AN ANALYSIS OF THE OPERATING POLICY AND PROCEDURES OF A FIRM PRODUCING DOMESTIC WALNUT VENEER

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ABSTRACT

AN ANALYSIS OF THE OPERATING POLICY
AND PROCEDURES OF A FIRM PRODUCING
DOMESTIC WALNUT VENEER

by

Monte Ralph Harold

The nature of any firm which converts timber into solid wood commodity-type products is unique because quality and quantity yield of the raw material is not easily determined in advance, since quality and quantity-reducing characteristics are often hidden. Quantity is estimated by the use of log rules which may or may not prove accurate. Quality is generally estimated by the use of log grades which have proven satisfactory for production of some wood products - hardwood factory lumber is one successful application.

Great demand for walnut wood products accompanied by a concurrent shortage of walnut timber has set the price structure for this species at a very high level. An average price per thousand board feet has been reported as high as $1,367 for prime log 24 inches in diameter and larger. In contrast, the price for yellow-poplar, a non-decorative

species, is reported at $171 for equivalent quality level and unit volume of this material. These relatively high unit prices and the lack of adequate methods for quality determination present a most difficult raw material acquisition problem for domestic veneer producers.

Raw material acquisition problems facing domestic walnut veneer producers became apparent through personal contact with a specific firm. It became obvious there was a general lack of confidence by management and log buyers in their current log grading system. A decision was made to study this problem in depth by gathering and analyzing data and operational information from this walnut veneer-producing firm.

The objective was to critically analyze the purchasing, processing and marketing system within this firm. The purpose was to search for methods by which improved efficiency of the system would result. A second objective was to test the use of modern analytical procedures and statistical methods in an effort to predict the unit value of resulting veneer from the exterior characteristics of the log.

The approach was to carefully select the study material over a range of physical sizes, quality levels and geographical ranges; collect the necessary raw material, conversion process and final product data; convert the data to useable form; develop a statistically sound predictive model; analyze the results and state the conclusions.

Two multivariate statistical methods, multiple regression and discriminant function analysis, were used in an effort to develop a predictive mathematical model. The ability of the regression model to account for only 13 percent of the variability of unit veneer price is considered to be of little consequence. Model improvement techniques also failed to significantly improve the model. Inability to develop a significant equation for distinquishing between grade classification by discriminant function was interpreted as failure of this method to solve the problem.

Conclusions of why these efforts failed fall into two general classes: (1) marketing system limitations, (2) buying system limitations.

The absence of objective grading rules for walnut veneer may be a major marketing system limitation. If product quality can not be stated in quantified terms, quality yield may vary over time and between output measurement units without being recognized. This standardization is a prerequisite to developing and maintaining a predictive output value model based on standardized input information.

It was concluded that inexperience may have resulted in several marketing weaknesses. Evidence was presented that veneer may be underpriced, especially the higher quality levels. The veneer price range for the firm was 1.0 to 8.0 cents per square foot; while the competitor firm price range was from 3.0 to 60.0 cents.

The firm has identified few specialized veneer markets; lacks the experience to identify these veneers; and fails to hold uniquely figured flitches in inventory to meet market opportunities. The export of walnut veneer to Europe is one of the markets to which the firm could respond, for high prices paid for export logs has been a factor in the competitive nature of log buying.

Certain buying system improvements warrant consideration. They are: (1) more thorough training of log buyers, (2) developing an incentive plan based on profits from logs purchased by the individual log buyers.

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CHAPTER I

INTRODUCTION

Black Walnut (*Juglans nigra* L.) is unquestionably our finest domestic hardwood. From the time the earliest settlers found it in huge trees up to six feet in diameter and 150 feet tall, walnut has served man in a myriad of uses because of its superior characteristics. The pioneer found the clear wood easily split and very durable, hence he used it for split rail fences as well as cabin logs and later as trim and paneling for his fine homes.

Walnut has been the primary wood for gunstocks from the time of the famous long rifle through World War II because of its strength, shock resistance, hardness, and ability to stay in place. Today the major uses for walnut are for all forms of household and office furniture, novelties, and decorative wall paneling.

The use trend of walnut timber has been expanding and changing since 1933. The volume of walnut wood used for all products ranged from a low of 28 million board feet in

1933 to 94 million board feet[1] in 1960. Sawmills, veneer mills, and log exporters purchase walnut timber, but until 1960 at least 75 percent of all walnut logs cut were manufactured into lumber. However, the volume of walnut wood used in domestic veneer manufacture has doubled in recent years. In 1963, domestic veneer mills used approximately 32 million board feet, international 1/4-inch log rule (1).

Walnut logs, bolts and hewn timbers are being exported in increasing quantities. Only 15 years ago less than a million board feet were exported annually. By 1963, exports had grown to more than 16 million board feet. A decrease to 11.2 million in exports in 1964 was the result of a quota placed in effect on February 14, 1964. The control on exports was removed in February 1965, and that year 23.6 million board feet were exported. Exports for the year 1970, the last year of available figures, were 17.4 million board feet (1).

This high demand accompanied by a concurrent shortage of walnut timber has set the price structure for this species at a very high level. An average price per thousand board feet, Doyle Log Scale, has been reported as high

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[1]A board foot is a volume of wood equal to a board one inch thick 12 inches square.

as $1,367 for prime veneer logs 24 inches in diameter and larger. In contrast, the price for yellow-poplar (Liriodendron tulipifera L.), a nondecorative species, is reported at $171 for the same class and unit volume of material (2). These relatively high unit prices and the lack of adequate methods for quality determination present a most difficult raw material acquisition problem for domestic veneer producers.

CHAPTER II

THE TIMBER QUALITY CLASSIFICATION PROBLEM

A. The General Problem

An industry that processes raw material such as mineral ore, basic chemicals or agricultural crops must have basic yield information on the quality and quantity of their specific raw material before purchase and manufacture to make a reliable estimate of the cost of the products to be produced. Success depends in part on a thorough knowledge of the raw material being used.

The nature of any firm which converts timber into solid wood commodity-type products is unique because quality and quantity yield of the raw material - the log - are not easily determined in advance, since quality and quantity-reducing defects are often hidden. Unless the output of a sawmill is all 1-inch lumber, the conventional log rules may not provide adequate estimates of product volume. For example, the Doyle Log Rule, because of blunders in its original construction, scales only logs near 26 inches in diameter correctly (3).

Classification of timber by quality requires log grading rules, which should be designed to provide (4):

1. A reasonably accurate estimate of the quantity and value of product output.

2. A basis for sorting trees or logs to make a particular product or products.

3. Significant differences in value or product yield between grades.

4. Grade specifications that are easily understood and applied.

5. Specifications that define the poorest log or tree that may be admitted in the system.

6. Yield data that are based on representative conversion systems.

7. Grades that will have wide application for a tree species throughout its commercial range.

8. Grades that are stable over time.

Currently there are a number of grading systems used to determine log quality. These grading rules include: the Purdue Hardwood Log Grades, the Ohio Standard Saw Log Grades, and the U.S. Forest Products Laboratory's Hardwood Log Grades for Standard Lumber. Figure 1 illustrates a typical log-grading specification adapted from the U.S. Forest Service, "Hardwood Log Grades for Standard Lumber" (5). In addition, many companies have modified one of the above rules or have developed their own quality classes.

Figure 1. Forest Service standard specifications for hardwood factory lumber logs. Source: (5)

Grading Factors		Log Grades							
		F1			F2				F3
Position in tree		Butts only	Butts & uppers		Butts & uppers				Butts & uppers
Diameter, scaling, inches		[1]13-15	16-19	20+	[2]11	12+			8+
Length without trim, feet		10+			10+	8-9	10-11	12+	8+
Clear cutting[3] on each 3 best faces	Length, min., ft.	7	5	3	3	3	3	3	2
	Number, maximum	2	2	2	2	2	2	3	No limit
	Fraction of log length required in clear cutting	5/6	5/6	5/6	2/3	3/4	2/3	2/3	1/2
Sweep and crook allowance (maximum) in percent gross volume	For logs with less than 1/4 of end in sound defects	15%			30%				50%
	For logs with more than 1/4 of end in sound defects	10%			20%				35%
Total scaling deduction including sweep and crook		[4]40%			[5]50%				50%

[1] Ash and basswood butts can be 12 inches if otherwise meeting requirements for small No. 1's.
[2] Ten-inch logs of all species can be No. 2 if otherwise meeting requirements for small No. 1's.
[3] A clear cutting is a portion of a face free of defects, extending the width of the face.
[4] Otherwise No. 1 logs with 41-60% deductions can be No. 2.
[5] Otherwise No. 2 logs with 51-60% deductions can be No. 3.

These rules vary widely as to number of quality classes, quality factors considered, diameter limitations of classes, and the percentage of clear log area specified. In general, great emphasis is placed on diameter limits and the clear area of the log surface expressed as a percentage of the total surface area. The number of faces considered for the percentage clear specifications also varies between grading rules. Some specify consideration of only three faces of the log, while others specify four faces. Another important consideration for domestic veneer and lumber logs is that most grading systems require the complete log be assigned one grade. This aspect will require some analysis later in this study, for each half-log is considered a separate processing entity in the system under analysis.

Newport, et al. (6) report that in an evaluation of more than 50 known grading systems, with possibly one or two exceptions, all of the systems examined had serious shortcomings. Many of these shortcomings stem from the fact that the grading specifications were determined rather arbitrarily on the basis of estimates of what logs with certain characteristics could yield in a given product. Many of these specifications rely too heavily on the grader's judgement. Performance data may be lacking or sometimes nonexistent.

It should be pointed out that many of these current grading systems have some desirable features and sound specifications. The "Hardwood Log Grades for Standard Lumber" of Figure 1 is well accepted by many as an excellent system. The specifications for these grades are correlated closely with the specifications for standard hardwood lumber grades. Hardwood factory lumber is graded on the basis of clear-faced or sound cuttings of a minimum size to comprise a certain fraction of the area of the board. To apply these log grades the log is divided into four faces. Each face is graded as though it were a board, except that rip cuttings and sound cuttings are not allowed. The face must furnish clear cuttings of a definite minimum size to comprise a specified fraction of the face. It has also been determined that the most accurate results were obtained by using only the three best log faces.

This direct correlation of the standard log grades with well defined standards or grades of lumber as a measure of product yield is important. Not only must the final product specification be deterministic and easily communicated, the end product must have specific market values. The hardwood log grading system for standard lumber meets these requirements.

In contrast to the generally well defined hardwood lumber grading rules existing hardwood veneer grading rules are not specific and leave much to the judgement of the grader. Table 1 is an example of a plain-sliced walnut veneer grading specification. These grades do not specify the number and size of defects allowed in the various grades. Hardwood veneer grading systems vary with the individual plant, the grader and plant procedures. Such systems may not have the consistent relationships nor express a specific market value. Value of the specific grade may vary between markets and over time. Precise specification of product yield in the development of veneer-log grades may be a definite limitation.

The U.S. Forest Service has developed interim veneer-log specifications to aid in timber sale appraisal work (5). To quote M. D. Ostrander:

> These specifications are based on limited information of factors influencing veneer-log quality... They should not be considered final but are intended merely to bridge the gap between the present and such time as studies are completed to supply the data for developing Forest Service standard veneer-log grades and accompanying veneer-grade yield tables.

B. Veneer Log Evaluation

A graphic analysis of the wood quality-log cost assessment problem is presented in Figure 2. The required

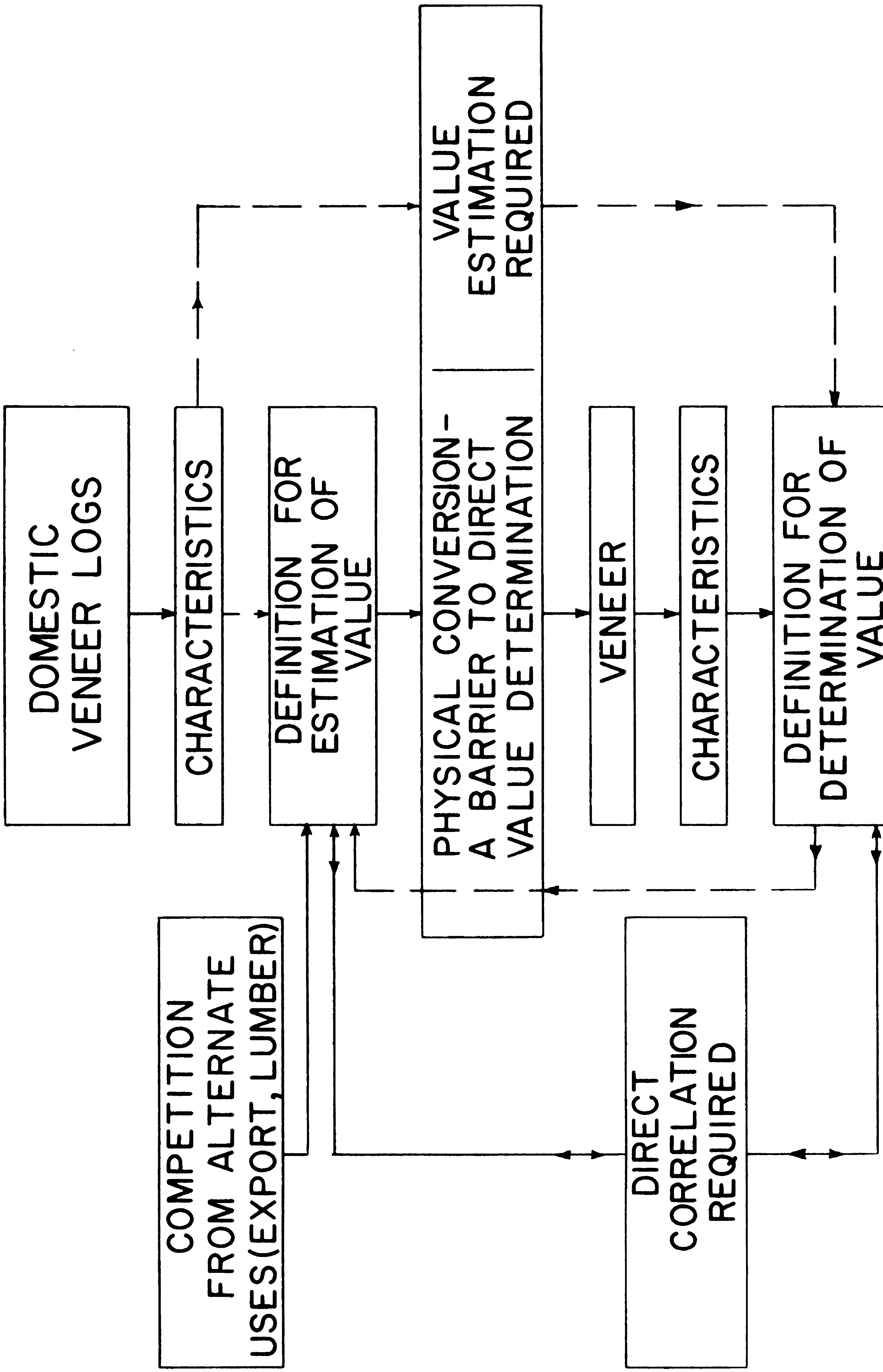
Table 1. Summary of veneer characteristics and defects of premium grade and good grade plain sliced walnut veneer. Source: (7)

Characteristics	Premium	Good
Sapwood	10%	20%
Heartwood	Yes	Yes
Color streaks or spots	Slight	Slight
Color variation	Yes	Yes
Mineral streaks	Slight	Yes
Small burls	Yes	Yes
Pin knots	Occasional	Yes
Knots (other than pin knots)	No	Sound
Worm holes	No	No
Open splits or joints	No	No
Shake or doze	No	No
Rough cut	No	No
Cross bars	No	No
Inconspicuous patches	Small	Yes
Type of matching	a	b

a - Book matched. Matched for color or grain at the joints (can be slip matched if customer specifies)

b - Sharp contrast will not be permitted.

Figure 2. Wood quality and the log cost assessment problem.


