United States
Department of
Agriculture

Forest Service

**Northeastern Forest
Experiment Station**

Research Paper
NE-563

1985

OPTIGRAMI: Optimum Lumber Grade Mix Program for Hardwood Dimension Parts

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Abstract

With rapidly increasing lumber prices and shortages of some grades and species, the furniture industry must find ways to use its hardwood lumber resource more efficiently. A computer program called OPTIGRAMI is designed to help managers determine the best lumber to use in producing furniture parts. OPTIGRAMI determines the least-cost grade mix of lumber required to produce a given cutting order of dimension parts. If the optimum grade mix is not available, the program can determine the best alternatives. It also can be useful in procurement and allocation planning. A description of the program and examples of its use are included.

Introduction

As mid-1984 arrived, lumber prices for No. 1 Common 4/4 plain-sawed northern red oak topped $600 per thousand board feet (M bf). The FAS grade, with premium, topped $950 per M bf. Cherry and tough ash were not far behind.

With spiraling lumber prices and shortages of some grades and species, the furniture industry must find ways to improve efficiency of lumber use. A computer program called OPTIGRAMI is a management tool that can do just that. With it you can determine the optimum, or least-cost, mix of lumber grades required to produce a given cutting order in a furniture rough mill; if this mix is not available, the next best mix can be determined. OPTIGRAMI also can be used in making decisions on improving lumber use practices.

In this paper, I discuss the OPTIGRAMI program and provide examples of how the program can be used to help solve day-to-day rough-mill decisions. Another report entitled "OPTIGRAMI Users' Manual" provides the users of OPTIGRAMI with step-by-step instructions for performing an analysis. It can be obtained from the Northeastern Forest Experiment Station's Forestry Sciences Laboratory, P.O. Box 152, Princeton, West Virginia 24740; or from the USDA Forest Service's Northeastern Area, State and Private Forestry, 370 Reed Road, Broomall, Pennsylvania 19008.

OPTIGRAMI

OPTIGRAMI is a computer program that was written for the person with little or no computer experience. Input to the program is straightforward and includes numerous prompts for the user's benefit.

Because the program is designed for use on any IBM mainframe computer with a mathematical programing system (MPS) in its program library, access can be through an on-site computer or through a remote terminal.

For users wishing to use a remote terminal, OPTIGRAMI has been placed on the Computerized Management Network (CMN), a national time-sharing computer service managed by the Virginia Cooperative Extension Service. The CMN software library consists of many problem-solving programs and resides on the computer at Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Access to CMN can be made with any ASCII terminal and a modem. You also can use a microcomputer with a communications program as a terminal. You can access CMN by dialing the computer directly and paying the long-distance charges on your monthly telephone bill.

Anyone can use CMN. Directions for obtaining a CMN userid and password are presented in the OPTIGRAMI Users' Manual.

For its data base OPTIGRAMI uses the predicted yields of dimension parts from standard grades of kiln-dried lumber developed at the USDA Forest Service's Forest Products Laboratory (Englerth and Schumann 1969). These yields were developed for hard maple, but they can be applied to most species graded by the same standard National Hardwood Lumber Association rules.

OPTIGRAMI uses linear programing techniques to correlate the input cost for each lumber grade with the predicted yields of various dimension part sizes to determine the least-cost combination of grades required to satisfy a given cutting order. The sensitivity of that combination to changes in the cost associated with each grade also is evaluated.

The OPTIGRAMI printout provides detailed information on production cost, yields by grade, and the size, number, and net board footage of cuttings obtainable from each grade.

The program is fast, simple to use, and inexpensive, usually costing less than $5 per analysis. It provides a quantitative basis for making decisions based on input information applicable to each specific situation.

Information Required

The only input information required is a description of what you want OPTIGRAMI to evaluate. In general, this consists of the cutting order to be evaluated; the grades of lumber you want considered and costs for each; and any conditions or limitations you may impose.

Cutting Order Information

Cutting order information typically includes some type of identification or furniture model number; the date and species for future reference; the thickness of lumber required; and the cutting order itself, which is a listing of the cuttings by length, width, type, and number required. Up to 50 different sizes of cuttings can be evaluated at one time. The yield tables accommodate lengths from 10 to 96 inches and specified widths up to 6 inches. A random-width description is used when the parts are to be glued into panels.

