying board data. The width of tapered lumber was measured following National Hardwood Lumber Association (NHLA 1998) grade rules, that is, one-third of the length of the board from its narrow end.

The lumber grader was the key team member. The same grader was used for all mill studies. Our grader had many years of familiarity with the NHLA grade rules and just prior to the study took a 1-week NHLA-sponsored short course. He also spent several days grading red oak lumber at the laboratory in Princeton, West Virginia.

The sample size for each study represented approximately 10 percent sample of a full shift's lumber input. At the higher production rough mills, the percentage of input boards sampled ranged from 5 to 10 percent because the volume of lumber passing the study team's lumber puller sometimes exceeded his ability to capture all of the marked boards. The number of boards sampled per mill ranged from 146 to 492 (average: 286 boards). For two mills where the sample size fell below 200 boards, repeated attempts to collect additional red oak data were unsuccessful.

Table 1. - *Lumber width distribution percentages*[a] *(based on number of boards*[b]*) by lumber grade for kiln-dried,* 4/4 *thickness, red oak lumber sampled in* 14 *rough mills.*

Width class	FAS	FAS-1F	Selects	1 Common	2A Common	3A Common
(in.)	0%	0%	39%	15%	14%	17%
<5.00	(0)	(0)	(235)	(291)	(104)	(23)
5.00 to 6.75	41%	41%	56%	46%	49%	43%
	(124)	(100)	(336)	(899)	(374)	(60)
7.00 to 8.75	33%	42%	3%	21%	21%	27%
	(99)	(103)	(19)	(423)	(157)	(37)
9.00 to 10.75	18%	13%	1%	11%	10%	9%
	(54)	(31)	(5)	(214)	(75)	(13)
11.00 to 12.75	7%	2%	0%	5%	4%	2%
	(20)	(6)	(0)	(93)	(30)	(3)
13.00 to 14.75	1%	1%	1%	1%	2%	1%
	(4)	(3)	(3)	(27)	(15)	(2)
15.00 to 16.75	0%	0%	0%	1%	0%	0%
	(1)	(\)	(0)	(12)	(2)	(0)
17.00+	0%	0%	0%	0%	0%	0%
	(0)	(0)	(0)	(3)	(2)	(0)
Boards in sample (no.)	302	244	598	1962	759	138

[a]Percentages in each column may not add to 100 due to rounding.
[b]Board counts are in parentheses.

Study limitations

This study was not set up to detect differences in the size and quality distributions of red oak lumber processed by industry sectors (e.g., the cabinet sector versus the furniture sector). For such a study to be valid, the number of study sites would have to have been substantially increased (not very plausible given the difficulties associated with coordinating these industry visits) in order to establish any confidence in sample representativeness.

Data analysis

We used SAS®[1,2] (statistical analysis software) for the statistical analyses (analysis of covariance and Tukey-Kramer multiple comparisons) of the lumber width data. The significance threshold used in these tests was $\alpha = .05$. Statistical tests were not performed on the lumber grade or length data due to uncertainty as to the degree to which our samples represented the partner rough mills' lumber grade and length distributions. Simple summary statistics were calculated for lumber grade and length.

[1]SAS Version 8, SAS Institute, Cary, North Carolina

[2]The use of trade, firm. or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

Results and discussion

Overall lumber width

The overall average width of the 4,003 dry, kiln-dried, red oak boards sampled in this study was 6.64 inches (sample standard deviation = 2.22). The 95 percent confidence interval for the overall mean board width from the 14 mills is 6.57 inches < $\overline{y}$ <6.75 inches. Forty-seven percent of the boards had widths of 5.00 to 6.75 inches (Fig. 1), 16 percent of the sample boards were narrower than 5 inches, while less than 6 percent of the boards were 11 inches or wider. The greatest number and volume of boards at each sample mill was in the 5.0- to 6.75-inch class, largely because the size of cants sawn from the log centers typically range from 4 to 6 inches in thickness/width class.

Percentages for volume-based width distribution were slightly higher in the wider lumber classes than those based on board count (Fig. 1). This was expected because volume is dependent on and directly related to width. On the basis of these results, the following volume-based lumber distribution should be used when sampling boards from data files for simulating rough mill processing by the dimension manufacturing industry:

- 9.5 percent of sample volume consists of boards narrower than 5 inches.
- 11.3 percent of sample volume consists of boards wider than 11 inches.
- 40.5 percent of sample volume consists of boards ranging in width from 5 to 6.75 inches.
- 24.3 percent of sample volume consists of boards ranging in width from 7 to 8.75 inches.
- 14.8 percent of sample volume consists of boards ranging in width from 9 to 10.75 inches.