DOMESTIC VENEER LOGS
CHARACTERISTICS
DEFINITION FOR ESTIMATION OF VALUE
PHYSICAL CONVERSION- A BARRIER TO DIRECT VALUE DETERMINATION
VALUE ESTIMATION REQUIRED
VENEER
CHARACTERISTICS
DEFINITION FOR DETERMINATION OF VALUE
COMPETITION FROM ALTERNATE USES(EXPORT, LUMBER)
DIRECT CORRELATION REQUIRED

correlation is between log cost and the value of the veneer produced from the logs. However, real value of the material is determined only after the conversion process. Therefore, any value or cost assignment of the logs must be an estimate based on the correlation between physical characteristics of the log and the physical characteristics used to determine the value of the resulting veneer. This is illustrated by the circuitous route of value determination (the broken line) in Figure 2. Impinging upon this evaluation is competition from alternate use of the raw material. In this case it would be export for conversion to veneer or domestic conversion to lumber.

Some illustrations of the effects log surface defects or characteristics have on resultant wood quality will aid in understanding the approach taken in this study. A knot and adventitious bud cluster are pictured as they appear on the surface of a walnut log in Figure 3. How these defect indicators affect the resulting veneer is illustrated in the photograph of the veneer produced from this section of the log is shown in Figure 4. These characteristics reduce the utility of the veneer for certain high quality products.

The small holes in the bark of the log shown in Figure 5 are caused by a class of birds called sap-suckers. They

Figure 3. Adventitious bud cluster and knot as defect indicators on a log surface.

Figure 4. Adventitious bud cluster and knot defects in walnut veneer.

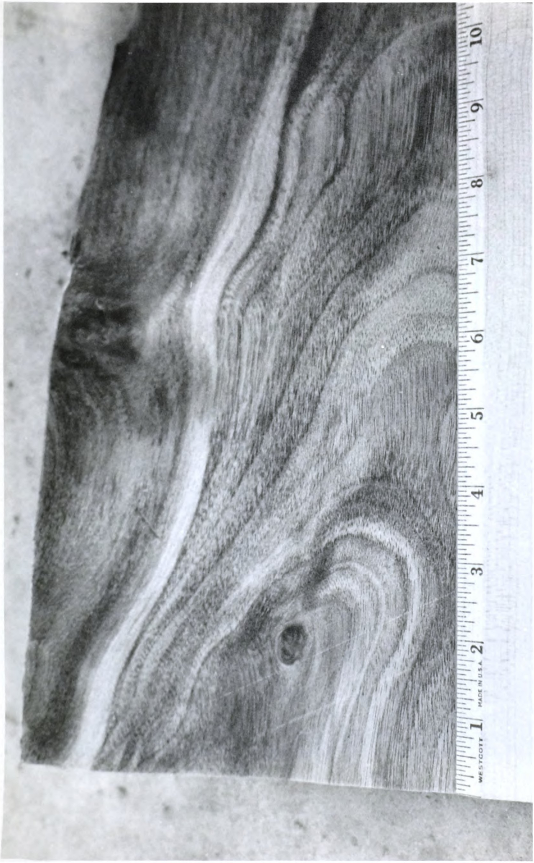

WESTCOTT
MADE IN U.S.A.

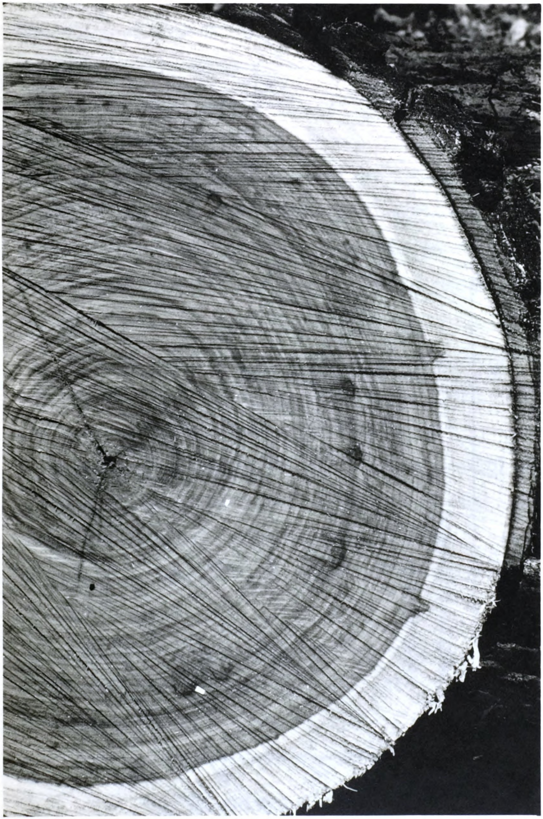
Figure 5. Bird peck holes in log bark surface.

feed on the inner bark, cambium and sap of living trees. Many of these holes result in damage to the wood caused by pathological stain entering the tree at this point. The appearance of this defect, termed bird peck in this study, on the end of the log is shown in Figure 6.

A consideration in the determination of wood quality is that we are dealing with biological material that is heterogeneous. Normally logs and trees vary significantly in their physical, mechanical and chemical properties. This variation is obviously reflected in product yields and value. Figure 7 illustrates the variation in value experienced in a stratified sample of log data gathered for this study. There are two important points evident in this data. First, the range in price of veneer from the same grade of log ranges from two cents per square foot to a high of six and one-half cents. Second, although unit values of timber products normally increase with an increase in diameter class, the only trend evident in this data is almost uniform average value over the range of diameter classes. Consequently, data behavior such as this only complicates problem analysis.

What may be needed is a store of fundamental information provided by research such as the recent work by

Figure 6. Bird peck as color distortion on the end of a log.



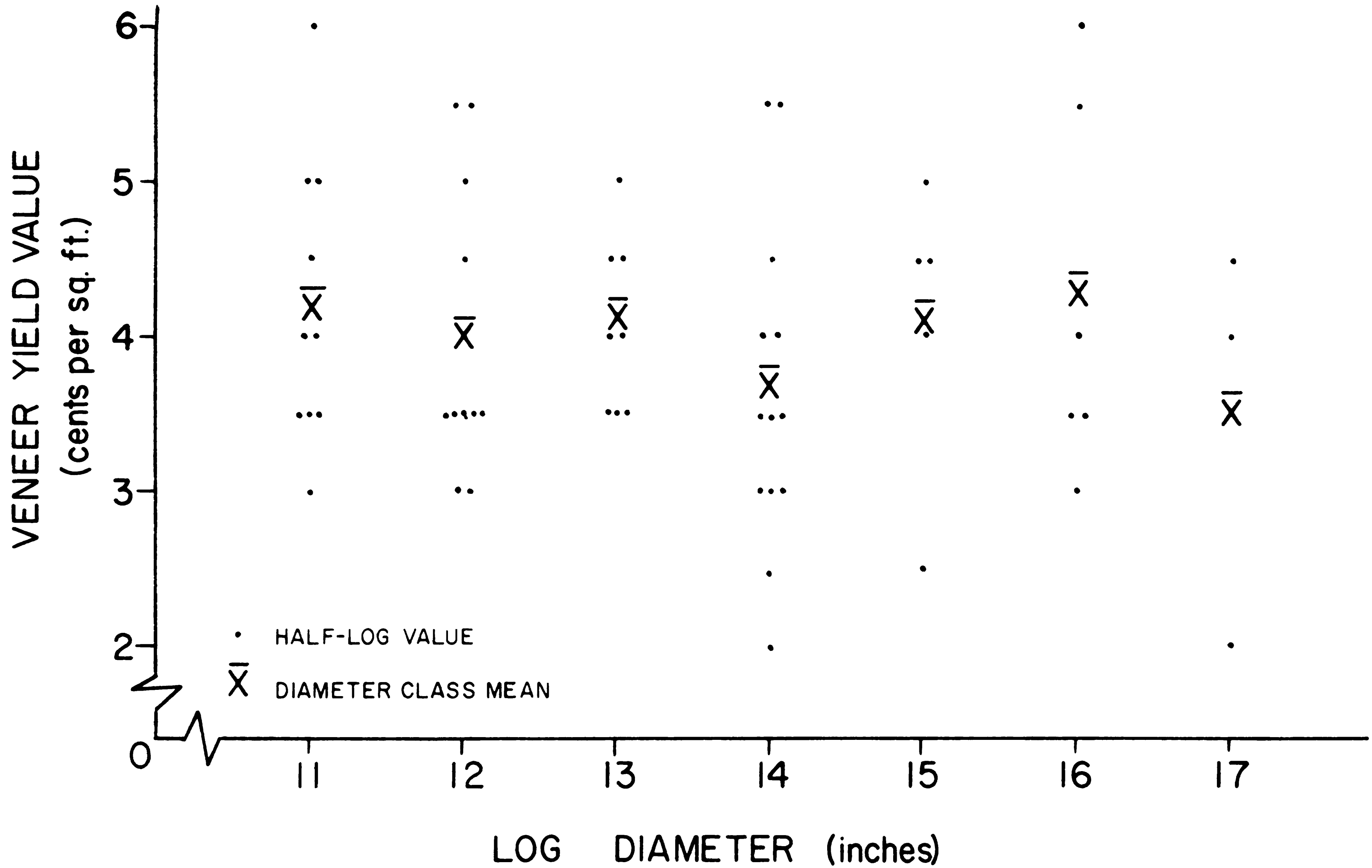


Figure 7. Veneer yield value as a function of log diameter for a stratified log quality sample.

Stayton, C. L. et al. (8). They have developed precise knowledge of the relationship between tree surface abnormalities and their associated interior defects. To learn more about this variation for sugar maple (Acer saccharum, Marsh.), they determined the percentage of each type of exterior defect indicator that had an associated interior defect, and observed how this percentage varied with the size of the indicator, its height above the stumps, tree diameter, tree age, and tree growth rate.

This and other relations such as the correlation of diameter to quality illustrate some of the complexities of identifying and evaluating quality in logs and trees. Diameter is interrelated with other characteristics such as tree age and growth rate, and the effect of these relationships on quality has not been well established. Log length is another attribute of size that has been shown to affect quality.

Lane (9) has stated the need for devising more adequate statistical techniques for developing and testing the performance of grading systems. Particularly needed, are electronic computer programs for machine processing of timber quality data. Gaines (10, 11) indicates that the real challenge in log and tree quality work is the development of more complete models. We need better expressions of the relations between log-surface characteristics and product yields, and between production-process activities and product yield.

In addition to the fact that quality and quantity yields of the raw material are not easily determined, the value added by the primary wood conversion process is low, hence, raw material cost is a high percentage of total cost. The inherent nature of such processes allows for little margin of error. If poor buying decisions are made there is little chance of recouping the loss in the conversion process.

CHAPTER III

THE DOMESTIC VENEER LOG GRADING PROBLEM

A. Study Firm

The raw material acquisition problems facing domestic walnut veneer producers became apparent through personal contact with a specific firm. It became obvious there was a general lack of confidence by management and log buyers in their current domestic log grading system. It was decided to study this problem in depth by gathering and analyzing data and operational information from this walnut veneer-producing firm, subsequently referred to as the "study firm".

This firm, located in north central Kentucky, has been purchasing exclusively walnut logs for its sawmill and veneer-log export operations for many years. In addition to lumber, the sawmill has produced half-log flitches, the basic form of raw material for sale to domestic walnut veneer producers. In an effort to grow and diversify, a veneer mill became operational about two years before this study was initiated.

The conversion process and material handling system are efficient by current production standards. The actual process is described in chapter four of this study. Annual production is about 20 million square feet of sliced veneer and is equivalent to a sales volume of about one million dollars annually.

One unique feature of the operation is the data processing system. Each individual log is identified from the time it is purchased in the field until it is sold as veneer. This system greatly facilitated the gathering and compilation of the study data. In addition, this data processing system serves as an efficient information system for management. Log buying efficiency can be assessed by individual buyer and by groups of logs. Log value can be assessed by geographical area of origin. Most important, log grade specifications can be tested for their ability to properly differentiate quality levels (value) of resultant products.

1. General Quality Levels

Currently the study firm, and other firms in the industry, believe that profit from purchasing and processing walnut logs can be maximized by segregating logs into three distinct quality levels. Premium quality logs, the very choice, as illustrated in Figure 8, are exported to Europe

Figure 8. Premium quality walnut logs such as this are exported to Europe for furniture veneer production.

for conversion into veneer for furniture manufacture. Medium quality logs are processed in this country, generally into flat-sliced veneer for furniture and wall paneling products. An example of this quality level of material is shown in Figure 9. Logs judged not capable of being processed profitably into veneer are sawn into lumber. This lowest quality class of logs is illustrated in Figure 10.

These three general quality levels can be compared to the three broad log-use classes outlined by the United States Forest Service in their approach to hardwood log grading. They each cover current utilization practices. The Forest Service's division by use is as follows: (1) factory class, the three grades as described in Figure 1, (2) construction class, an ungraded category intended to be used for structural purposes, (3) local-use class, those suitable for products not usually covered by standard product specifications.

2. Domestic Veneer Log Grades

The normal procedure for a sawmill buying woods-run logs of a species other than walnut, and using the Forest Services log grades would be to have four grade sorts: factory log grades, one, two, three, and a local-use or industrial grade. If veneer logs were sold, they would be

Figure 9. Medium quality logs as illustrated here are processed domestically into flat-sliced veneer.

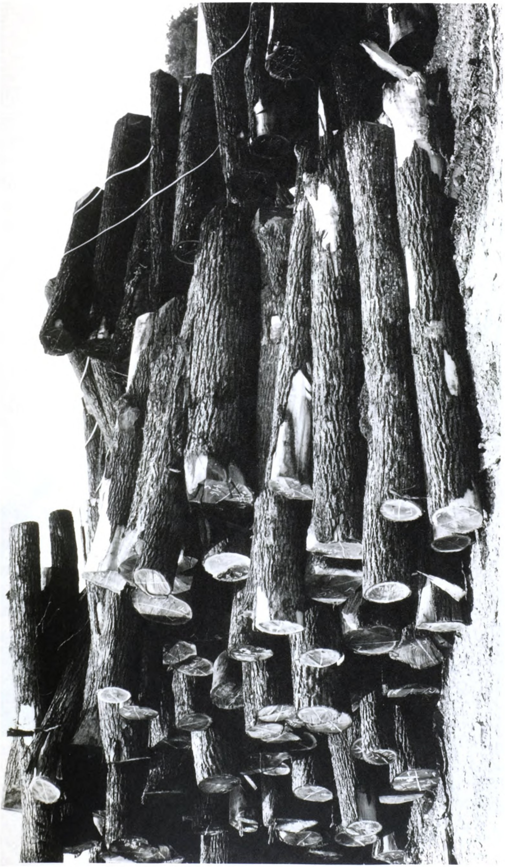


Figure 10. Lower quality walnut logs such as these are sawn into lumber.

withdrawn from factory grades one and two. This procedure is somewhat different than the operating procedure of the study firm. They have taken woods-run logs and divided them into three general quality levels previously described. These general quality levels have been further divided as follows:

1. Export veneer logs-grades 1 thru 6
2. Domestic veneer logs-grades A, B, C, D, E and F
3. Domestic lumber logs-grades L1 thru L4

The grade description and instructions for use of the domestic veneer logs are presented in Figure 11.

Not only are these grade rules complex, they are changed from time to time without verification from deterministic yield data. Information such as that contained in Figure 7 illustrates that the application of these quality level specifications by log buyers in the field does not enable them to satisfactorily separate logs into quality levels to which distinct average end-product values can be assigned. This ability is required to allow buyers to determine what maximum price can be paid for a given quality of logs and still allow the firm to make a reasonable profit with a minimum of risk. This is one of the basic problems facing the firm and one to which this study has been directed.

Figure 11. Domestic walnut veneer log grade rules.

Instructions: Divide veneer logs into two faces corresponding to flitching line. Measure off all unsound defects and double heart before determining length, diameter and grade. Measure diameter inside the bark at the smallest circumference (not at swell where tree has started to fork or branch). Drop second cut logs one grade, as grades are for butt logs only. Do not cut back log length on tally for purpose of raising diameter - logs must be bucked.

A Fresh cut, woods grown, and judged practically free of pin knots. 9' to 16' in length (normally 13' maximum). Diameters 16" and Up, except allowing 15" logs with 13" of sapwood. Measured diameter must be 90% heartwood. Logs containing 81' to 134' must be free of all defects; 135' and Up must yield 95% in two cuttings. Requires excellent color and conformation, no worms. Minimum cutting length is 8'.