Lumber Grades and Costs

You can select up to three grades of lumber to be considered for possible inclusion in the least-cost mix. These can be picked from First and Seconds (FAS), Selects (SEL), No. 1 Common (No. 1 C), No. 2 Common (No. 2 C), or No. 1 Common and Better (No. 1 C and Better). The input cost for each grade, expressed in dollars per M bf, is the sum of all costs through the rough mill. Cost items to be included are at the discretion of the user but could include costs for lumber purchase, delivery, drying and handling, rough-mill cut-up, inventory, inspection, and overhead (Table 1).

Table 1.—Cost items to consider when determining production cost per lumber grade

Lumber grade	Purchase price	Delivery	Drying and handling	Cut-up	Inventory and storage	Overhead and other	Total
			Dollars/M bf				
2 C	292	20	100	80	8	70	570
1 C	588	20	100	50	10	75	835
FAS	768	20	100	40	12	80	1020

Volume Limitations and Yield Adjustments

The volume limitations and yield adjustments are simply options you can use to tailor the OPTIGRAMI analysis to fit your specific situation. You can limit the volume of a grade being considered by placing a volume constraint on that grade. The resulting OPTIGRAMI evaluation may or may not use all of the grade in limited supply; but in no case will the least-cost grade mix contain more of that grade than the volume allowed.

You also can adjust the predicted yields of any of the grades with a yield adjustment factor. Acting as multipliers, yield adjustment factors can be used to adapt the basic yields for individual species, admissible defects, heavy thicknesses of lumber, and general rough-mill efficiency.

What's the Best You Can Do?

The OPTIGRAMI printout consists of four sections: (1) the input information that you have evaluated; (2) the optimum of least-cost grade mix; (3) the range and sensitivity analysis; and (4) the cutting instructions to obtain the desired cuttings. The first three sections usually would be retained by the plant manager and filed for future reference. The last section would go to the rough-mill foreman for use in establishing the cutting instructions.

Input Information

The first section is strictly for reference purposes. It records the input information you have asked to be evaluated. Appendix I includes our cutting order identification, species, and date, and the grades we wanted evaluated, lumber cost, yield adjustment factor, volume constraints, and lumber thickness.

Next we have the cutting order that we have evaluated. The length, width, type, and number of pieces were input. The net board feet of each cutting was calculated by the program. The cutting bill does not need to be entered in any given order; the program will arrange it by type of cutting, whether random or specified, and by longest length first.

Least-Cost Grade Mix

The second section provides the least-cost grade mix solution (Appendix II). In addition to the cutting order identification, the printout shows which grades were being considered, the input cost for each grade, and the least-cost grade mix. The printout contains, for each lumber grade, the predicted lumber volumes required; each grade's contribution to the total production cost; the net board feet of cuttings; the percent yield; and the totals of these for the entire cutting order. In our example, the least-cost grade mix had a total cost of $14,538 and contained 7.268 M bf of No. 2C, 5.298 M bf of No. 1 C, and 5.855 M bf of FAS (Appendix II). For the conditions we have imposed, that is the best we can do. There is no other combination of grades that will result in a lower total cost.

Range and Sensitivity Analysis

The range and sensitivity section provides information on how responsive our optimum grade mix is to changes in the input cost of the various grades being considered (Appendix II). For decision purposes, it is probably the most important part of the OPTIGRAMI printout.

By varying the input cost of one grade while holding the others constant, OPTIGRAMI determines at what level of input cost there would be a change in how the grades are used to obtain the cuttings required. In essence, the program says that if the input cost of a given grade were to change to this new level, assuming that the cost of others remains the same, there would be another combination of volumes that would be as good as the least-cost grade mix we have now. In other words, at those input costs both volume combinations would have the same total cost. The program also calculates the amount of that grade that would be used in the alternative least-cost grade mix associated with that level of input cost.

Another way to consider these cost limits for a grade is that within the cost range between them, assuming that the cost of other grades remains constant, the least-cost grade mix will not change. True, the total cost will change depending on the level of input cost being considered; but the specific volumes of the grades given in the least-cost solution always will provide the lowest total cost for those conditions.

For example, consider the cost of No. 1 C in our range and sensitivity analysis (Appendix II). Although the input cost is $835.00 per M bf, it could range from a low of $834.23 to a high of $851.64 per M bf without changing the least-cost grade mix.

However, at an input cost of $834.23 per M bf, less than a dollar per M bf from our current cost, there would be another combination of grades with the same total cost, but it would use 10,281 board feet of No. 1 C. That is nearly twice as much as our current optimum mix.