This estimate of the width distribution of kiln-dried, 4/4-thickness, red oak lumber processed by furniture and cabinet manufacturers in the eastern United States currently is the best one available. However, if a particular rough mill or segment of the secondary processing industry (e.g. moulding) is being studied, one should use distributions based on the lumber inputs of the specific target audience. If the study focuses on a particular lumber grade, use the grade-based distributions shown in Table 1 absent more specific distribution data. In Table 1, note the numbers of boards included in each sample: the 2A and Selects sample sizes are only one-third as large as the 1 Common sample, and the other samples are even smaller.

Lumber width statistical model

Statistical evaluation of the lumber width data (dependent variable) using SAS" software and analysis of covariance indicated that lumber length, grade, and mill (within region) have a significant effect on lumber width *(p* < .05). The linear model used transformed width data (reciprocal of the square root of width) because the residual probability plot of the nontransformed width data was not normally distributed. The addition of the two-variable interaction term, grade*length, improved the main effects model. The significance of the grade*length interaction term indicates that the effect of length is dependent on grade. The significance of the nested effect, mill within region, means that for at least one region there were differences among mills. Both the overall model and the interaction term were highly significant *(p* < .0001):

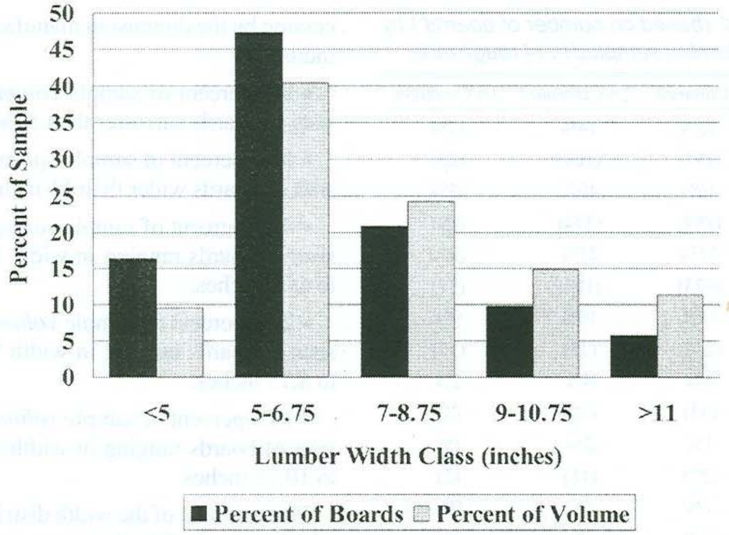

Figure 1. — Lumber width distribution of 4,003 dry, 4/4 thickness, red oak boards measured at 14 rough mills.

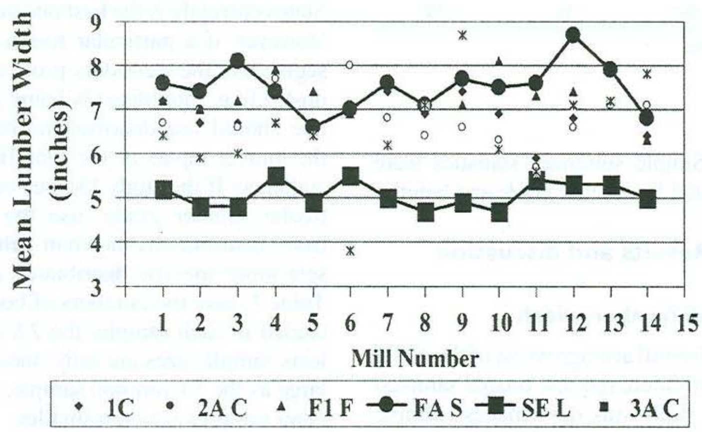

Figure 2. — Average lumber width by grade and by mill for dry, 4/4 thickness, red oak boards measured at 14 rough mills; lines between points are to help with visualization – no trend is implied.

Table 2. — Mean width and confidence intervals by lumber grade of kiln-dried, red oak lumber measured at 14 mills.