B Fresh cut, woods grown, judged reasonably free of pin knots. 8'-6" to 16' (normally, 13' maximum). Diameters 15" and Up, except will allow 14" log with 12 1/2" of heartwood if 9' or longer. Measured diameter must be 85% heartwood. Logs 60' to 80' must be free of defects; 81' to 105' must yield 95% in two cuts; 106' and Up, 90% in two cuts or 95% in three cuts. Requires very good color and no signs of worms or peck. If logs shorter than 8'-6", drop to C. Minimum cutting is 5'.

C Logs 6' to 16', 14" and Up, except 6' & 7' logs must be at least 15". 80% of measured diameter must be heartwood. 45' to 59', free of defects; 60' to 80', 95% in two cuts; 81' to 105', 90% in two cuts or 95% in three cuts; 106' and Up, 85% in two cuts or 90% in not over four cuts. Good color, minor signs of worms allowed only if logs 100% clear, 9' - 13' in length. Allow no more than 20% 6' and 7' logs in any purchase, dropping balance to grade D. Clear logs, good color, no worms, 9' to 13', 14" and larger, having metal in one face, may be graded C, with measurement cut in half. Minimum cutting 5'.

D Same as C, except admits 45' to 59' yielding 90% in two cuts; 60' to 105' yielding 75% in two cuts, 106' and Up yielding 75% in not over four cuts. Drop excess (over 20%) 6' and 7' logs one grade.

E Same as C, except admits 45' to 105' yielding 50% in one cut; 106' and Up yielding 50% in not over four cuts. Excess over 20% 6' & 7' logs to be placed in appropriate lumber grade.

F Butts only, 9' to 13', 12" and 13", thin sapped, quality and conformation equivalent to Grade A.

Table 2 illustrates the results of the application of the six log grades described in Figure 11 for an operating period of one month. Adjusted gross income, line one, is the total sales value of the resulting veneer per thousand board feet(MBF) Doyle Log Scale less all costs except direct log costs associated with each log grade. Quality level for these grades would generally be expected to decrease from left to right. The actual values, however, indicate that the top three grades (A, B, F) yield veneer priced at nearly the same level. The lower three grades (C, D, E), while somewhat more variable, yield veneer of a distinctly lower level of value.

Log cost, line two, reflects the general trend of assumed value level of log grades. These costs reflect the competitive situation of various buyers and quality aspects of geographic area of purchase. Net pre-tax profit, line three, is the profit or loss in dollars resulting from purchases of individual log grades for the month. The range in pre-tax profit is extreme. It varies from a loss of $285 per MBF for grade A logs to a profit of $397 for grade F logs. Twenty percent of gross income has been set by the firm as a net pre-tax profit goal. The variance in dollars from the stated profit goal by log grade appears on line five.

Table 2. Monthly profit variance report for domestic veneer log grades (Dollars per 1000 board feet Doyle Log Scale)

Item		FIRM DOMESTIC WALNUT VENEER LOG GRADES						
	Line	A	B	F	C	D	E	Average
Adjusted Gross Income	1	1131	1204	1272	659	879	703	863
Log Cost	2	1414	1375	875	837	588	593	777
Net Pre-tax Profit	3	-285	-171	397	-179	291	110	86
Net Pre-tax Profit goal (20% Gross Profit)	4	226	241	254	132	176	141	173
Variance (line 3 less line 4)	5	-511	-412	+143	-311	+115	-31	-87
Portion of profit goal attained (percent)	6	-226%	-171%	+156%	-236%	+165%	-077%	-050%

The portion of profit goal attained, line six, is the net pre-tax profit goal expressed as a percentage. This ratio is used as a management tool to measure the effectiveness of the log purchasing system. An analysis of the ratio and the cost-value variance leads one to pose such questions as, "Why is it necessary to pay unprofitably high prices for log grades A, B and C while grades F, D and E are more in line with company objectives"? These results, which are typical, reflect a very inefficient grading system, in fact, money and effort spend on such a system may well be wasted. This and other questions leads us to the objective of this study.

B. Objective

The objective is to critically analyze the domestic walnut veneer-log purchasing, flat-sliced processing and veneer marketing system within a single producing firm. The purpose is to search for methods by which improved efficiency of the system may result. A second objective is to test the use of modern analytical procedures and statistical methods in an effort to predict the unit value of resulting veneer from the exterior characteristic of the log. Any results which would increase the efficiency of this log-purchasing system or the system in general would be a significant contribution to this important phase of forest products marketing and production.

CHAPTER IV

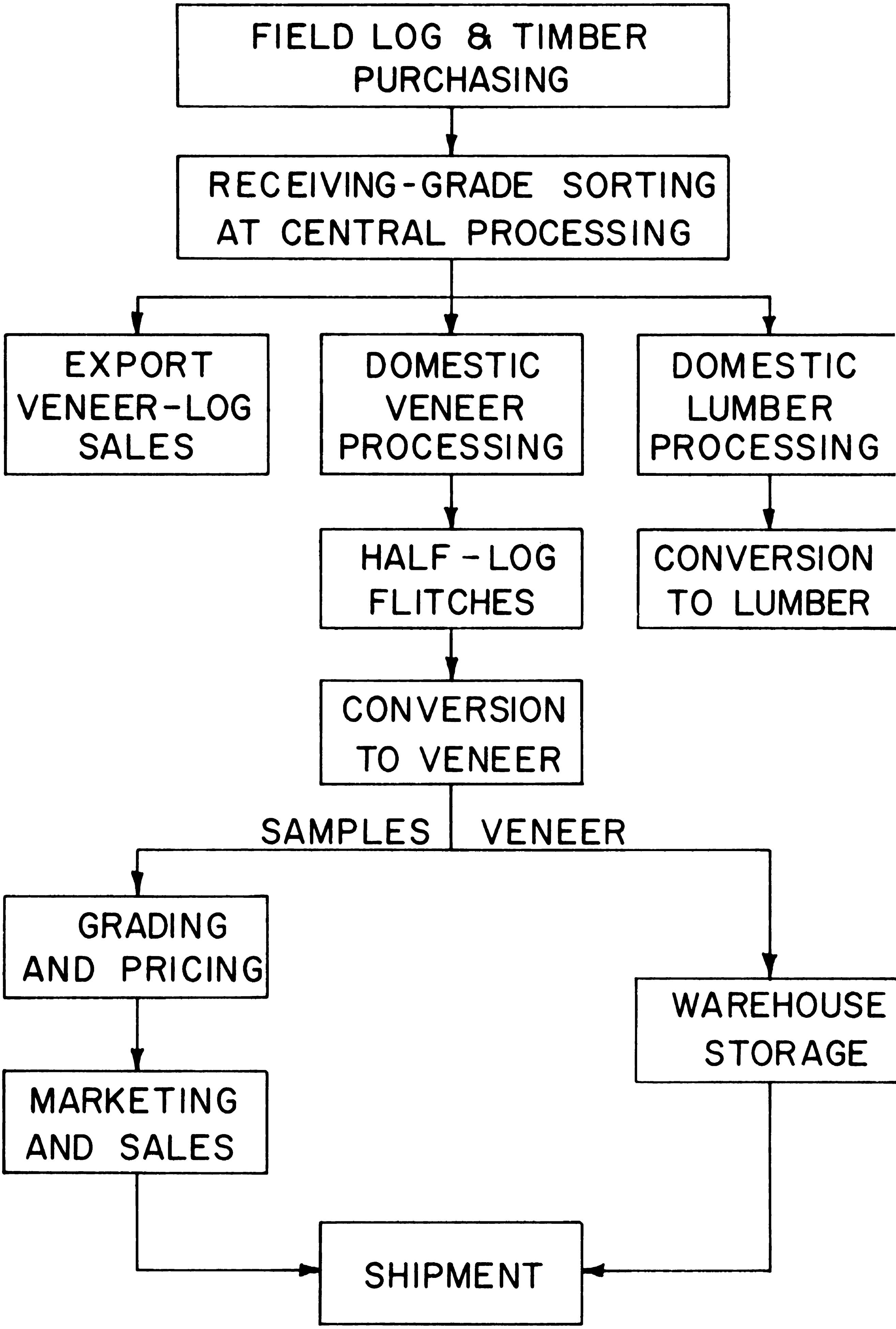
THE STUDY FIRM'S ACQUISITION, PROCESSING AND MARKETING SYSTEM

A. Acquisition

The organization of the study firm's operating system does not vary significantly from the typical walnut veneer firm. The following chart of Figure 12 illustrates this system. The acquisition or buyer organization does differ from the typical hardwood veneer mill because of the scattered nature and geographical range of walnut. Eight to ten buyers operate in the walnut-processing area of Ohio, Indiana, Illinois, Kentucky and Tennessee. With only one supervisor to oversee these scattered people, it becomes obvious they operate with a minimum of supervision. The buyers are also responsible for logging timber, concentration and shipment of purchased logs to the central processing plant.

Generally buyers are not professional foresters but have a wide range of educational backgrounds. Most have working experience as loggers or related occupations. Many have had previous experience buying walnut or other species

Figure 12. Flowchart of study firm's operating system.


FIELD LOG & TIMBER PURCHASING
RECEIVING-GRADE SORTING AT CENTRAL PROCESSING
EXPORT VENEER-LOG SALES
DOMESTIC VENEER PROCESSING
DOMESTIC LUMBER PROCESSING
HALF-LOG FLITCHES
CONVERSION TO LUMBER
CONVERSION TO VENEER
SAMPLES
VENEER
GRADING AND PRICING
WAREHOUSE STORAGE
MARKETING AND SALES
SHIPMENT

of timber or timber products. The mode of independent operation and the large sums of money involved can well influence the temptation to operate for the buyers own well-being. Authenticated and hearsay accounts of timber and log thefts, fraud and kickback are often heard in the walnut timber business.

An informal training period of up to six months is given each new buyer, depending on his previous training and experience. Log-grading, company operating procedures, and pricing policies are stressed in training. New buyers work under the supervision of an experienced buyer; first in the receiving yard and then in the field. They are then assigned a buying territory of their own.

B. Processing

After the logs are purchased and shipped to the central processing site, important receiving, inspection and grading functions are performed. Several very important decisions are made at this point. They are:

1. Final log grade assignment
2. Allocation to:
    a) export sales
    b) domestic veneer processing or,
    c) lumber processing

3. Determination of flitch orientation by establishing central saw line on end sections of domestic veneer logs only.

The conversion of half-log flitches is performed by conventional sawmill equipment. Logs are slabbed and sawn in half as illustrated in Figure 13. This is a critical processing decision center, for once the central cut is made the location of defects is determined in the resulting veneer flitch. Company policy calls for the sawyer to saw the flitches as prescribed by the receiving inspector. The flitch line marks are evident on the end of veneer logs as in Figure 9.

However, as the process continues there are two processing steps at which these decisions may be altered. First, after the logs are debarked; second, after slabs are removed from at least three of the log's faces but before the flitch line is sawn. Each of these actions may reveal information which could alter the decision made by the inspector. Under these conditions the sawyer is allowed to change the decisions made by the receiving yard inspector.

Domestic lumber conversion on a production basis is performed by the same personnel and conversion unit that is also engaged in veneer flitch production. The decision process and production rate for lumber production varies

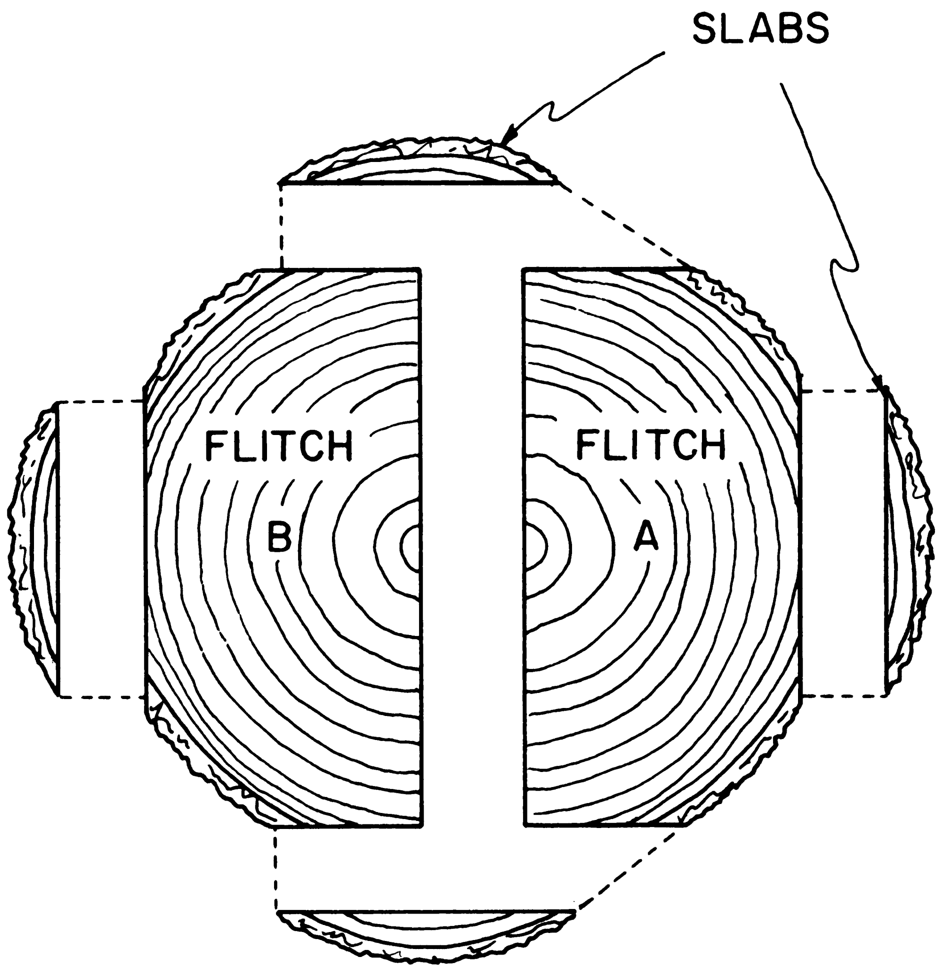


Figure 13. Schematic drawing of log to flitch conversion process.

considerably from that required for veneer flitch conversion.

The conversion of half-log flitches at the veneer plant includes heating prior to slicing, slicing, steaming (aging) before drying, drying, and packaging prior to movement to the warehouse for storage. Veneer area, in square feet, of each flitch is determined automatically at the outfeed end of the drier. Three "sample" sheets of veneer from the thickness quarter-points of the flitch are also removed at this point in processing. These sample sheets represent the quality of the complete flitch. They are the basis for the assignment of product, grade and unit price of the flitch. After these assignments are made the sample sheets are used by the marketing division as a sales tool to represent the quality of the entire flitch to potential buyers.

C. Marketing

The two general product classifications of walnut veneer are furniture manufacture and decorative wall paneling. The use requirements for veneer in these products may differ considerably. Within the paneling product class there are three sub-classes: (1) architectural (2) commerical and (3) architectural door skins. A length of at least 100 inches is a requirement for veneer used in panel manufacture;

except for door skins. Size of major defects and frequency of minor defects are important factors by which grades are segregated within this product class, grain pattern and color are very important quality factors for better panel grades.

Furniture manufacture requires clear cuttings of a specific length for a specific end use. Long length and a high percent yield are very important quality factors. Grain pattern and color within the clear cuttings are other important determinates of quality within this product class. Matching of grain pattern is especially important in higher quality furniture production. Minor defect frequency, grain pattern, color and color matching of veneer are less important in the manufacture of lower quality furniture.

CHAPTER V

PROCEDURE, SAMPLING AND DATA COLLECTION

A. General

It was obvious from the analysis of the current log grading system in use by the study firm that it does not meet log value estimation requirements. The system does not adequately separate logs or groups of logs into quality classes with significant differences in value of end products. One objective of this study was to use modern quantitative and statistical methods to develop a replacement system: a system which will predict the unit value of veneer from a quantification of the exterior characteristics of the log. The procedure used for achieving this objective is outlined in Figure 14.