In linear programing, the range values often are referred to as critical points, representing the intersection of two limiting constraints in the optimal solution. Consequently, they provide two equal solutions.

In our example, the alternate solution would use 4,983 board feet more No. 1 C. Since it must have the same total cost as the original grade mix, it stands to reason that it will use less of the other grades. Note that the associated volume for No. 2 C drops from 7,268 board feet to 5,785 board feet, and FAS drops from 5,855 board feet to 2,609 board feet.

By comparing the total cost for the two solutions, you can confirm their equality:

	No. 1 C		*No. 2 C*		*FAS*		*Total*
Current solution	($834.23 × 5.298)	+	($570 × 7.268)	+	($1020 × 5.855)	=	$14,535
Alternative solution	($834.23 × 10.281)	+	($570 × 5.785)	+	($1020 × 2.609)	=	$14,535

This particular cutting bill is sensitive to input price, especially that of No. 1 C. Information regarding the alternative grade mix can be of tremendous value to the rough-mill manager.

Cutting Information

The last section of the OPTIGRAMI printout is the cutting information for obtaining the required furniture parts from the proposed grade mix (Appendix III). This is the section that would be given to the rough-mill foreman. It provides the input volume of each grade according to the optimal grade mix, the part sizes that should be obtained from each grade, and the number of pieces that are expected from that volume of lumber.

This section also provides a value called "board feet shorts." In the case of No. 2 C, it shows 625 board feet, or the net board feet of volume that would be available in 10-inch-long, random-width cuttings. This value was included in the program to provide an indication of how well the resource is being used. In our example cutting order, the shortest length is 19-1/2 inches. Consequently, there would be substantial material available for 10-inch cuttings.

As you would expect, the longer pieces are from the better grades while the short pieces are from all grades. For our cutting order, all of the requirements for 87-3/4-inch, 80-3/8-inch, and 56-inch cuttings would be obtained from FAS, as would some of our shorter pieces.

The longest length to be obtained from No. 1 C would be 64-3/8 inches. However, the full requirement, 200 pieces, would be obtained from No. 1 C, as would the full requirement for the 48-1/4-inch random cuttings.

The requirements for the 33-1/8-inch cuttings were split between FAS and No. 1 C, and the 23-1/2-inch cuttings were split between No. 1 C and No. 2 C. The shortest two lengths would be obtained from all three grades. Information regarding specific lengths and number of pieces to be derived from each grade can have a major impact on improving yields from the raw material.

If You Can't Have Optimum, What Is Next Best?

Optimum is best, and we always would conduct as unconstrained OPTIGRAMI analysis as our first step. Because most furniture rough mills do not have unlimited supplies of every species, grade, and thickness, OPTIGRAMI is useful in helping the rough-mill manager allocate the available raw material most efficiently.

The key to determining the next best alternative for lumber allocation is the range and sensitivity analysis section. In general, when the upper or lower cost limit is near the current input cost and is accompanied by a major change in the associated gross volume, our least-cost solution would be considered sensitive. By contrast, if a major change in the input cost would result in a relatively minor change in the associated gross volume used in the alternative solution, our current solution would be considered relatively insensitive to the cost of that grade. Essentially, everyone would agree with these definitions of sensitivity at the extremes. However, between these extremes is a gray area of what is sensitive and what is not. Sensitivity is really a measure of what is of practical importance; it is at best a subjective judgment. As a result, changes in the total cost of our cutting order or in the volume of a grade of lumber used that seem important enough for us to take advantage of today might be considered a nuisance 6 months from now.

Use of the range and sensitivity analysis of OPTIGRAMI can be helpful in determining our next best alternatives when we have a limited supply of a grade, or are trying to conserve a grade that is in short supply, or have run out of a grade entirely.

Limited Supply of a Grade

With all of the different species, grades, and thicknesses required to operate a modern rough mill, occasionally there will be an insufficient supply of available dry lumber of a given grade and thickness needed for the least-cost grade mix. However, the fact remains that whatever other option we decide to take, the total cost will be greater than if we had the optimum mix of grades.