Statistical measure	Grade Group 1		Grade Group 2			Grade Group 3
	FAS	F1F	1C	2AC	3AC	Selects
Mean width (in.)	7.2	7.1	6.3	6.4	6.0	4.9
95% C.I.	$6.9<\bar{y}<7.5$	$6.8<\bar{y}<7.5$	$6.2<\bar{y}<6.4$	$6.2<\bar{y}<6.5$	$5.7<\bar{y}<6.4$	$4.8<\bar{y}<5.0$

(width) ^{½} *= f (region, mill (region), length, grade, grade* x *length)*

The r^2 for this model was only 0.1693, so the model is minimally effective in explaining variation in the data. The model appears unbiased on the basis of a comparison of the mean square predicted error (MSPR) for a validation subset of the width data (1,001 randomly selected boards; see Eq. [1]) and the mean square error (MSE) of the model building data set (the remaining 3,002 boards). The MSPR for the validation data set was .003021 and the MSE for the model building set was .003038:

$$\text{MSPR}=\frac{\sum_{1}^{n}(Y_i-\hat{Y}_i)^2}{n} \quad [1]$$

where:

Y; = value of the response variable in the ith validation case

9; = value of the predicted value for the ith validation case

n = number of cases in the validation data set

Using the Tukey-Kramer multiple comparison test, the main effect *grade* and the nested effect *mill within region* were examined to detect significant differences among the levels of these factors. Group 1 grades had the widest lumber (F AS and F1F), Group 2 grades were intermediate in width (No. 1, 2A, and 3A), and Group 3 grades had the narrowest widths (Selects).

The mill within region Tukey-Kramer comparison showed that there was one pair of mills in the WVA region for which the width measurements differed significantly for red oak lumber, two pairs in the SVA region with significantly different widths, and one mill pair in the NCP region with significantly different lumber widths.

Lumber width by lumber grade and length

The overall mean width of the red oak lumber samples measured for each grade demonstrates the significant influence of grade on lumber width detected in the analysis of covariance tests (Table 2). Mean widths are least squares means, which are estimates of the expected means for each class for a balanced design with the covariate, lumber length, held at its mean value.

Figure 2 shows that the FAS grade lumber had the highest mean width at 7 of the 14 mills. The F1F lumber had the highest mean width at four mills. The Selects lumber was consistently the narrowest, having the lowest mean width at 13 mills. The Selects grade, however, is not used at many mills, particularly in the central and southern Appalachian regions. If mills buy FAS-1F and FAS lumber only, most of the Selects-grade boards will be graded as 1 Common. This lowers the average width of the 1 Common lumber grade but improves the overall quality of the 1 Common lumber (more clear area for cuttings).

The significant *grade*length* interaction implies that the mean widths given in Table 2 are not reliable for creating

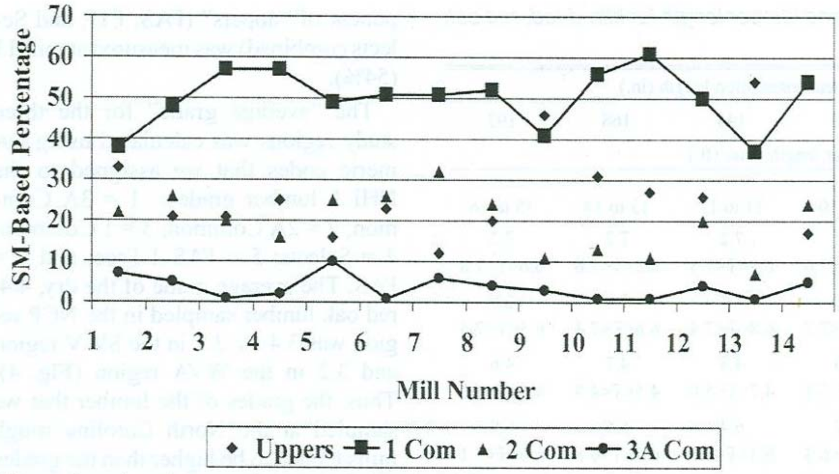

Figure 3. — Lumber grade percentages by mill based on board surface measure for dry, 4/4 thickness, red oak boards measured at 14 rough mills.