B. Procedures

In general, the approach was to: carefully select the study material (veneer logs) over a range of physical sizes, quality levels and geographical ranges; collect the necessary raw material, conversion process and final product data; convert the data to useable form; develop a predictive

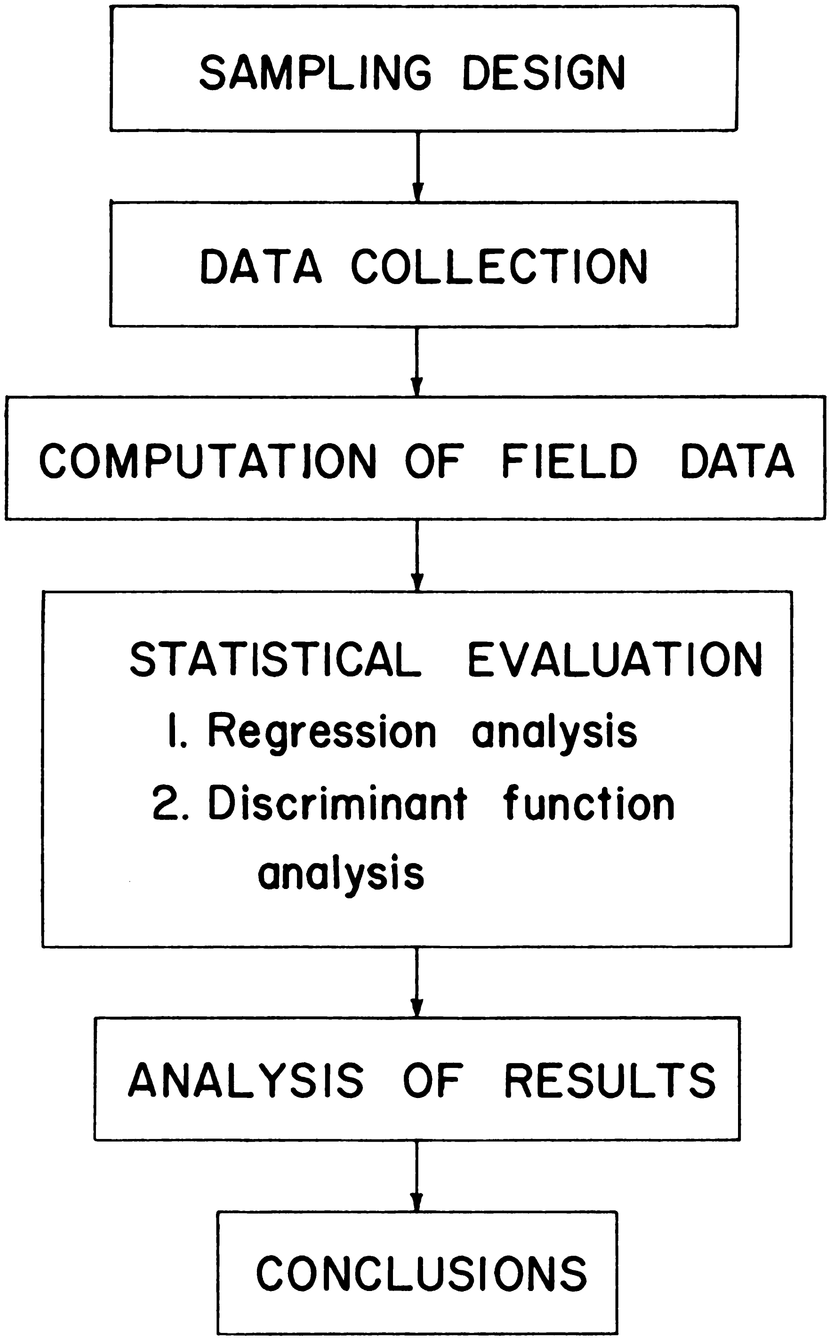


Figure 14. Flowchart of the approach taken to develop a replacement system for log grading.

statistically sound model; analyze the results and state the conclusions.

The problem was to establish numerical expressions for each log characteristic (independent variables), which were then related mathematically, using multivariate analysis and electronic computers, to an expression of product quality (dependent variables). Many characteristics must be tested to evaluate their contribution toward predicting the value of the resultant product. The complexity of this problem can not be overstated because of the large number of variables and the interrelationship that exist. Some of these characteristics are visible defect indicators on the log surface, some have to do with tree form, and others are in the interior with no obvious outer evidence of their existence.

C. Sampling

A determined effort was made to stratify sampling over the range of log sizes and surface clearnesses available. Since quality variation in the population was unknown an estimate of sample size could not be made. Henley et al. (12) state that if past experience with lumber logs is indicative, a sample of 30 logs per one-inch diameter class would be required for each species if they are representative of the possible quality range.

The objective in log size sampling was to select 30 flitches (15 logs) in each one-inch diameter class between 12 inches and 24 inches. The skewed distribution of Figure 15 illustrates the actual sample of the diameter classes obtained. Although it was generally agreed that logs under 12 inches were not to be purchased their occurence was such that 20 flitches were included in the sample. Domestic veneer grade logs with diameter class greater than 15 inches were not sufficiently available to meet the above requirements during the five-week period data was collected.

It is believed the length distribution of the sample as illustrated in Figure 16 represents quite well the actual population. The maximum length capable of being processed is limited to 13.5 feet by the slicer. The small number of logs shorter than eight feet reflects the limitation that short logs are inefficient to process and company log grades discriminate against them.

The histogram of Figure 17 represents the quality distribution of the sample flitches as expressed by the current log-grading system of the study firm. Logs of grades one through six are normally shipped as export logs. Grades A through E are domestic veneer log grades, and grades L1 and L2 are the top two of four lumber log grades. The current

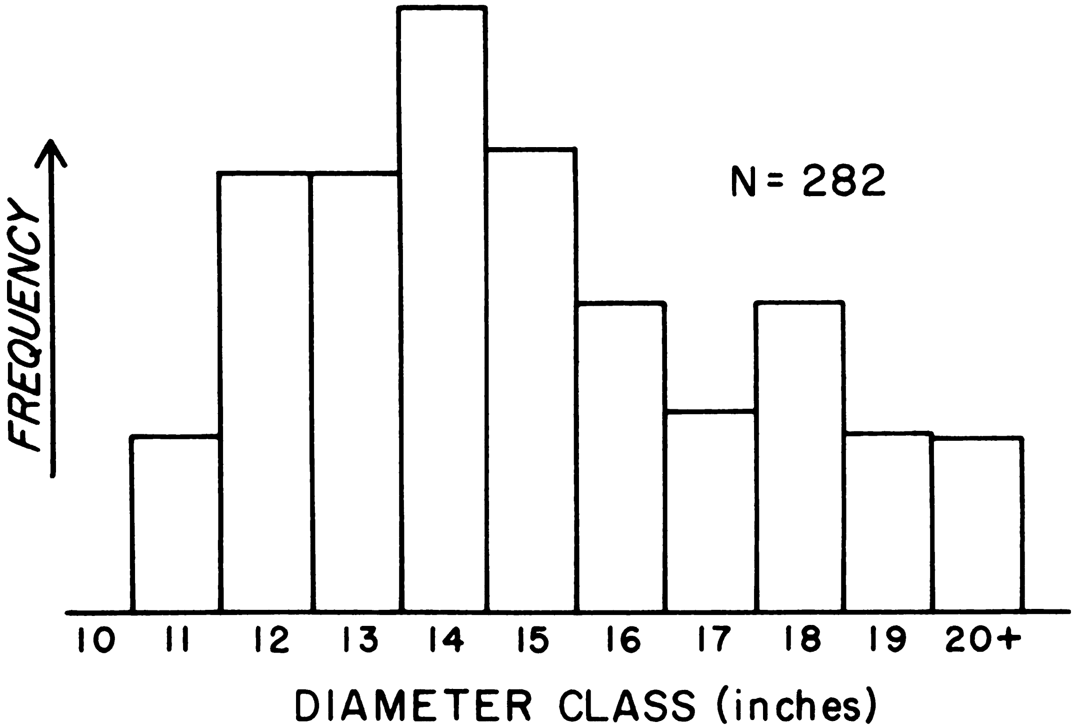


Figure 15. Frequency distribution of sample log diameter.

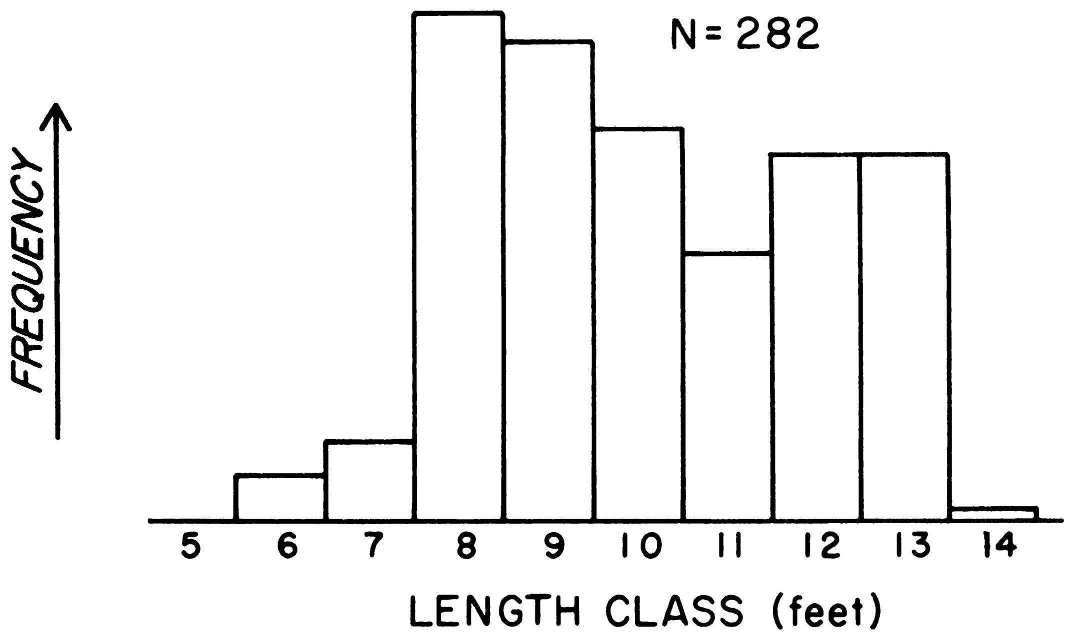


Figure 16. Frequency distribution of sample log length.

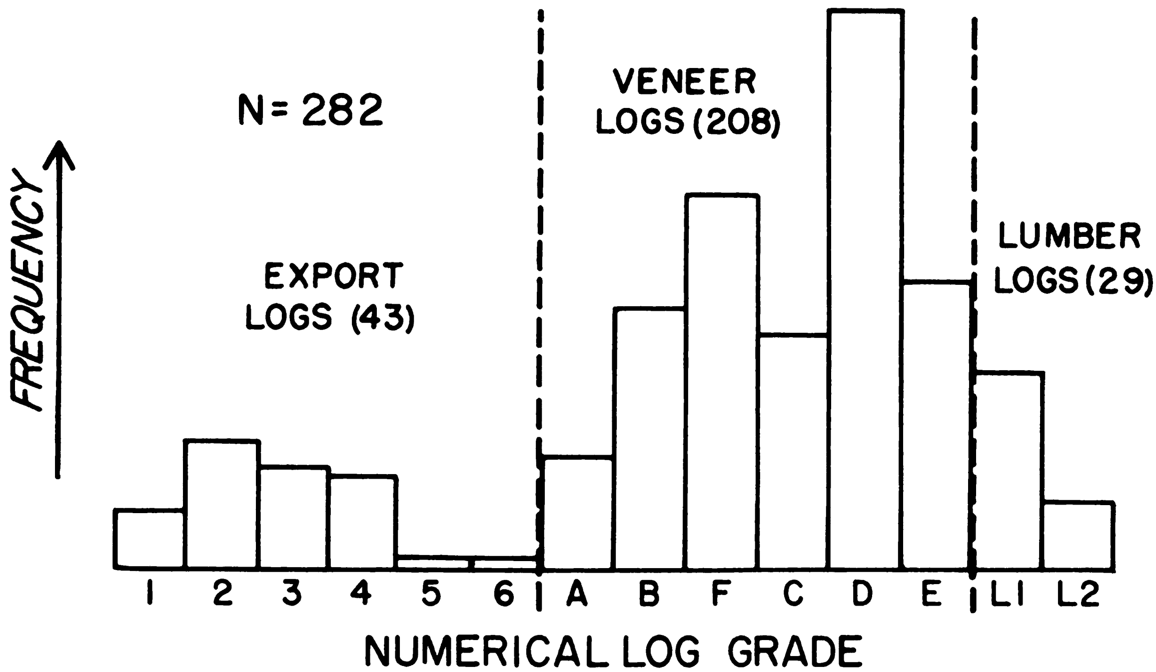


Figure 17. Frequency distribution of sample log original grade.

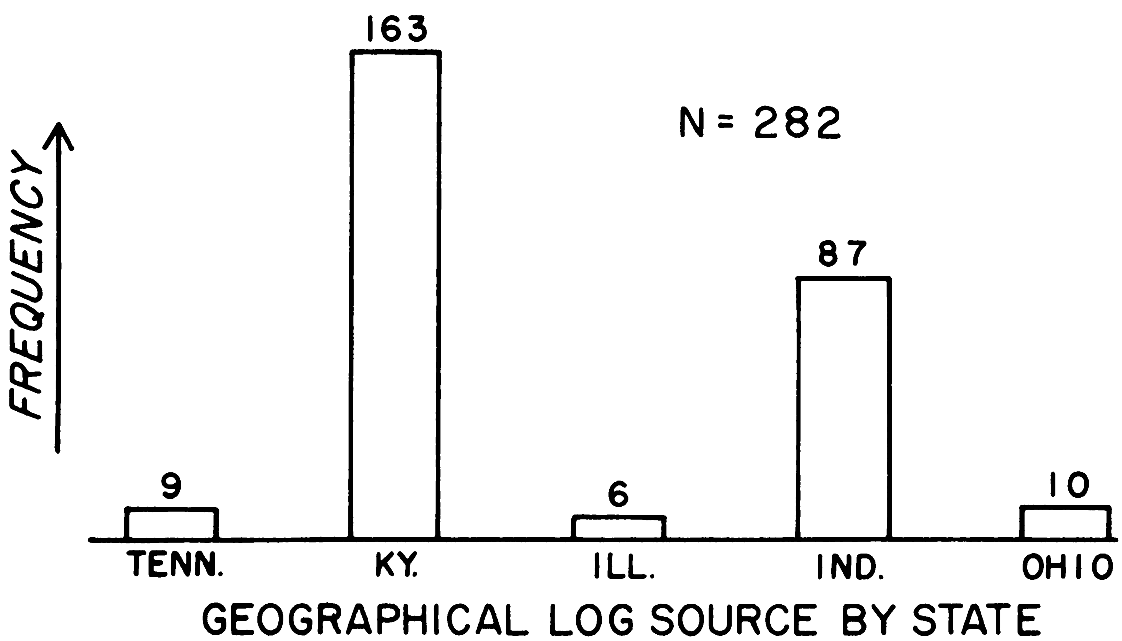


Figure 18. Frequency distribution of sample log geographical source.

domestic and lumber grades were assumed to represent a stratified sample of quality. Export grades were included to gain additional sample space for diameter classes greater than 15 inches.

There has been some evidence that geographical source as a quality indicator is important in wood quality studies. An effort was made to include logs from the total area over which logs were normally purchased. The sample frequency distribution by state is shown in Figure 18. It reflects what is considered to be the long term purchases by area of the firm.

D. <u>Data Collection</u>

Log and veneer information was obtained by a procedure specifically developed by Bulgrin (13) for wood quality evaluation studies. This involved diagramming[1] the sample logs, following them through all stages of processing and recording pertinent information including the resultant quality of each veneer flitch produced.

The exterior surface of every log was examined, defect indicators, and all identifying data recorded. All surface abnormalities were considered potential defects, with no

---

[1]A log diagram is a graphic representation of the exterior surface and end section of a log that accurately depicts the nature and location of observable and definite features that are known to or may affect the utilization of the log.

preconceived ideas of their significances. These data on defect types, size and locations provided a complete description of the exterior surfaces of the logs.

For purposes of this study the variables, both independent and dependent, have been classed as follows:

1. Measured variables
   a. Continuous
   b. Discontinuous

2. Ranked variables

3. Attributes

4. Computed variables

See Appendix I for full documentation of the variables, their identification and the coding methods used for electronic computer processing.

1. Measured Variables

a. Continuous Measured Variables. These variables can be expressed in a numerically ordered fashion and can assume an infinite number of values between any two fixed point values. The last digit of the measurement should imply precision, that is, the limits on the measurement scale between which we believe the true measurement to be. The continuous variables recorded for the logs included in the study are listed in Appendix II. They are variables such as length, diameter, crook and sweep; variables one would expect in such an analysis. The log in Figure 19 illustrates many of these variables. Crook is, of course, the most evident characteristic of this log. These variables normally present no problems of expression or interpretation and are most easily handled in statistical and other analytical procedures.

b. Discontinuous Measured Variables. These are variables which have only certain fixed numerical values, with no intermediate values possible between them. A limited number of variables in this study are discrete. In fact the only one in the list of raw data is the number of log surface defects.