Certain types of cutting orders appear to have certain grades or grade mixes that are most appropriate for them. For instance, cutting orders for dining room chairs typically require a high proportion of No. 2 C in the least-cost mix. Buffets, on the other hand, call for mostly No. 1 C. An indication of the appropriateness of a given grade to a cutting order can be derived from the upper and lower cost limits in the range and sensitivity section. For example, if OPTIGRAMI has been used to evaluate a cutting order for dining chairs, the upper cost limit for No. 2 C might be $80 or $90 above the current input cost that was used. This would be interpreted to mean that if the cost of the other grades remains unchanged, the input cost level of No. 2 C could increase by $80 or $90 without changing the amount of the No. 2 C used in the least-cost solution. Therefore, No. 2 C would be considered well suited to this cutting order. In other words, this cutting order is insensitive to the cost changes of No. 2 C. It also means that if there is a shortage of No. 2 C, this would not be a good cutting order to be forced to substitute No. 1 C to fulfill the total lumber requirements.

Although OPTIGRAMI evaluates each cutting order individually, the printouts from these individual analyses can be helpful in making decisions that involve a number of cutting orders.

With this in mind, assume that we were evaluating the OPTIGRAMI solutions with unconstrained lumber volumes for three individual cutting orders that together required a total of 60 M bf of No. 2 C 4/4 pecan. From our inventory records we determined that only 40 M bf are available. Therefore, we must substitute some of our higher grades, probably No. 1 C, to complete the orders. Our problem becomes: Where can we substitute most effectively? By looking at the individual range and sensitivity analyses for No. 2 C, we note the following:

Cutting bill	*Input cost and levels*	*Associated gross volumes*
	Dollars/M bf	*M bf*
A	463.50	18
	410.00	20
B	497.25	28
	410.00	30
C	418.85	7
	410.00	10

Our logic would be as follows: On the basis of the upper limits shown, we might consider that No. 2 C could be worth as much as $497 per M bf to us relative to the costs of the other grades when it is being used in cutting order B. Consequently, cutting order B provides our highest value use of No. 2 C and should receive all of the No. 2 C it requires—30 M bf. In other words, B is the most insensitive to changes in the cost of No. 2 C and, therefore, least suited for substitution. Cutting order A would be next and should receive the remainder. However, since there is not enough No. 2 C to fulfill A's 20 M bf requirement, it should be reanalyzed by OPTIGRAMI but this time with a 10 M bf volume constraint on No. 2 C. OPTIGRAMI will then give the least-cost grade mix for A based on this limitation. Cutting order C is the most sensitive to the cost of No. 2 C, and OPTIGRAMI automatically would reduce the amount of No. 2 C used if the level of input cost increased by as much as $9 per M bf. Therefore, cutting order C should be reevaluated by OPTIGRAMI and not include No. 2 C in the grades to be evaluated. By using the 40 M bf of No. 2 C pecan in these combinations for the three individual cutting orders, our combined cost for all three will be at a minimum for the conditions that exist.

Conserving Grades in Short Supply

If a given grade and thickness of a species is expected to be in limited supply over a prolonged period, OPTIGRAMI can help determine ways to conserve it. In this case, each time an OPTIGRAMI evaluation indicates the use of this grade in the optimum mix, the range and sensitivity analysis should be examined for possible alternatives. If the analysis indicates that the optimum solution is sensitive (i.e., upper or lower cost limits are close to input cost), then that cutting order may be a good place to elect to substitute at least some of another grade and thereby conserve the one in short supply. By being sensitive, it points up the opportunity to be able to change the grade mix from optimum at a relatively small sacrifice in increased total cost. It is less costly in the long run to substitute some of another grade at each opportunity rather than to run out of a grade and then be forced to substitute in a cutting order that clearly is suited to the grade that is no longer available.

This is where sensitivity becomes subjective. How much are we willing to increase the total cost of a given cutting order to conserve a specific grade of lumber? In the case of our example cutting order, there would be little additional cost. As an example, suppose we wish to conserve No. 2 C. From the printout in Appendix II, we could determine that the next best grade mix would use 5.785 M bf of No. 2 C instead of 7.268 M bf. Since at the input cost of $572.59 per M bf both mixes would have the same total cost, we can determine that we could conserve 1,483 board feet of No. 2 C at a sacrifice of $3.84 in increased total cost. This is calculated by multiplying the change in input cost by the change in volume at the limit ([$572.59 − $570] × [7.268 − 5.785] = $3.84). Is it worth $4 to us to save 1,480 board feet of No. 2 C?

If it is, then we also might want to consider going beyond the limits of this OPTIGRAMI evaluation and rerun it with a constrained volume for No. 2 C below the current limit volume of 5.785 M bf. This would provide another alternative for saving the grade that we might wish to consider.