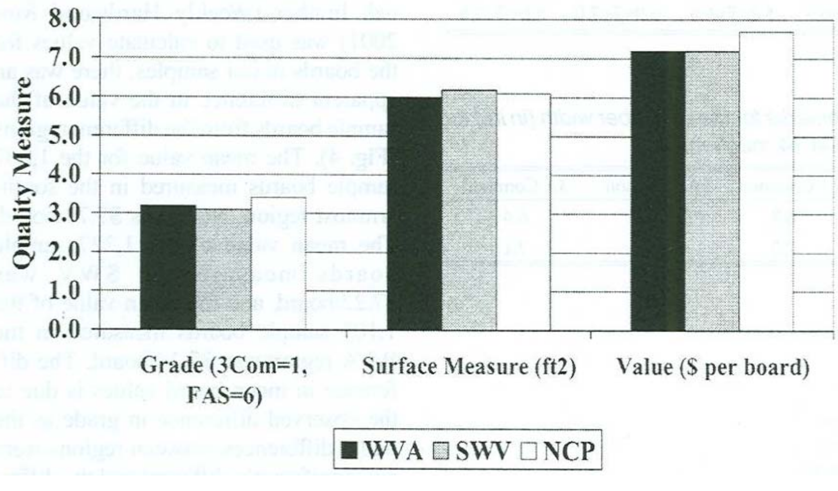

Figure 4. - Average grade, surface measure, and value by study region for dry, 4/4 thickness, red oak boards.

study samples if the sample of interest does not span the full spectrum of grades or lengths. For instance, if a specific grade of lumber is being examined in a simulation study, the widths of lumber ascribed to lumber packages of different lengths should be based on the grade-specific width distributions for each length. Ideally, this will come from a mill-specific study of widths for the species, grade(s), and length(s) of interest.

Least-squares estimates of mean widths for each lumber grade at specific lengths (midpoint lengths of each of six lumber length groupings) are given along with 95 percent confidence intervals in Table 3. Wide confidence intervals indicate a high degree of variability in the measurements. These means are the LSMEANS values that are reported by SAS® software.

The mean lumber widths for the FAS and FAS-1 Face grade lumber illustrate the *grade*length* interaction (Table 3). The predicted mean lumber width for FAS lumber remains constant for the different lumber-length classes while the mean width for FAS-1 Face lumber declines by approximately 0.1 inch for each 2-foot increase in lumber length.

Another obvious grade-related width effect is evident in the Selects data (Table 3). The mean width for 6-footlong Selects lumber is 5.4 inches while the mean width for 8-foot Selects grade lumber is only 5.1 inches; longer Selects boards are even narrower. This reflects size limitations imposed by the NHLA grade rules (1998). These rules prohibit the grading of high-quality boards less than 8 feet long as FAS or FAS-1F. These boards, including some wide boards, are included in the Selects grade (which can be as short as 6 feet). Similarly, high-quality longer boards must be at least 6 inches wide to meet the minimum FAS and FAS-1F width specifications so these narrow boards are included in the Selects grade (which can be as narrow as 4 inches).

Differences in width between rough mills

Differences between mills (nested within regions) were observed for the dependent variable width. Figure 2 shows that the FAS and FAS-1F grades are made up of wider lumber than the other grades; this was true for 8 of the 14 mills. Also, the Selects grade lumber is consistently narrower than the other lumber grades (13 mills). However, Selects grade is used at few mills in the Mid-Atlantic, Southern, and Central to Southern Appalachian regions. If mills buy FAS-1F and FAS lumber only, most of the Selects-grade boards will be graded as 1 Common. This will lower the average width of the 1 Common lumber grade but improve the quality of the 1 Common lumber overall (more clear area for cuttings).

By comparing the average lumber widths calculated for each grade at each rough mill, we gain insight on what constitutes midlevel (50th percentile) and 3rd quartile (75th percentile) averages for dry, 4/4, red oak lumber widths (Table 4). For many rough mill operations, procuring wider lumber is important to yield and productivity, particularly in gang-rip-first mills (Wiedenbeck 2001). A mill's optimal lumber width distribution also depends on the widths of the parts that are cut by the rough mill. Many mills generate data on average lumber width via computers that are tied to board-width scanners. For operations that reap large benefits from processing wider boards, having a mean board width that is lower than the 50th or 75th percentile width levels given in Table 4 may be cause for concern. Knowledge of the widths of lumber utilized by other rough mills may lead rough mill owners/supervisors to design new procurement strategies to obtain a larger portion of wide lumber.

Lumber grade distributions

The grade distribution of the red oak lumber utilized by the 14 mills in this study was heavily weighted toward 1 Common; 49 percent of the boards and

Table 3. — Mean estimated widths by grade and lumber length for kiln-dried, red oak lumber measured at 14 mills.