2. Ranked Variables

Some variables cannot be measured but can at least be ordered or ranked by their magnitude. The difference in magnitude between ranks is not necessarily identical or even proportional. Color, for example, is a very important factor in the determination of walnut veneer quality. There are sophisticated methods of color measurement and communication. These methods present problems when an attempt is made to apply them to wood (14). As a result of these problems, heartwood color designation at the end of fresh cut logs was assigned one of the color ranking described in Appendix III.

Figure 19. A walnut veneer log illustrating such variables as crook, bark thickness, sap thickness and an unsound knot.

Other variables such as stain, grain contrast, ring pattern and freshness were assigned similar ranking.

3. Attributes

Variables which cannot be measured but which must be expressed qualitatively are called attributes (Examples - black, white; male, female). When such attributes are combined with frequencies they can be treated statistically. Certain attributes that can be ranked or ordered can be coded to become ranked variables. The attributes recorded for this study are listed in Appendix III. Log type is an excellent example of this class of variables. The butt, or bottom, log of a tree is generally considered to contain the highest quality wood because of the general lack of limbs or knots which results in defect-free wood. Any logs above this first log are a second class and are referred to as upper logs.

4. Computed Variables

The majority of variables in any biological work such as this are observations recorded as direct measurements, counts or perhaps outputs of instruments. However, there is an important class of variables which we may call computed or derived variables. These are generally based on two or more independently measured variables whose relations are expressed in a certain way. Ratios and percentages are examples of this class of variables. A ratio expresses as a single value the relation which two variables have one to the other. The number of pin knots per square foot is an example of this type of variable. The two independent variables are (1) number of pin knots observed on the surface of a log (2) the area of the log which in turn is the product of the circumference and length of the log. The resultant computed variables is the occurance of pin knots per unit area, in this case, per square foot.

D. Defect Recording System

Most log quality specifications require certain fractions of the log surface to be clear of defect indicators. The system developed for use in this study to manipulate input data to calculate various combinations of clear cutting length and width is unique. The following is a description of that system.

Certain physical divisions were defined and used to record the location of visible defect indicators such as overgrown knots, sound and unsound knots, seams, bumps, surface rises, and bark distortions on the bark surface and end of the log. The end of each log was divided into eight

sectors as illustrated in Figure 20A. The location of the flitch line as prescribed by the receiving log inspector served as the reference line for sector location.

The log was further divided into six-inch sections along its length (see Figure 20B). This development is a grid or matrix system which will allow location of defects by coordinates. Defects can easily be located by a sector (face number) and a section number. For example, the top knot in Figure 20B would be located in sector one, section 11 and 12, the other knot in sector four, section 17.

The basic unit for calculations is a pie-shaped cylinder section with dimensions as shown in Figure 21. To more efficiently express the effect of clear wood volume on quality this unit was divided in half on a volume basis. The dark area is the outer volume layer, the light area the inner volume layer. This division allowed specification of defects into three severity levels as follows:

Level 1 - If the defect affects only the outer volume layer
Level 2 - If the defect affects only the inner volume layer
Level 3 - If the defect affects the total volume (both volume layers)

The defect indicators were recorded with these designations along with other log information on the diagramming form. This system allowed the computation of clear areas

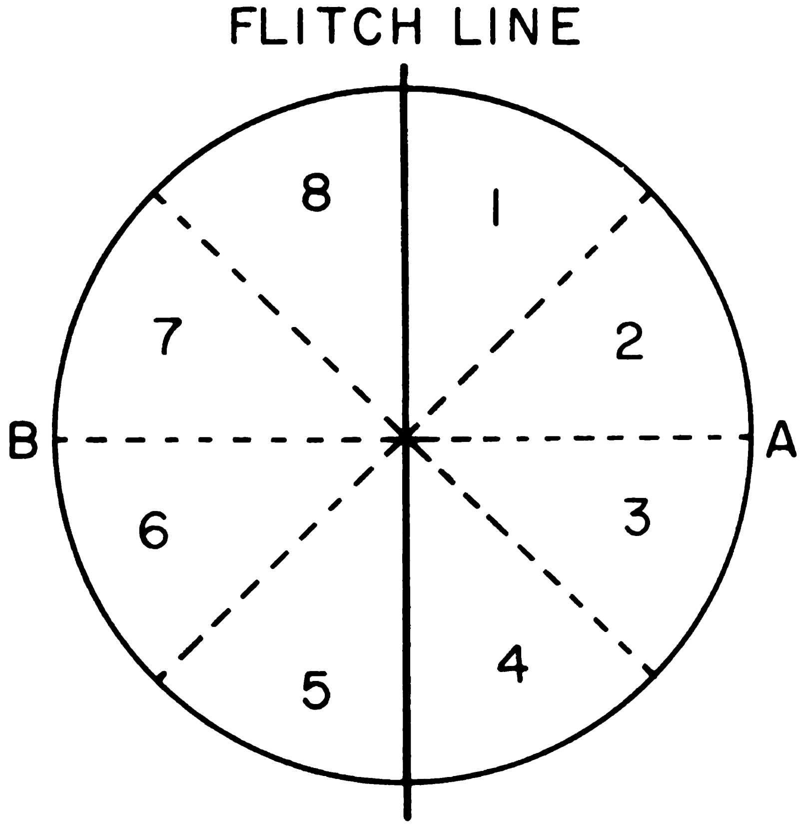


Figure 20A. Log sector designation for field data collection.

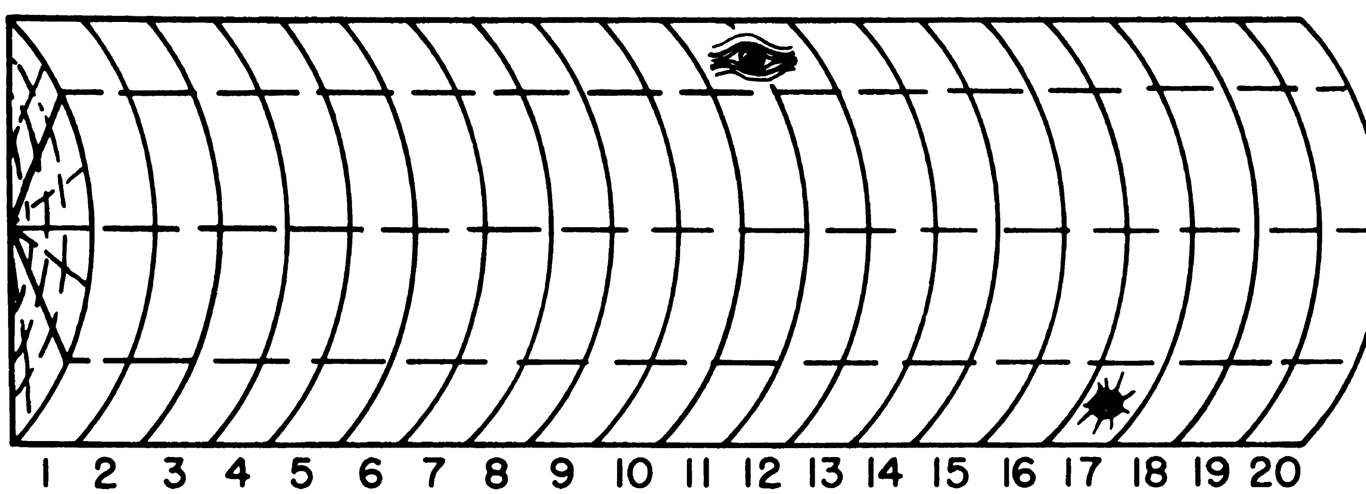


Figure 20B. Log section designation for field data collection.

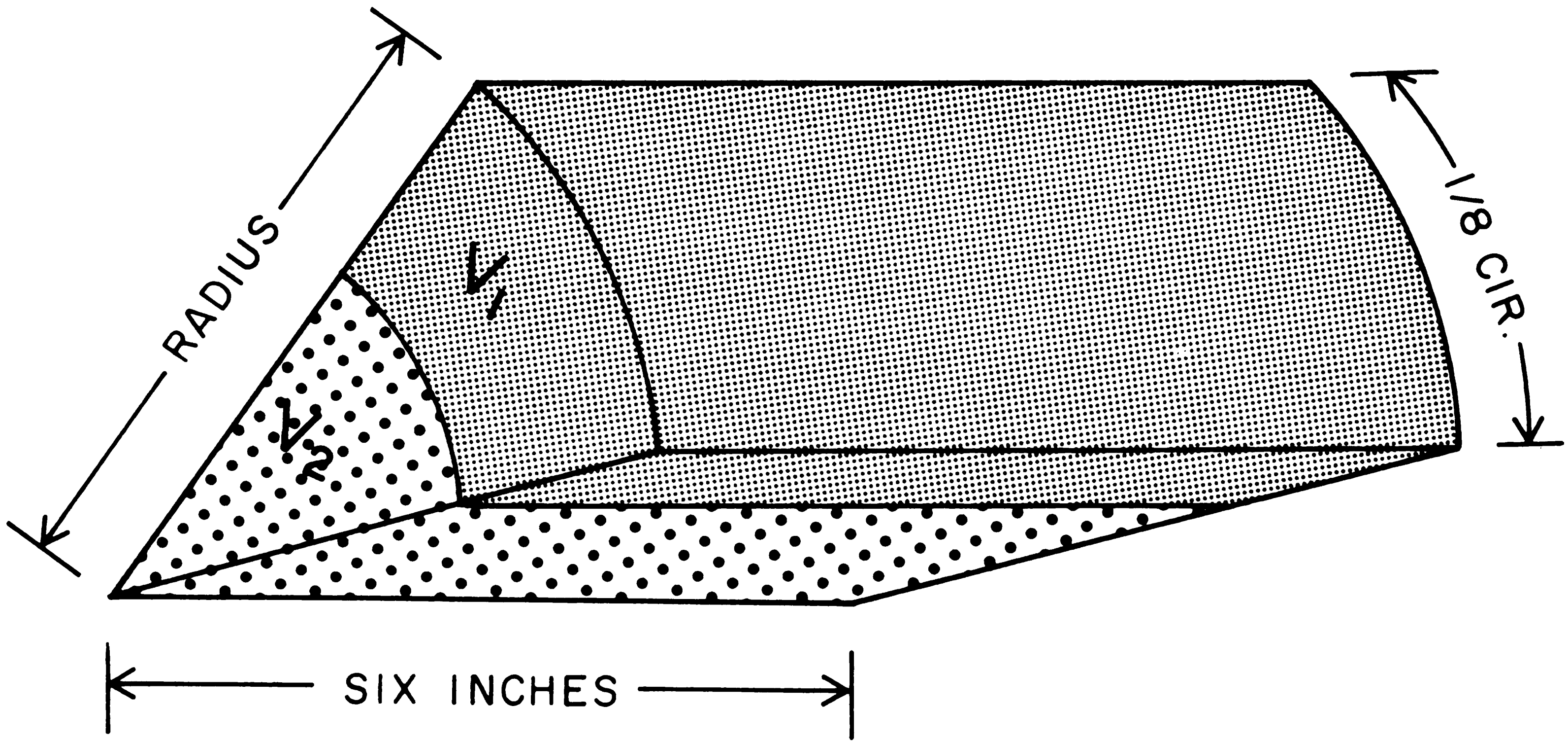


Figure 21. Minimum clear cutting and clear volume unit.

of log surface and volumes of clear wood by specification of cutting width in number of log sections and minimum cutting length.

F. Yield Data

Several product yield variables were determined. Flitch length was recorded as a check against log length. Flitch area, in square feet of veneer 1/35 of an inch thick, was determined mechanically as a normal firm operating procedure. Flitch area multiplied by the unit value determined the price of the resultant veneer. The nearly normal frequency distribution of unit veneer value is illustrated in Figure 22. The mean unit value was 4.2 cents with a range from 1.0 cents to 8.0 cents.

In addition to price, the veneer produced was assigned a grade designation. This assignment was governed by quality characteristics of the veneer for use in furniture or wall paneling production. The characteristics for these individual products are described on page 47. The composite product frequency distribution of these grades is shown in Figure 23. Seven of the grades are furniture veneer products; six are paneling veneer products. In general the quality level decreases from left to right.

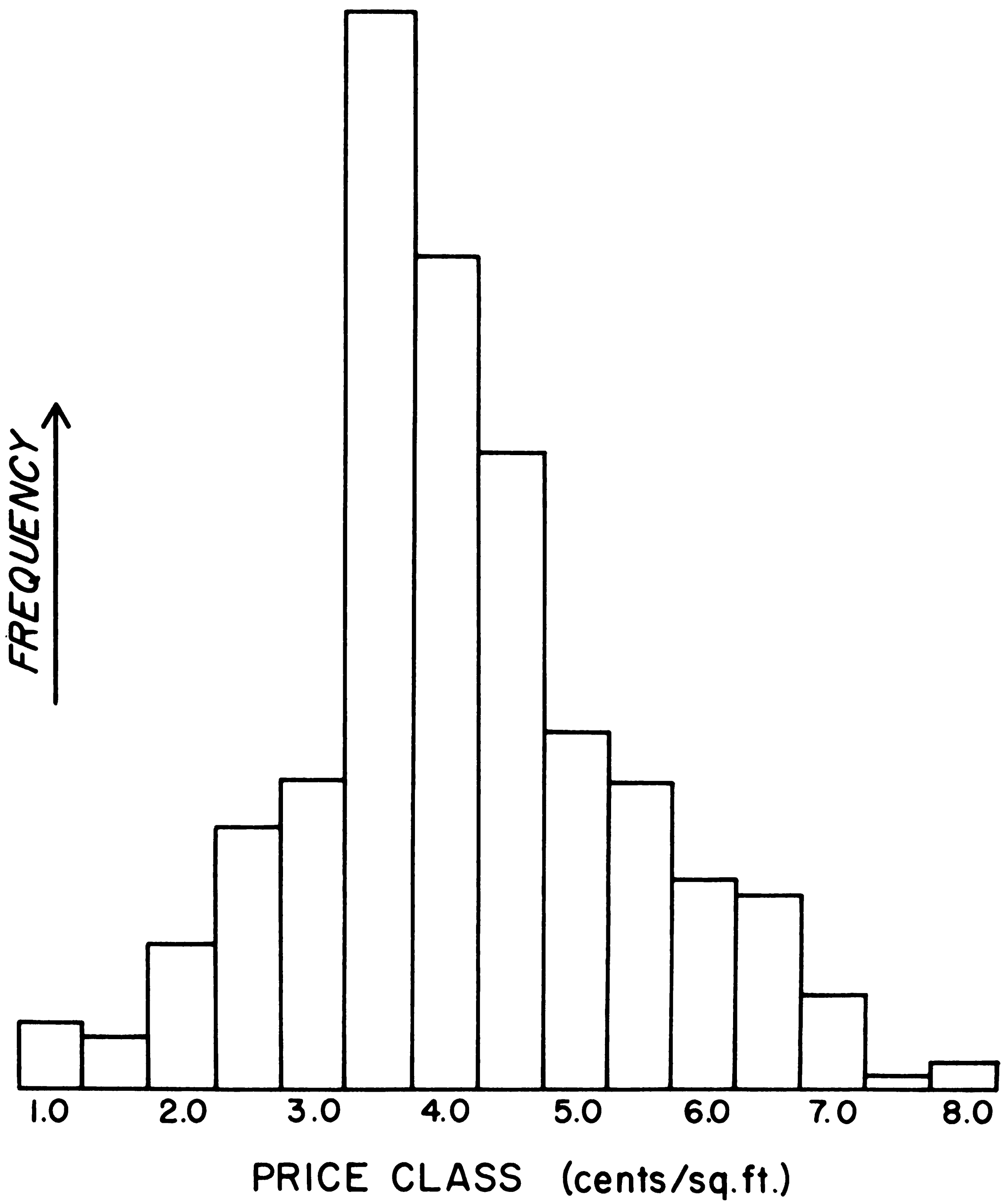


Figure 22. Frequency distribution of sample flitch veneer unit price class.