What Is Next Best if You Run Out of a Grade

When you are out of one of the grades contained in the least-cost mix, you should first rerun OPTIGRAMI, omitting this grade from those being considered, and then compare the total cost of the two evaluations. If the additional cost is not considered serious, then you have the next best solution.

If the additional cost is considered prohibitive, OPTIGRAMI can be used to help you evaluate other possibilities, such as purchasing additional dry lumber or purchasing some or all of the parts in the cutting bill.

Cutting Orders with Low Yields

When evaluating a cutting order, OPTIGRAMI also provides the expected percent yield of cuttings and the expected residual of 10-inch cuttings for each lumber grade in the least-cost mix and for the mix as a whole. These should be monitored closely.

Low percent yields or high amounts of short material indicate inefficient use of the raw material, which results in higher than normal costs. When this occurs, other alternatives should be considered to reduce these costs. First determine whether the low predicted yields are caused by an abnormal distribution of cutting sizes or by a small number of dimension sizes in the cutting bill; when this is determined, consider remedial alternatives.

How Can You Do Better in the Future?

By reviewing OPTIGRAMI printouts of the cutting orders for the last 3 months to 1 year, you can evaluate instances where other than optimum results were achieved. Then by recalling the prevailing circumstances, you can determine if these instances can be avoided in the future.

With OPTIGRAMI we can make management decisions regarding (1) the grades of lumber that should be purchased; (2) scheduling of lumber to be dried; (3) improving mill efficiency; (4) purchasing dimension parts; and (5) improving yields through changes in design or size requirements. Creative managers will discover additional ingenious applications for OPTIGRAMI in furniture and dimension operations.

Literature Cited

Englerth, George H.; Schumann, David R. *Charts for calculating dimension yields from hard maple lumber.* Res. Pap. FPL-118. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; 1969. 12 p.

Acknowledgments

We greatly appreciate the cooperation of members of the faculty of the School of Forest Resources, North Carolina State University, who provided guidance and technical support during this study. We also thank USDA Forest Service employees Daniel E. Dunmire III and Edward K. Pepke for their help in demonstrating the concept's validity in industrial situations through the Rough Mill Improvement Program; and Kenneth R. Whitenack for his programing efforts.

Appendix I

Input Information Section of OPTIGRAMI Printout

July 10, 1984—COUNTRY SQUIRE SUITE—HARD MAPLE[a]

LUMBER GRADE[b]	PRODUCTION COSTS[c] (Dollars/M bf)	GRADE YIELD ADJUSTMENT FACTOR[d]	VOLUME CONSTRAINTS[e] (M bf)	LUMBER THICKNESS[f] (Inches)
NUMBER 2 COMMON	570.00	100.0	None	4/4
NUMBER 1 COMMON	835.00	100.0	None	4/4
FIRST AND SECONDS	1020.00	100.0	None	4/4

INPUT CUTTING ORDER

CUTTING SIZE LENGTH (Inches)	CUTTING SIZE WIDTH (Inches)	TYPE OF CUTTING RANDOM (R) OR SPECIFIED (S)	NUMBER OF CUTTINGS	NET BOARD FEET OF CUTTINGS
48.250	20.000	R	360	2412.5
30.000	19.000	R	608	2406.7
87.750	2.250	S	406	556.7
80.375	2.250	S	200	251.2
64.375	2.250	S	200	201.2
56.000	3.250	S	1850	2338.2
33.125	4.125	S	844	800.9
28.250	3.000	S	130	76.5
23.500	4.000	S	1850	1207.6
22.750	2.250	S	300	106.6
21.000	4.250	S	550	340.9
19.500	2.750	S	470	175.0
Total			7768	10873.9

[a] Cutting order identification, species, and date.
[b] Standard lumber grades chosen to be evaluated.
[c] Total production cost per M bf assigned to each grade.
[d] Adjustment made to the yield of each grade.
[e] Volume constraints imposed on each grade.
[f] Lumber thickness being considered.