	Least-square mean estimation length (in.)					
	60	84	120	144	168	192
	Lumber length class (ft.)					
Grade and measurement	4 to 6	7 to 8	9 to 10	11 to 12	13 to 14	15 to 16
FAS width	--	7.2	7.2	7.2	7.2	7.2
95% C.I.	--	$6.7<\bar{y}<7.8$	$6.9<\bar{y}<7.6$	$6.9<\bar{y}<7.5$	$6.8<\bar{y}<7.6$	$6.6<\bar{y}<7.8$
F1F width	--	7.3	7.2	7.1	7.0	6.9
95% C.I.	--	$6.7<\bar{y}<8.0$	$6.8<\bar{y}<7.7$	$6.8<\bar{y}<7.4$	$6.6<\bar{y}<7.4$	$6.3<\bar{y}<7.5$
SEL width	5.4	5.1	5.0	4.8	4.7	4.6
95% C.I.	$5.1<\bar{y}<5.7$	$5.0<\bar{y}<5.3$	$4.9<\bar{y}<5.1$	$4.7<\bar{y}<5.0$	$4.5<\bar{y}<4.9$	$4.3<\bar{y}<4.8$
1 Com width	5.8	6.0	6.2	6.4	6.6	6.9
95% C.I.	$5.6<\bar{y}<6.0$	$5.9<\bar{y}<6.2$	$6.1<\bar{y}<6.3$	$6.3<\bar{y}<6.5$	$6.5<\bar{y}<6.8$	$6.6<\bar{y}<7.1$
2 Com width	5.8	6.1	6.3	6.5	6.7	6.9
95% C.I.	$5.5<\bar{y}<6.1$	$5.9<\bar{y}<6.3$	$6.1<\bar{y}<6.4$	$6.3<\bar{y}<6.6$	$6.4<\bar{y}<6.9$	$6.6<\bar{y}<7.2$
3 Com width	5.3	5.7	5.9	6.2	6.5	6.8
95% C.I.	$4.7<\bar{y}<6.1$	$5.2<\bar{y}<6.2$	$5.6<\bar{y}<6.3$	$5.8<\bar{y}<6.6$	$6.0<\bar{y}<7.0$	$6.0<\bar{y}<7.6$

Table 4. — The 50th and 75th percentile benchmarks for mean lumber width (in in.) for dry, 4/4 thickness, red oak lumber measured at 14 rough mills.

Percentile	FAS	F1F	Selects	1 Common	2A Common	3A Common
50th	7.6	7.3	5.0	6.8	6.6	6.4
75th	7.7	7.6	5.3	7.2	7.1	7.1

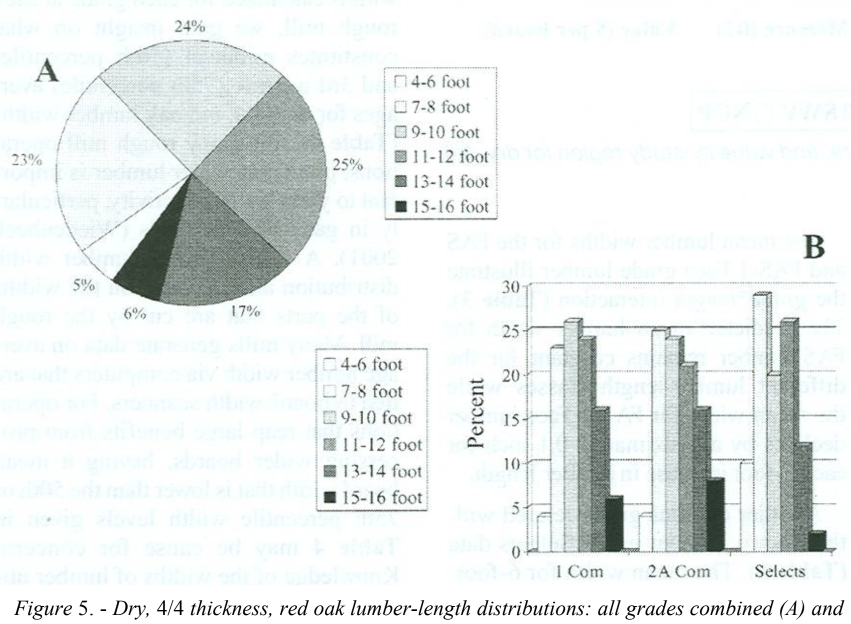

Figure 5. - Dry, 4/4 thickness, red oak lumber-length distributions: all grades combined (A) and 1 Common, 2A Common, and Selects compared (B).

50 percent of the board-surface measure were in the 1 Common grade (Table 5). Figure 3 substantiates the importance of 1 Common lumber in furniture and cabinet industry rough mills. It was the dominant lumber grade in the samples measured at 12 of the 14 mills. The 1 Common component of the input lumber mix ranged from 37 percent (mill 13) to 61 percent (mill 11). The largest 3A Common component (10%) was measured at mill number 5 (Fig. 3). The largest component of "uppers" (FAS, F] F, and Selects combined) was measured at mi1113 (54%).