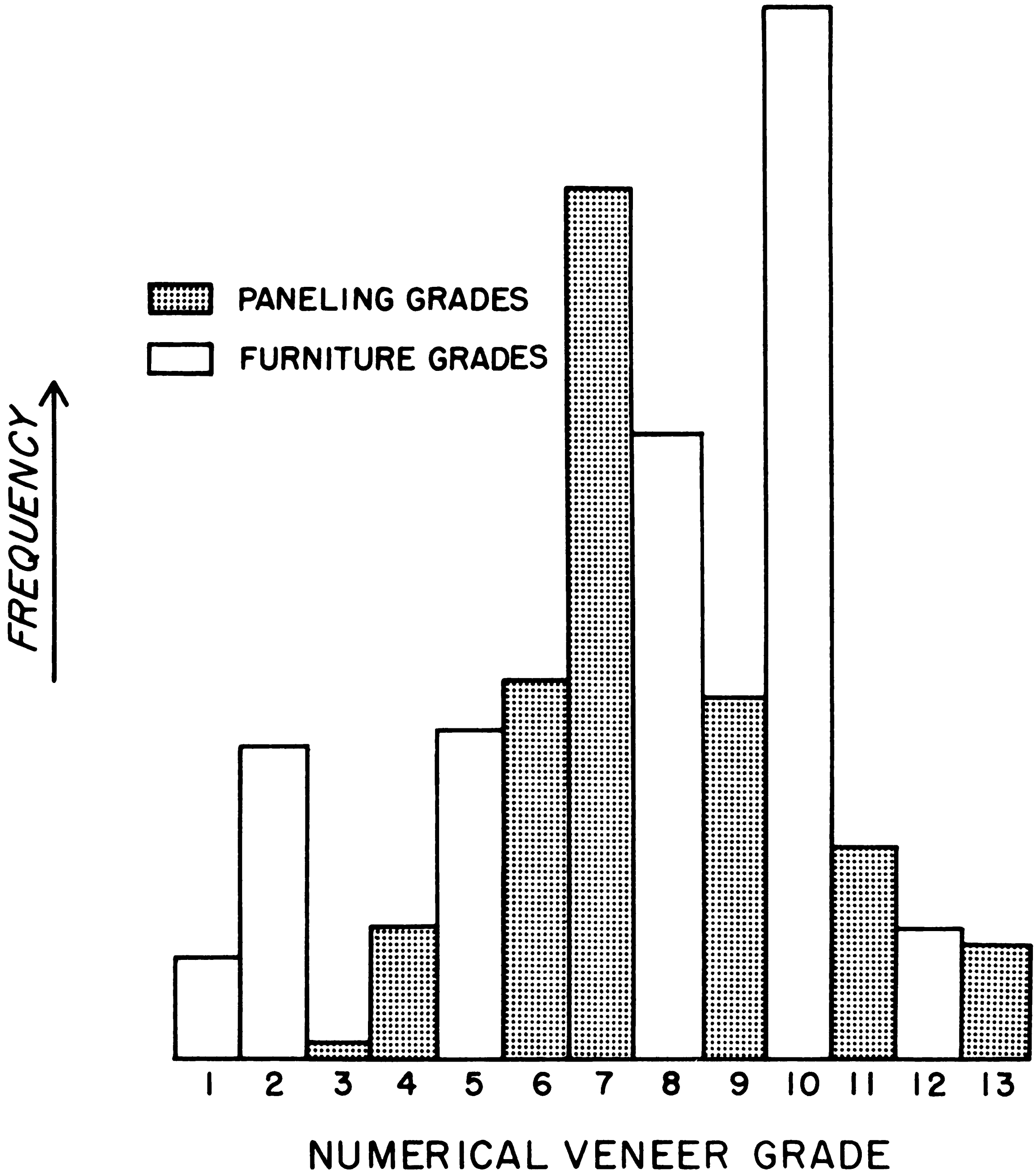


Figure 23. Frequency distribution of sample flitch veneer grade.

CHAPTER VI

PRELIMINARY COMPUTATION OF FIELD DATA

A. General

The previous chapter described the collection and classification of field data. Before these variables were tested for their ability to predict the value of veneer yield in terms of quantity and quality, data conversions were made which would increase their predictive value. A computer program, LOGAN (LOG ANalysis), was written to handle the mass of data and to compute the various clear cutting width and length combinations deemed necessary to test. The computations fell into three classes: (1) log characteristics, (2) log volume corrections, (3) clear area cuttings and clear volume computations.

B. Log Characteristics

There were a host of alternatives available for combination and conversion of the log characteristic variables. Certain decisions were made intuitively while other conversions were made and subsequently tested against alternatives to determine their relative merits.

Log sweep was converted to a computed variable - sweep in inches per foot of log length - to reflect the effect of log length. For example, an eight-foot log with three inches of sweep and a 12-foot log with three-inch sweep do not have the same degree of sweep. Mean values (large and small-end averages) of bark thickness, sapwood thickness and pith displacement were calculated and were used as variables rather than individual log-end values. This was done to reduce the number of variables and to more nearly reflect the average condition within the log. The ranked variables of bark growth visibility, new bark color and old bark vigor were combined into one variable - mean bark vigor.

Attribute variables log type and growth rate uniformity were converted to ranked variables. Butt logs were ranked as the higher value log type while upper logs were considered lower value logs. For the growth rate uniformity variable, logs with uniform growth rate were ranked above those with non-uniform growth rates.

C. Log Volume Correction

Although most walnut logs are purchased using the Doyle Log Scale as a volume determinate, it poorly reflects the actual board foot volume of the log. It underscales small logs and overscales those over 26 inches in diameter. To

insure accurate log volume determination for this study, the log was assumed to be a cylinder with a circular cross section equal to the small-end diameter. The equation used to determine board feet of a flitch was:

$$V = \frac{0.00545416 \times D^2 \times L \times 12}{2}$$

$$= 0.03072472 \times D^2 \times L \qquad (4)$$

Where:

V = volume - actual board feet

D = small end diameter - inches

L = length - feet

These volume calculations were corrected for several factors to reflect more accurately their actual volume. Reductions were made in flitch volume to correct for log sweep and crook.

Volume adjustments were made between flitches of the same log for two reasons. First, pith location is an important reference point for grain pattern development. The normal practice, if both flitches are to be sliced, is to saw the log into flitches of equal volume using the pith as a guide. Logs with displaced piths are sawn as close to the pith as possible. This action results in flitches whose volumes must be corrected to reflect the amount of pith displacement. Second, those logs whose quality and/or size dictate that one half must be processed into lumber, are sawn so that the pith is located approximately one inch into the veneer-flitch half of the log. This practice results in increased yield by allowing the flitch to be sliced to the pith. These volume correlations were used to reflect changes in the basic unit volume for clear cutting calculations.

D. Clear Area Cuttings and Clear Wood Volume Computations

The most complex problem was developing a technique for transforming defect location and severity level information into log surface and volume data for various combinations of clear cutting lengths and widths. To keep this development relatively straight forward, the initial assumption is that the defect severity level is three, that is, the basic volume unit is completely defective.

The minimum width of clear cutting, one sector (1/8 of log circumference), of a ten-foot half log is illustrated in Figure 24. The two hatched areas represent defective basic units. If we assume a minimum clear cutting length of six feet, the dotted portion represents surface area, hence log volume, not qualified for clear cuttings. The light area represents three clear cuttings one sector wide, two of which are ten feet long and the third eight feet long.

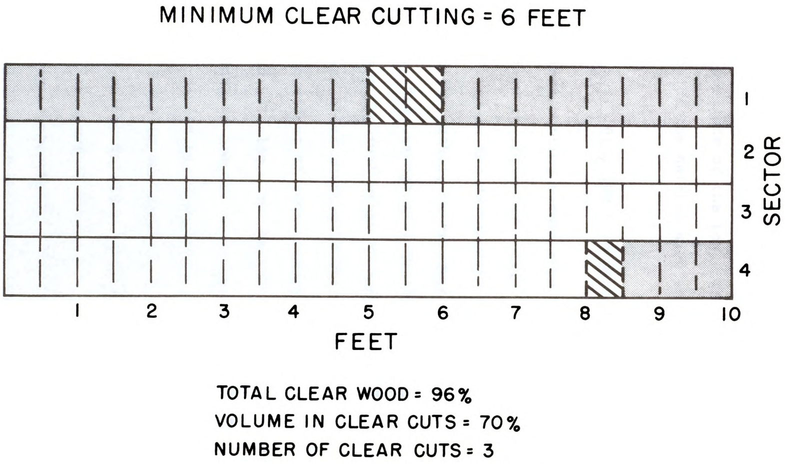


Figure 24. Clear cutting development for 1/8-log sectors.

Under these assumptions and on the basis of number of units, we can calculate several variables which reflect the clear and defective portions of the log. The percent clear wood, the volume outside the hatched area in Figure 24, can also be computed:

$$\frac{(2 \times 20 + 16)}{80} \times 100 = 70 \text{ percent.}$$

The minimum clear cutting encountered longer than the minimum specified is eight feet long.

The next step in the development was to increase the width of the clear cutting to two sectors or 1/4 of the log circumference. The assumption made here is that the defect would now affect the full width of the quarter-log face interrupting any clear cutting in that face. Figure 25 illustrates the effect of this assumption using the previously discussed half-log. The percentage of the half-log in clear cuttings is reduced to 40 percent while the total clear wood is reduced to 92 percent. The number of clear cuttings is reduced to one eight-foot long cut.

The final change in clear cutting width is to full half-log basis as shown in Figure 26. The result is that no clear cutting is obtainable. The total clear wood is reduced to 85 percent of the total volume. The effect of clear cutting length specification change can also be

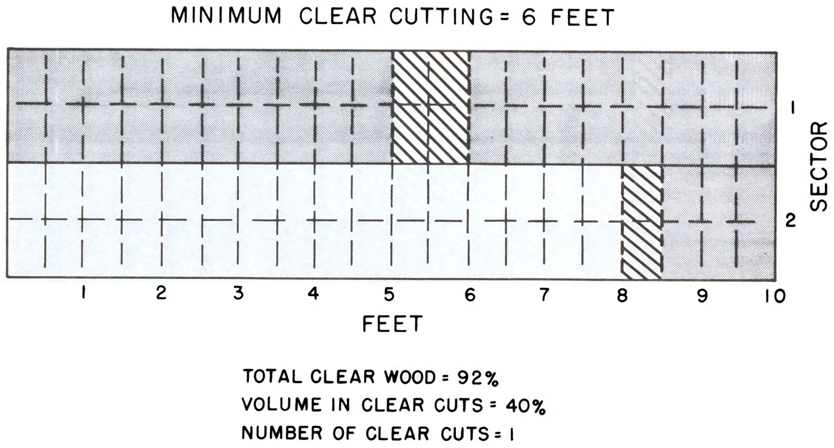


Figure 25. Clear cutting development for 1/4-log sectors.

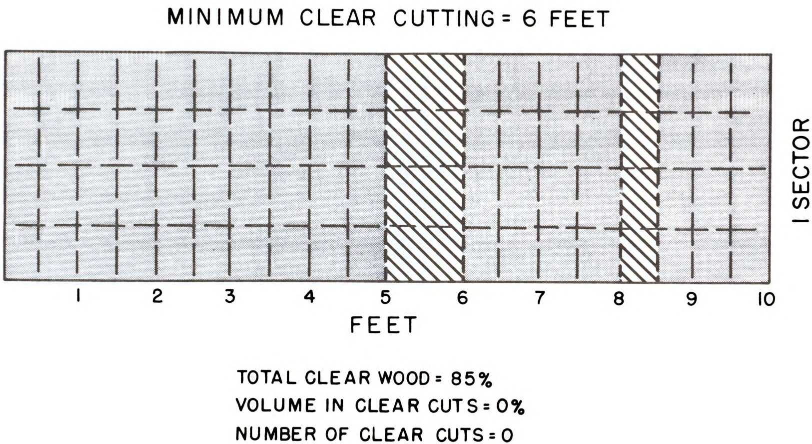


Figure 26. Clear cutting development for 1/2-log sectors.

illustrated in Figure 26. If the minimum length of clear cutting was reduced to five feet, there would be one five-foot clear cutting, 50 percent of the log would be in clear cuttings, while the total clear wood would remain at 85 percent.

The preceeding analysis was applied to each volume layer as described on page 62 of each half-log.

The following variables were developed for later statistical testing for all clear cutting widths and various minimum clear cutting lengths:

A. Combined volume layers.
   1. Length of clear cutting encountered above minimum length.
   2. Percent total clear wood in basic volume units.
   3. Percent volume in minimum length clear cuts.
   4. Number of clear cuts encountered.

B. Individual volume layers.
   1. Percent volume in minimum length clear cuts.
   2. Number of clear cuts encountered.

It becomes obvious that the complexity of the problem, the routine nature of the calculations and the mass of data make the digital computer the logical choice of a calculating machine. A program was written in Fortran IV for execution on the Control Data 3600 at the Michigan State University computer center. The computer program LOGAN allows the substitution of two statement cards to vary the width and length of clear cutting size. The output of program LOGAN on punched cards forms the input for the multiple regression computer programs (see Appendix IV, V and VI for program output variable classification, format and flowchart).

CHAPTER VII

STATISTICAL EVALUATION

A. General Approach

The approach taken to solve the log value assignment problem faced by the study firm was to develop a general quality estimator. This general estimator would be in the form of a mathematical model which would relate the surface characteristics and physical size of the log to the value of the resultant veneer. Our problem is that complex inter-relations make it very difficult to derive a complete model.

The success of this approach depends on the model being sufficiently complete to account for the main components of variation in the population. The value of such an estimator is, of course, based on the truth that product value is continuous. Any method such as log grades that divides the value scale into discrete parts will inject a grouping error. Another consideration is, if price changes, or changes in quality classes of end-product should make the estimator unsuitable, then this type of estimator would be easier to revise than log grade specifications. It would only be necessary to recalculate the coefficients in the model.

Since mathematical models express the relationship being studied, they should ideally be derived from basic physical laws or relationships, or at least from logical hypotheses about relationships. However, we often have no basis for hypotheses, or we admit our hypothesis is weak or incomplete. In this case, we may resort to empirical methods.

In practice, models for analyzing timber quality problems will rarely be entirely rational or empirical. A solution may be chiefly one or the other, but almost always it will contain elements of both. Complex problems such as the one treated in this study may require, at least initially, models that are chiefly empirical. Simpler problems may permit use of more rationalistic models.

One objective of research should be to improve the rationale of the model. It is to this end that a portion of this study was directed. Specifically, in our case, the rationale lies in the assumption that a strong correlation exists between the relative site of the clear areas of the log surface and the veneer quality and that this relationship is reflected in veneer prices. This rational analysis

in union with an empirical analysis forms the premise that a valid predictive equation for unit veneer value can be developed.

B. Regression Methods

Most researchers have discovered the usefulness of simple regression methods in deriving and testing empirical relationships among various observed phenomena. Stated simply it is a method of determining the way one variable changes when another changes. The most common and easily expressed change is according to a straight-line function. This relationship would be expressed as

$$Y = a + bX \qquad (1)$$

This equation states that the Y value of any individual unit is due to the regression of mean Y on X plus a deviation from the mean. The usual method for fitting such a line is the least squares method. It consists of the estimation of a straight line with the characteristic that the sum of the squared perpendicular distances from each point to the line is a minimum.

As stated above there is a complex relation between veneer value (a dependent variable) and a number of log characteristics (independent variables) which may effect the value. This relation can be represented by the equation

$$Y = a + b_1X_1 + b_2X_2 + \ldots b_nX_n + e \qquad (2)$$

Where:

> Y = the dependent variable - veneer price per square foot
>
> a = the constant term (Y-intercept)
>
> b_k = the coefficient of, (k = 1, 2, ... n)
>
> X_k = an independent variable (log characteristic)
>
> e = the increment by which any individual Y may fall off the regression line - an error term

An understanding of the several constants in this equation can be gathered by making up a simple example of our problem at hand. Assume that we want to compute the unit price per square foot of several walnut veneer logs which are all alike except for diameter and percent clear and that the unit value of each is computed as follows:

> Minimum value, \$0.02 per square foot
>
> Log diameter, contribution \$0.0015 per inch of log diameter
>
> Percent clear, contribution \$0.0003 per percentage point

Using Y to represent the value per square foot of the veneer, X_1 to represent the diameter of the log in inches and X_2 to represent the clear area of the half-log as a ratio of the total area, we can state the method of computing the unit selling price with a single equation as follows:

$$Y = 0.02 + 0.0015X_1 + 0.0003X_2 \qquad (3)$$

Equation (3) is called a multiple regression equation.