Appendix II

Least-Cost Grade Mix Solution and Range and Sensitivity Analysis

Information Sections of OPTIGRAMI Printout

LEAST-COST GRADE MIX SOLUTION

July 10, 1984—COUNTRY SQUIRE SUITE—HARD MAPLE[a]

SUMMARY BY GRADE

SELECTED GRADES[b]	INPUT COST/M bf[c] (Dollars)	GROSS VOLUME[d] (M bf)	TOTAL PRODUCTION COST[e] (Dollars)	BOARD FEET OF CUTTINGS[f]	PERCENT YIELD[g]
NUMBER 2 COMMON	570	7.268	4142	3541.4	48.7
NUMBER 1 COMMON	835	5.298	4424	3378.1	63.7
FIRST AND SECONDS	1020	5.855	5972	3954.5	67.5
TOTALS		18.421	14538	10873.9	59.0

RANGE AND SENSITIVITY ANALYSIS INFORMATION

SELECTED GRADES		INPUT COST AND LEVELS/M bf[h] (Dollars)	ASSOCIATED GROSS VOLUMES (M bf)[i]
	Upper	572.59	5.785
NUMBER 2 COMMON		570.00	7.268
	Lower	559.27	7.985
	Upper	851.64	4.947
NUMBER 1 COMMON		835.00	5.298
	Lower	834.23	10.281
	Upper	1021.18	2.609
FIRST AND SECONDS		1020.00	5.855
	Lower	1009.27	6.188

[a] Identifying name or title of the cutting order, species, and date.
[b] Standard lumber grades chosen to be evaluated by OPTIGRAMI.
[c] Total production cost per M bf assigned to each grade.
[d] Quantities of each grade contained in the least-cost grade mix.
[e] Total costs for the amount of each grade of lumber used in the least-cost mix.
[f] Quantity of cuttings expected from each grade.
[g] Anticipated percent yield to be obtained from each grade.
[h] Range of input costs for each grade.
[i] Volume of that grade used in the alternate least-cost grade mix at that level of input cost.

Appendix III

Optimum Solution Cutting Information Section of OPTIGRAMI Printout

OPTIMUM SOLUTION CUTTING INFORMATION

July 10, 1984—COUNTRY SQUIRE SUITE—HARD MAPLE

SELECTED GRADES	LUMBER THICKNESS	GROSS VOLUME	CUTTING SIZE[a] LENGTH	CUTTING SIZE[a] WIDTH	TYPE OF CUTTING	NUMBER OF CUTTINGS[b]	NET BOARD FEET[c]
	(Inches)	*(M bf)*	- - - - *(Inches)*	- - - -			
NUMBER 2 COMMON	4/4	7.268					
			30.000	19.000	R	608	2406.7
			28.250	3.000	S	130	76.5
			23.500	4.000	S	1117	729.2
			22.750	2.250	S	300	106.6
			21.000	4.250	S	172	106.4
			19.500	2.750	S	311	116.0
NET BOARD FEET/GRADE[d] = 3541.4							
BOARD FEET SHORTS[e] = 625.0							
NUMBER 1 COMMON		5.298					
			48.250	20.000	R	360	2412.5
			64.375	2.250	S	200	201.2
			33.125	4.125	S	202	191.8
			23.500	4.000	S	733	478.5
			21.000	4.250	S	91	56.4
			19.500	2.750	S	101	37.7
NET BOARD FEET/GRADE = 3378.1							
BOARD FEET SHORTS = 217.2							
FIRST AND SECONDS		5.855					
			87.750	2.250	S	406	556.7
			80.375	2.250	S	200	251.2
			56.000	3.250	S	1850	2338.2
			33.125	4.125	S	642	609.0
			21.000	4.250	S	287	178.1
			19.500	2.750	S	57	21.3
NET BOARD FEET/GRADE = 3954.5							
BOARD FEET SHORTS = 140.5							

TOTAL GROSS VOLUME (M bf)	TOTAL NET BOARD FEET	TOTAL SHORTS (bf)	TOTAL NUMBER OF PIECES
18.421	10873.9	982.8	7768

[a] Cuttings obtained from each grade in the least-cost solution.
[b] Expected number of each cutting to be obtained from each grade.
[c] Anticipated quantity of each cutting obtained from each grade.
[d] Total quantity of all cuttings expected from each grade.
[e] Cumulative unused net board footage of 10-inch-long cuttings available in each grade.

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.

Martens, David G.; Nevel, Jr., Robert L. **OPTIGRAMI: Optimum lumber grade mix program for hardwood dimension parts.** Res. Pap. NE-563. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1985. 10 p.

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ODC 836.1

Keywords: Furniture; hardwood dimension; lumber yields; dimension yields

☆U.S. GOVERNMENT PRINTING OFFICE: 1985-505-028:20025

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- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania, in cooperation with the Pennsylvania State University.
- Warren, Pennsylvania.