The "average grade" for the three study regions was calculated using numeric codes that we assigned to the NHLA lumber grades: 1 = 3A Common; 2 = 2A Common; 3 = 1 Common; 4 = Selects; 5 = FAS 1-Face; and 6 = FAS. The average grade of the dry, 4/4, red oak lumber sampled in the NCP region was 3.4 vs. 3.1 in the SWV region and 3.2 in the WVA region (Fig. 4). Thus, the grades of the lumber that we sampled at the North Carolina rough mills tended to be higher than the grades of the lumber sampled in the Virginia and West Virginia mills.

When the price of kiln-dried, 4/4, red oak lumber (Weekly Hardwood Rev. 2001) was used to calculate values for the boards in our samples, there was an apparent difference in the value of the sample boards from the different regions (Fig. 4). The mean value for the 1,667 sample boards measured in the southernmost region, NCP, was $7.70/board. The mean value of the 1,227 sample boards measured in SWV was $7.22/board, and the mean value of the 1,109 sample boards measured in the WV A region was $7.24/board. The difference in mean board values is due to the observed difference in grade as the width differences between regions were not significantly different and the differences in average board length between regions were negligible. If real, such differences may be attributable to market pressures in the NCP region. The full run of boards cut from the southern red oak resource is thought to be somewhat lower in quality than lumber cut from red oak grown farther north. It is likely that some of the lumber suppliers to the North Carolina rough mills are from lower elevation (southern red oak) growing regions. Thus, the presence of higher quality lumber in NCP rough mills could indicate that these mills are purposefully buying more high-grade lumber to meet their furniture/cabinet part needs.

Distribution of lumber lengths

The overall lumber-length distribution of the boards that we sampled at the 14 rough mills was nearly equally represented by boards in the 7- to 8-foot, 9-to-10-foot, and 11 - to 12-foot nominal

Table 5. - Lumber grade distribution for 4/4, red oak lumber measured at 14 rough mills.

Grade	Count-based % of sample	Surface-measure-based % of sample
FAS	7.5	9.3
F1F	6.1	7.4
Selects	14.9	10.5
1 Common	49.0	50.1
2A Common	19.0	193
3A Common	3.5	3.4

Table 6. - Lumber distribution by grade, length (ft.), and width (in.) based on board count for 4/4, red oak lumber measured at 14 rough mills (in %).

		Lumber length (ft.)					
Grade	Width	4 to 6	7 to 8	9 to 10	11 to 12	13 to 14	15 to 16
	(in.)						
1 Common	<5	1.1	3.5	4.6	3.3	2.0	0.5
	5 to 6.75	23	11.3	11.4	11.1	6.9	2.8
	7 to 8.75	0.7	5.4	4.8	5.2	4.1	1.3
	9 to 10.75	0.2	1.8	3.2	2.9	2.0	0.8
	11 to 12.75	0.1	0.9	1.2	1.2	1.0	0.4
	13+	--	0.3	0.5	0.7	03	0.2
	No. of boards	84	453	504	479	324	118
2A Common	<5	2.1	3.3	4.2	2.6	0.9	0.5
	5 to 6.75	1.7	11.9	12.4	10.3	8.2	4.9
	7 to 8.75	0.4	5.4	5.0	4.7	4.0	1.2
	9 to 10.75	--	2.8	1.7	2.1	2.0	1.3
	11 to 12.75	--	0.9	0.5	1.2	1.1	03
	13+	0.1	0.6	0.5	0.9	0.1	0.1
	No. of boards	33	189	185	166	123	63
Selects	<5	2.7	9.7	10.5	11.2	4.2	1.0
	5 to 6.75	5.2	16.6	10.0	15.2	8.0	1.2
	7 to 8.75	1.7	1.7	--	--	--	--
	9 to 10.75	03	0.2	--	--	--	--
	11 to 12.75	--	--	--	--	--	--
	13+	0.3	0.2	--	--	--	--
	No. of boards	61	170	123	158	73	13
Uppers (FAS, F1F, & Sel)	<5	1.4	5.1	5.5	5.9	2.2	0.5
	5 to 6.75	2.7	11.7	93	14.5	8.3	2.5
	7 to 8.75	0.9	2.8	3.9	5.8	4.5	1.3
	9 to 10.75	0.2	1.7	1.6	2.4	1.3	0.8
	11 to 12.75	--	03	0.5	1.0	03	0.1
	13+	0.2	0.2	--	0.2	03	--
	No. of boards	61	249	238	342	195	59