Ordinarily, of course, the regression relationship will not be known but must be estimated from observation made on a sample of the individual units - logs in our case. For each of the selected units we will observe the value of Y (veneer value) and each of the associated X's (diameter, length, bird peck, etc). From these observations, we must derive an estimate of the coefficients (a, b_1, b_2, ... b_n) in the regression equation. This estimate is usually determined by solving simultaneously a set of the least squares normal equations. It is a common procedure available in most any advanced statistics reference (15) (16) (17).

Before we select a mathematical function or model which we think may represent the desired relationship we must recognize two broad classes of functions; those that are linear in the coefficients and those that are not linear in the coefficients (15). An equation in which the coefficients are raised to only the first power and combined only by addition or subtraction is said to be linear in the coefficients. Some examples are:

$$Y = a + b_1 e^{b_2 X}$$

$$Y = a + b_1 X_1 + b_2 (b_3)^X$$

Note that the model can be linear in the coefficients even though it is nonlinear as far as the variables are concerned.

An equation in which the coefficients are raised to other than the first power, appear as exponents, or are combined other than by addition or subtraction are said to be nonlinear in the coefficients. The following are examples:

$$Y = a + b^X$$

$$Y = aX^b$$

In some cases equations that are nonlinear in the coefficients can be converted into linear form by a transformation of the variables. Thus, the second equation above could be converted into linear form by taking the logarithm of both sides, giving

$$\log Y = \log a + b \log X$$

This study will be limited to the fitting and testing of linear models. While this may be a restriction, it will often be found that a linear model provides a very good approximation to the nonlinear relationship.

After developing equations by which values of a dependent variable may be estimated from those of two or more independent variables, it is desirable to know: (1) how closely such estimates agree with the actual values, (2) how closely the variable is associated with the variation in the several independent variables, (3) whether the dependent variable is significantly related to a particular independent variable, and if it is to what extent.

1. Confidence Limits

a. The Standard Error of Estimate (SEE). This value is a measure of the closeness with which the original value may be estimated or reproduced. It is the standard deviation of the individual difference between predicted Y values and the actual Y values corrected for the size of the sample and the number of independent variables used.

b. The Coefficient of Multiple Correlation (R). This value measures the combined importance of the independent factors as a means of explaining the difference in the dependent factor. It is the ratio of the standard deviation of the estimated values to the standard deviation of the actual values. The square of this coefficient, the coefficient of multiple determination (R^2), indicates the proportion of the variance in the dependent variable which has been mathematically accounted for.

c. Coefficient Significance Test. The procedure to test if an independent variable is significantly related to

the dependent variable is to test the null hypothesis that its coefficient equals zero against the alternative that it does not equal zero. The test, an F-test, is the ratio of additional variance explained by the addition of the independent variable to the residual about the maximum model. If this ratio is significantly large, then the coefficient of the variable is different from zero and the variable should be included in the equation.

The extent to which a specific independent variable can account for variation in the dependent variable can be determined by calculation of the R^2 delete value. It is the R^2 that would be obtained if the independent variable were deleted from the least squares equation and the equation recalculated. The portion of the variance in the dependent variable which has been mathematically accounted for by the specific independent variable then is the difference between the total equation R^2 and the R^2 delete for that independent variable.

1. Developing the Best Equation

If we wish to establish a linear equation for a dependent variable Y in terms of independent or predictor variables X_1, X_2..., X_i, we assume the independent variables are the complete set from which the equation is to be chosen.

Usually two opposing criteria of selecting a resultant equation are involved. They are: (1) To make the equation useful for predictive purposes we should want it to include as many X's as possible so that reliable values can be determined, (2) Because of the cost involved in obtaining information on a large number of X's we should like the equation to include as few X's as possible. There is no unique statistical procedure for selecting this best regression equation, and personal judgement will be a necessary part of any of these methods.

Although there is a host of possible procedures for this process, the three used in this study will be discussed. They are: (1) all possible regressions, (2) backward elimination, (3) forward selection.

a. All Possible Regressions. This procedure requires the fitting of every possible regression equation which involves a constant and any number and combination of the variables. The equations are usually ordered in sets and the results of each set is ordered according to the value of the R^2. The leaders in this ordering within each set are then selected for further examination and a decision is made on which equation(s) is(are) best to use. The process is rather cumbersome and its use was limited to certain sets of equations selected by the following procedures. The Michigan State Agricultural Experiment Station library program No. 7 "LS" was used for this procedure (18).

b. Backward Elimination. This method is an improvement on the "all regressions" method in that it permits the examination, not of all regressions, but of only the "best" regression containing a limited number of variables. The basic steps in the procedure are these: (1) a regression equation containing all variables is computed. (2) The F-test is performed as described previously for every variable treated as though it were the last variable to enter the equation. (3) The variables are selected on the order basis of which will reduce R^2 the least if dropped. The Michigan State Agricultural Experiment Station library program No. 8 "LSDEL" was used for this procedure (19).

c. Forward Selection. The forward selection procedure is an attempt to achieve a similar conclusion from the opposite direction, that is, to insert variables in turn until the regression equation is satisfactory. As each variable is entered into the regression, the following values are examined: (1) R^2, the multiple correlation coefficient, (2) the F-test for the variable most recently entered is performed, which shows whether the variable has taken up a

significant amount of variation over that removed by variables previously in the regression. When the F-test related to the most recently entered variable becomes nonsignificant, the process is terminated. The library program "LSADD" was used for this procedure (20).

3. Variable Transformation

Transformation is the process of selecting a mathematical model to be fitted and tested as a description of the relationship between the dependent and independent variable. Its use in this study was limited to the transformation of the ranked variables into relationships which more nearly reflect the true relationship of these independent variables to the dependent variables. Suitable transformation of the independent variables are often suggested by plotting the data in various ways (21).

4. Dummy Variables

The variables considered in regression equations usually take on values over some continuous range. Occasionally we must introduce a factor which has two or more distinct levels. For example, in our case we could not set up a continuous scale for the variable geographical log source, log type or veneer product. We must assign to these variables some levels in order to take account of the fact that the various log sources, log types or veneer products may have separate deterministic effects on the response. Earlier we referred to these variables as attributes. They are usually unrelated to any physical levels that might exist in the factors themselves (15).

For example, in our case we wanted to introduce into the model the fact there are two log types that may produce different levels of response (quality), in addition to the variables. One way of doing this is to add to the model a "dummy" or "internal" variable Z and a regression coefficient so that an additional term Z appears in the model. The coefficient must be estimated the same time the other variable coefficients are estimated. Values are assigned to Z as follows:

$Z = 0$ if the observation is from a butt log

$Z = 1$ if the observation is from an upper log

Any two distinct values of the Z would be suitable, though the above is usually best. The estimated response, quality in price per square foot, for butt logs would be the calculated Y value of the equation. The estimated response for upper logs would be the Y value <u>plus</u> the coefficient. The normal assumption in log quality studies is that upper logs are of lesser value hence the coefficient would be expected to have a negative value.

5. Model Testing

A series of regression models were tested, by employing the previously discussed regression method, for their ability to predict the value of veneer. The initial model included 37 variables listed in Appendix V. This model was also used to test the effect of clear cutting width and length on the predictive ability of the model. All combinations of clear cutting width of one, two and four sectors and clear cutting lengths of three, four, five, six and eight feet were tested. Backward elimination was used to select the variables significant at the 10 percent level to predict unit veneer value. Forward selection was used as a check method.

The mean value for each half-cent price class was plotted as a function of the coded value to reveal the true relationship between the ranked independent variables of log freshness, annual ring pattern, grain contrast, bird peck, growth rate uniformity, log type, wood color and stain with the dependent variable, veneer value. Figure 27 is an example of the lack of correlation between qualitative log factors and veneer quality. As a result, logarithmic, exponential and hyperbolic transformations of these independent variables were made in an attempt to improve the correlation with the dependent variable.

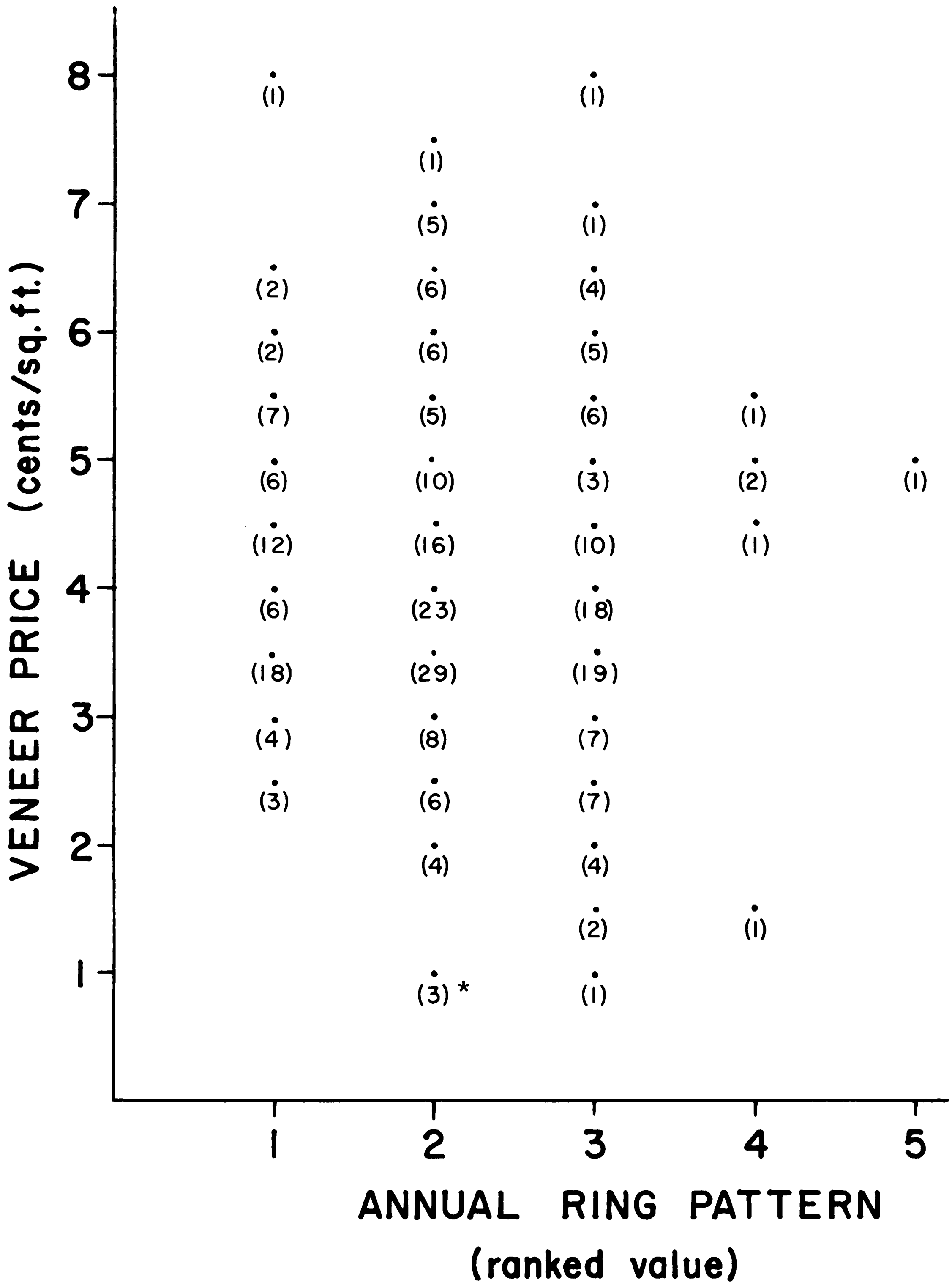


Figure 27. Veneer price as a function of annual ring pattern. * (X) = number of occurences

Transformations which improved the correlation of the independent variables with the dependent variable were freshness cubed, annual ring pattern to the fourth power and a hyperbolic transformation of grain contrast. Figure 28 illustrates the result of transforming annual ring pattern by increasing its value to the fourth power. The three transformed variables mentioned above were included in subsequent model tests.

Models were developed, using the dummy variable method, to test the contribution of log type (butt or upper) and veneer product (furniture or paneling) in predicting veneer quality. Veneer product does present the problem that it is not determined until after the logs are processed. Separate models were developed for paneling-grade veneer and furniture-grade veneer half logs. It was postulated that by using the two models different log characteristics might prove to be significant in the individual predictive models.

Only the heartwood of walnut has the color desirable for most uses, although the sapwood can be stained in finishing to resemble heartwood. For this reason a set of data was computed and regression model tested specifying the diameter of the heartwood as log diameter.

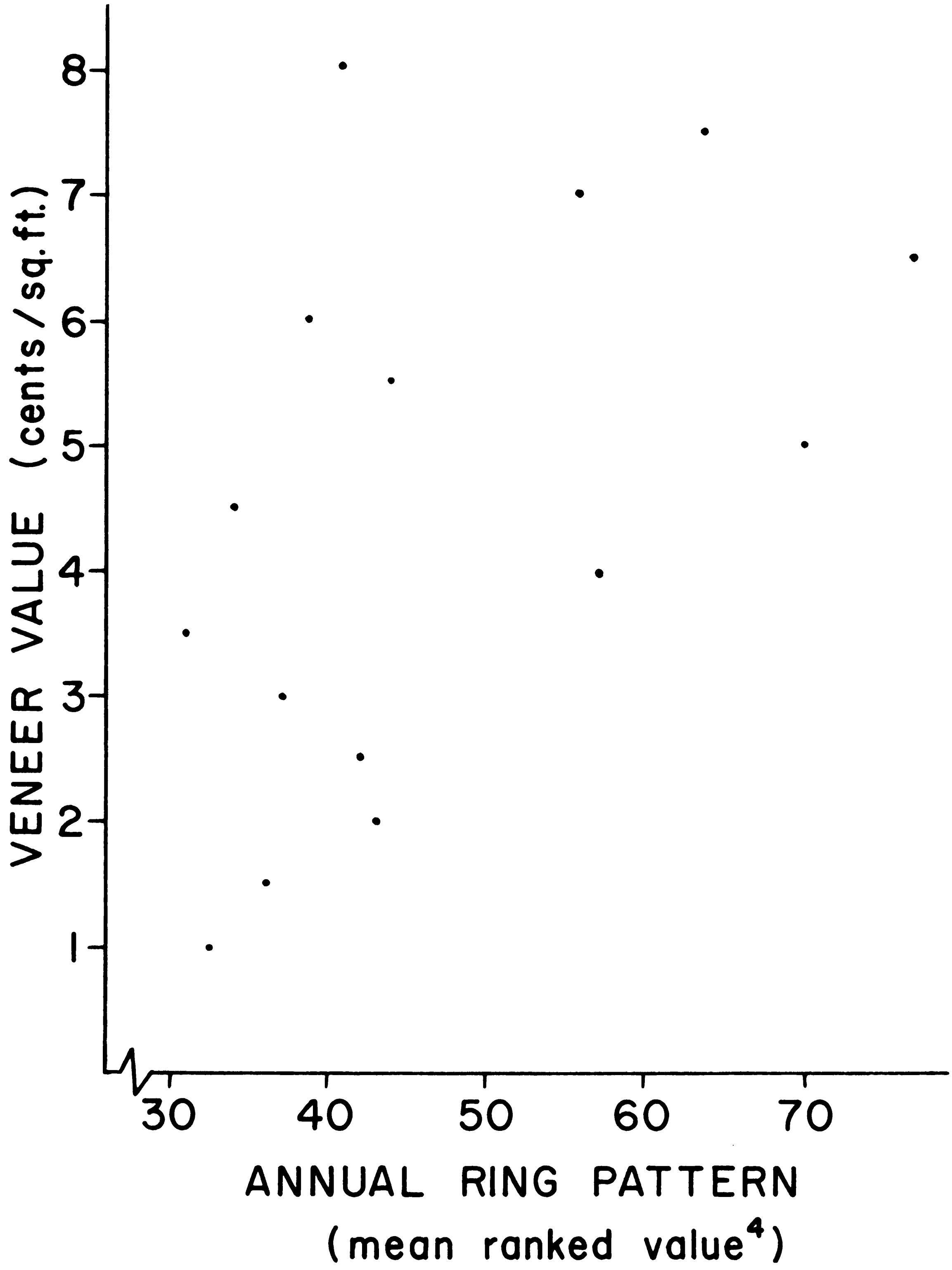


Figure 28. Veneer price as a function of annual ring pattern transformed to the fourth power.