length classes (Fig. 5). This is true both for the entire 4,003-board sample and for the 1 and 2A Common samples (comprised of 1,962 and 759 boards, respectively). By comparison, the length distribution of the sample of Selects boards was 10 percent short lumber (4 - to 6-foot nominal length; Fig. 5). An additional 29 percent of the Selects lumber sample was 7 to 8 feet long. Length distributions for FAS, F1F, and 3A Common lumber grades are not given because fewer than 500 boards were sampled in these grades. The odd-length lumber proportion is lower in all other grades than in Selects due to the relatively high percentage of 7-foot-long Selects boards (9% of Selects sample). For all grades combined, only 4 percent of the sample boards are 7 feet long (this includes the influence of the 598 Selects boards). The unusually high percentage of 7-foot-long Selects reflects the degree to which sawmills are sawing logs for Selects recovery and trimming lumber to raise the grade of the lumber. The FAS, F1F, and Selects red oak lumber grades are priced 25 to 35 percent higher than 1 Common lumber, so mills can trim 1 Common boards with end defects and excessive wane (usually by 1 to 2 feet) to obtain the higher grade, higher value board. Since 8-foot-long 1 Common lumber that is trimmed for grade is too short to make the FAS and F1F grades (which have minimum lengths of 8 feet), all of these boards end up as 7-foot-long Selects. Overall, odd-length boards (5-, 7-, 11-, 13-, and 15-foot nominal lengths) constitute 11.7 percent of the boards and 13.7 percent of the board surface measure in the full lumber sample. This percentage is higher than is found in the 1998 data bank for kiln-dried red oak lumber; the board-count-based odd-length lumber percentage in the data bank was only 8.5 percent (Gatchell et al. 1998). If this represents a real trend toward greater usage of odd lengths, then stacking and drying procedures and limitations on kiln capacity merit greater attention. The mean lumber lengths for the FAS and F1F lumber samples were 141 and 144 inches, respectively. These lengths are notably greater than those of the lumber in the other grade groups: Selects = 122 inches; 1 Common = 131 inches; 2A Common = 132 inches; 3A Common = 134 inches. An obvious contributor to this variance is that lumber shorter than 8 feet (96 inches) is not permitted in the FAS and FAS-1F grades. A less obvious contributor is that both the FAS and FAS-1F samples on average had a higher proportion of 13- to 14-foot-long lumber (5% to 6% more) than the other grades.

Lumber length and width sampling for different lumber grades

Figure 1 does not provide sufficient information with which to create an "industry standard" lumber sample for conducting ripping and cutting simulations. As noted earlier, since the analysis of covariance indicated that lumber width is influenced by grade, the length*grade interaction, and mill (nested within region), the most valid way of selecting a lumber sample for use in simulation is to sample the input lumber distribution at a mill or several mills of interest and create a study sample that reflects the measured distribution. However, researchers looking to address industry-wide questions need guidelines for sample selection. The distribution data in Table 6 can serve this purpose but should be used with the understanding that differences between mills can be significant.

Data for 3A Common is not given because the sample size, 138 boards, is too small to impart confidence in a length-by-width breakdown. The width-only breakdown (Table 1) can be used to create a 3A Common sample in the absence of better information on the size distribution of 3A Common lumber. For the same reason, FAS and FAS-1F are not cited independently but rather are compiled together with the Selects grade under the heading "Uppers" (Table 6). Since "Selects and Better" lumber is frequently specified and traded, this grouping should be useful for creating study samples that mimic industry practice. The difference between the Selects distribution of lumber sizes and the Uppers distribution again points out how short and narrow Selects lumber is when obtained from a supplier who also separates out FAS and FAS-1F into distinct lumber packages.

Researchers who use the 1998 data bank for kiln-dried red oak lumber (Gatchell et al. 1998) should note that the distributions of board sizes within the different lumber grades contained in the data bank differ substantially from the distributions measured in this study. Gatchell et al. indicated that the 1998 data bank likely contained more short boards and fewer narrow boards than are found in industry due to the sampling methods used. A comparison of the board-count-based distributions from Gatchell et al. (1998) and our study revealed the following differences:

- In the 1 C and 2AC grades, Gatchell et al's lumber-length distributions contain a distinctly higher percentage of boards (more than 10% variance) in the 4- to 6-foot length class than do our distributions.
- In the 1 C, 2AC, and Uppers grades, Gatchell et al.'s lumber-length distributions contain a significantly lower percentage of boards (more than 5% variance) in the 11- to 12-foot and 13- to 14-foot length classes than do our distributions.
- In the Uppers group, Gatchell et al.'s lumber-length distribution contain a distinctly higher percentage of boards (more than 10% variance) in the 15- to 16-foot class than the Uppers distribution in our study.
- For the 1 C, 2AC, and Uppers grades, Gatchell et al.'s lumber-width distributions contain a lower percentage of boards (more than 5% for 1 C and more than 10% for Uppers) in the narrowest width class «5 in.) than do the distributions in this study.

This study is thought to be the more representative sample of the size distribution of lumber processed by the furniture and cabinet industry. Lumber grade and size were measured at 14 rough mills with lumber from multiple lumber suppliers represented at each sampling site. Gatchell et al's. (1998) lumber sample was almost entirely from six lumber suppliers. An additional point to consider in judging the relative reliability of these samples is sample size. Both the Uppers and 2A Common samples from the Gatchell et al. study were of similar size to the samples in this study (Gatchell et al. had approximately 150 more boards in each), but the 1 Common lumber sample in our study has 924 more boards than the 1 Common data bank (1,962 versus 1,038 boards). Thus, our lumber size distributions should be adopted as the current guideline when conducting industry-wide rough mill studies on red oak lumber.

Summary and conclusions

The overall average width of the 4,003 4/4 thickness, kiln-dried, red oak boards sampled at 14 rough mills was 6.64 inches. Forty-seven percent of the boards had widths between 5.00 and 6.75 inches. Sixteen percent of the 4,003 boards were narrower than 5.00 inches while less than 6 percent of the boards were 11.00 inches or wider. Analysis of covariance indicates that lumber length, lumber grade, and mill (nested within region) have significant influences on lumber width. Multiple comparison testing indicates that three distinct grade groups can be isolated: FAS / F1F lumber widths> 1 Common / 2A Common / 3A Common lumber widths> Selects lumber widths.

The grade distribution of the red oak lumber that was utilized at the 14 study mills was heavily weighted toward 1 Common with 49 percent of the boards and 50 percent of the board surface measure falling in the 1 Common grade. The "average grades" for the three study regions (West Virginia, southern Virginia, North Carolina Piedmont) on a scale of 1 to 6 (1 = 3A Common; 6 = FAS) were 3.2, 3.1, and 3.4 with North Carolina rough mills having a higher average grade for 4/4, red oak lumber inputs.

The overall lumber length distribution of the boards sampled at the 14 rough mills in this study was almost equally represented by boards in the 7- to 8-foot, 9- to 10- foot, and 11- to 12- foot nominal length classes. This is true both for the full sample and for the 1 Common and 2A Common samples. By comparison, 10 percent of the Selects sample boards were short boards (4 to 6 feet in nominal length). Odd-length boards constituted 11.7 percent of the boards and 13.7 percent of the board surface measure for the total board sample. The mean lumber lengths for the FAS and F1F lumber samples were 141 and 144 inches, respectively. The mean lengths for the Selects, 1 Common, 2A Common, and 3A Common grades were notably shorter: 122 inches, 131 inches, 132 inches, and 134 inches, respectively. The influence of lumber grade and length on lumber width together with the variability in the grade of the lumber inputs measured at the 14 rough mills clearly indicates how important it is for secondary processors and their consultants to be aware of these differences when contemplating grade changes, supplier changes, processing changes, and product changes. Simulation and mill studies designed to assess the impact of potential system changes on productivity and profitability can be designed using the lumber size/grade attribute results given in this paper. Since lumber width varies from mill to mill, using mill-specific lumber size data will produce the most accurate study results.

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Discussion of the lumber width and grade distributions represented in the 1998 Data Bank for Kiln-dried Red Oak Lumber (Gatchell et al. 1998) is included in this paper because several users have sampled from the data bank as if the lumber distribution was a representative distribution. The 1998 Data Bank was never intended to be a representation of market availability and this is explicitly stated in the data bank publication. Instead, it is a collection of precisely graded kiln-dried, straight 4/4 red oak boards. It is the raw material for rough mill computer simulations using such tools as the ROMI series by Thomas. Data bank users are expected to provide their own length, width, and grade specifications. Please contact the Forestry Sciences Lab in Princeton, WV (phone: 304-431-2700) for copies of the data bank publication and actual board data.