Volume determination of the log as a conical section rather than a right cylinder was also investigated as a model improvement factor. Several rates of taper were used to calculate log volume. Models were also constructed to test alternate volume correction measures for log sweep and crook.

The effect of weighting log sectors two and three (see Figure 20A) heavier than sectors one and four (adjacent to flitch line) as a model improvement technique was also investigated. The logic being that if an equivalent defect appeared in the outside sector rather than the inside sector more useable veneer would result in the flitch. It would also be easier to remove a defect in the clipping operation if it appeared in the outside regions of the flitch.

Log bark distortions were classified into heavy, medium and light ranks for data collection purposes. A test regression model was developed to verify the assumptions of this procedure.

6. Results

The results of the initial analysis showed that 13.2 percent of the variability (R^2=13.2%) of the price per square foot could be accounted for by the 37 variables

included in this model. When the minimum size of clear cutting was varied between four and eight feet in length this percentage varied between 13 and 14, therefore, the variability increase due to clear cutting length change did not exceed one percent.

Table 3 summarizes the results of the testing of the various models. The dummy variable model analysis of log type resulted in a coefficient not significantly different from zero at the 10 percent level of confidence. Apparently other variables properly differentiated log quality differences between butt and upper log, or there was in fact no difference.

Veneer product (paneling-grade or furniture-grade veneer) proved to be a significant factor in the determination of veneer value. However, there were but slight differences in the variables that were significant in the two models and separation into two distinct log populations was not possible.

The volume correction models of heartwood, conical section and sector weighting results in no significant improvement in the predictive ability of the model. The sweep and crook correction factor models were also rejected for their inability to improve the model.

Table 3. Summary of model testing results.

Model	Results
Dummy Variable:	
Log type	No improvement
Veneer product	Statistically significant (no practical application)
Volume Corrections:	
Heartwood	No improvement
Conical log form	No improvement
Sector weighting	No improvement
Sweep and crook correction	No improvement
Clear Cutting Corrections:	
Influence of defects	Light bark distortion proved to be no defect

The systematic effort to determine the effect of minimum clear cutting widths of one sector, quarter and half-log faces and lengths of four, five, six and eight feet resulted in insignificant model differences. It was determined that there was a significant increase in the coefficient of multiple determination (R^2) if light bark distortions such as the one picture in Figure 29 were not allowed to interrupt clear cuttings.

Thirteen variables appeared significant at the 10 percent level in at least two of the 40 regression equations developed by all three selection processes in the above analysis. These variables were then analyzed as a combined product model by the backward selection process. The four variables shown in Table 4 were significant, and accounted for 19.6 percent of the variability of veneer quality. This was 6.6 percentage points above the initial model. Geographical log source accounted for 7.0 percent of the variability. Minimum cutting length, the next most important factor, 5.8 percent. Log length and ring pattern transformed to the fourth power were the other significant variables with 1.0 and 1.4 percent respectively.

It was expected that this regression analysis would show the nature of the relationships between independent

Figure 29. An example of light bark distortion defects not sufficiently severe to interrupt clear cuttings.

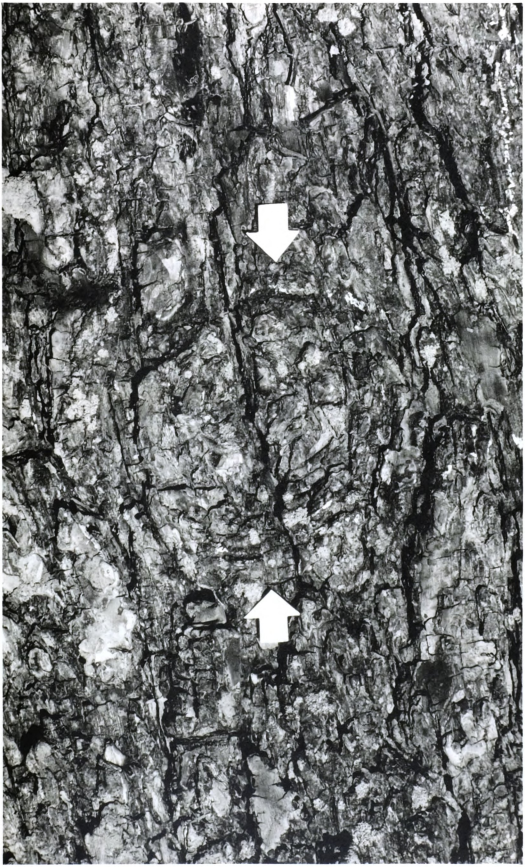


Table 4. Regression coefficients of independent variables significant for predicting price per square foot of walnut veneer.[a]

VARIABLE	REGRESSION COEFFICIENT	SIGNIFICANCE PERCENT[b]
Constant	1.5053	4.4
Minimum Cutting Length	.0215	5.8
Log Length	.0662	1.0
Geographical Log Source	.6825	7.0
Ring Pattern-To Fourth Power	.0025	1.4
		19.6

(a) Cutting width: half-log face.
(b) Minimum significance: 10 percent level.

and dependent variables, and would indicate that a final regression equation, or set of regression equations, composed of practical statistically important independent variables could be obtained to predict quality adequately. However, the computed regression, although statistically significant, accounted for a low portion of the total variance of veneer quality. Those variables having the highest correlation of all combinations of area veneer products and minimum clear cutting size were used as the basis for further analysis.

C. Discriminant Function

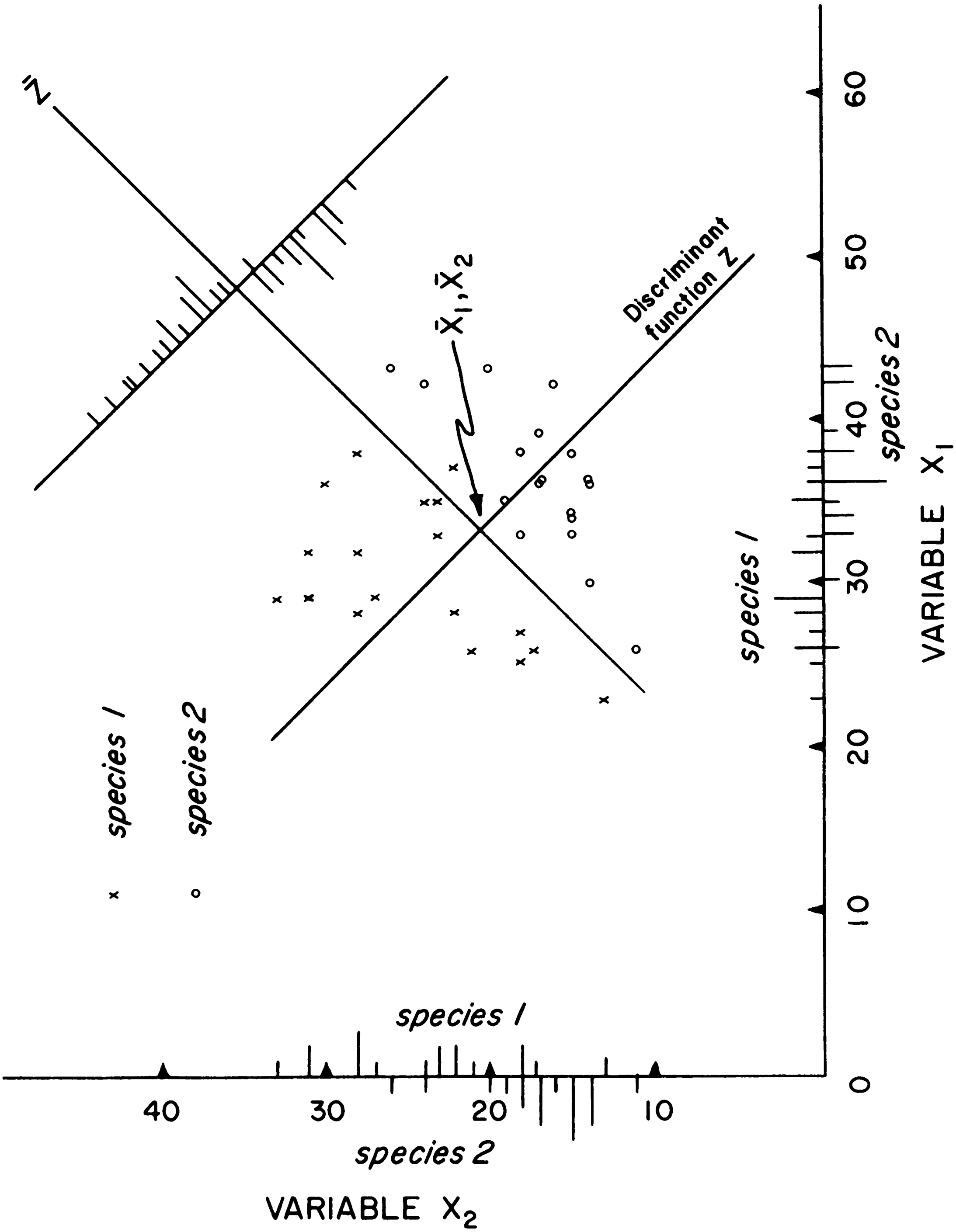
The technique of discriminant functions, although known since the thirties, has only recently (due to the availability of digital computers) been much applied to various biological fields (21). The basic problem it solves is easy to explain. Suppose we have two samples representing different populations, such as different sexes or possibly different species. We have measured one characteristic for them and find that though their means for this characteristic are not identical, their distributions overlap considerably. On the basis of this characteristic one could not, with any degree of accuracy, identify one unknown specimen as belonging to either of the two populations.

A second characteristic might also differentiate them somewhat, but not absolutely. An example of this is shown in Figure 30. This represents samples of two species plotted against two variables X_1 and X_2 commonly used to distinguish them. Regarded from the point of view of either X_1 or X_2, it would be impossible to assign an unknown specimen to either of the two species with any reasonable degree of certainty. The histogram along the coordinate axes make this clear.

Discriminant function analysis computes a new variable Z, which is a linear function of both variables X_1 and X_2. This function is of a type $Z = b_1 X_1 + b_2X_2$ which is the equation of a line cutting across the intermixed cluster of points representing the two species. This function is constructed in such a way that as many members of one population as possible have high values for Z and as many of the members of the other as possible have low values, so that Z serves as a much better discriminant of the two populations than does variable X_1 or X_2 taken singly.

This can be seen in Figure 30 by the line drawn parallel to the discriminant function on which a histogram of the Z-values (discriminant function scores) has been graphed. Note that except for a single individual of species 1, which

Figure 30. Illustration of a discriminant function.
Source: (21)



species 1
species 2
Discriminant function Z
Z'
$\bar{X}_1, \bar{X}_2$
VARIABLE X_1
VARIABLE X_2
0
10
20
30
40
50
60

is included with species 2, all other members of species 1 are in a group by themselves. Clearly, the discriminant function has served to separate the two groups. If you are faced with a new, unknown specimen, you would measure X_1 and X_2 for it, from these calculate a value of Z employing the previously calculated coefficients b_1 and b_2 and with an estimable degree of accuracy allocate the new individual to the correct group.

This is a very useful device whenever we need to identify unknown specimens and assign them to previously recognized groups. This is true in group identification where previous classes have already been established. Where the previous groups have not been established, discriminant function is of no assistance. Statistical tests are available to test the significance of the equations developed and the contribution of individual variables or sets of variables. These tests are very similar to those used in regression methods.

1. Model Testing

In our case this technique was used to classify logs into one of two groups in which the value of the veneer produced is significantly different. Two basic models were developed and tested. In model I veneer price was the basis

for assignment to the recognized groups for development of a predictive equation. Veneer with a value of 4.0 cents or more per square foot comprised the higher quality grade, below 4.0 cents, the lower grade. The variables listed in Table 5 were included in the analysis. They were selected on the basis that they were the eight most significant variables in the regression analysis.

For model II-A the assignment to the recognized groups was on the basis of the length of the longest clear cutting. Half-logs with a clear cutting of eight feet or longer were selected for the higher grade, between four feet and eight feet for the lower grade.

Model II-B was tested using the grade division of model II-A, but included only variables significant in the analysis of model II-A.

2. Results

The analysis of the model I resulted in a nonsignificant equation for distinguishing between the two grade classifications.

Model II-A resulted in a highly significant equation, the results of which are shown in Table 5. Two of the eight variables were significant at the 10 percent level. The results of model II-B are shown in Table 6. The equation

Table 5. Results of the discriminant analysis test of the two grade, eight variable model (model II-A).

Variable	Discriminant Coefficient	Significant (10% level)
Pin knots	0.1724	No
Sweep	-3.1403	No
Crook	-0.3503	No
Length	-1.1771	Yes
Minimum clear cut length	-0.1257	Yes
Geographical source	-0.2469	No
Ring pattern - fourth power	0.0015	No
Freshness	-0.2824	No

Table 6. Results of the two grade, two variable discriminant model (model II-B).

Function:

Variable	Coefficient	Significance Level
Length	-1.1349	0.001
Minimum clear cut length	-0.1230	0.001

Classification Matrix (logs):

	Grade			
Grade	1	2	Total	Correctly Assigned
1	63	3	66	95%
2	7	95	102	93%

Mean Value Difference:

Grade	Value Per Square Foot (cents)
1	3.91
2	4.32
	-0.41

for this model was also highly significant. Log length and minimum clear cutting length were the significant variables. The equation correctly assigned 95 percent (63 of 66) of the sample logs that were grade one to that grade, and 93 percent (95 of 102) of the sample logs that were grade two to that grade (see Table 6). The mean value difference per square foot of the veneer is 0.41 cents higher in the lower grade of logs.

CHAPTER VIII

ANALYSIS OF RESULTS AND CONCLUSIONS

A. Background

One objective of this study was to test the use of modern analytical procedures and statistical methods in an effort to predict the unit values of resulting veneer from the exterior characteristics of the log. A firm with such predictive capability and a knowledge of current selling, administrative and manufacturing costs could determine maximum raw material cost levels and still maintain a high probability of reaching predetermined profit goals. The purpose of this effort was to improve the current grading system in use by the study firm.

B. Analysis of Results

In summary, however, these modern analytical methods have not proven more successful than the present industry methods. Neither system really works but people in industry certainly know walnut timber; how to buy, process and sell the products. This discussion is in no way faulting the

system, for we have not been able to improve on it. What may have to be done is to improve or completely change the marketing system.

The ability of the initial model to account for only 13 percent of variability of the unit price of veneer with 37 variables is of little consequence. At least half (50 percent) of the variability should be explainable with a limited number of variables before a model would begin to be considered successful.

Model improvement techniques also failed to significantly improve the predictive ability of the regression equation. Four variables accounting for 19.6 percent of the variation of veneer unit cost in the final model cannot be considered satisfactory results.

The inability to develop a significant equation for distinguishing between grade classification by discriminant function methods can only be interpreted as failure for this method. This result confirms the low coefficient of multiple determination of the regression analysis. Efforts to separate log grades on the basis of clear area resulted in a significant equation but mean value difference was less than one-half cent per square foot.

Although only a small portion of the variability of veneer value can be accounted for, the study has identified those variables making this contribution. They are: minimum clear cutting length, log length, geographical log source, and ring pattern. This information should give direction to future research. The system developed for recording data, manipulating this data and the computer program for determination of the clear cutting variables is considered a significant contribution to timber quality study methodology.

C. <u>Conclusions</u>

The question is, of course, what factors have been identified as being responsible for failure of the quantitative methods and what conclusions have resulted from the analysis of the study firm's purchasing, processing, and marketing system. The factors and conclusions fall into two general classifications, they are: (1) marketing system limitations (2) buying system limitations.

1. Marketing System Limitations

a. Veneer grading. Perhaps the most serious limitation of the current walnut veneer marketing system is the lack of objective veneer grading rules. The current system lacks one of the basic requirements of a grading system; that is, the end products must have well-defined standards or grades before a grading system can be developed for logs that produce that end product. This is a general industry limitation and not one applying specifically to the study firm. Grading rules similar to the hardwood lumber grades could be developed. Clear cutting lengths could be specified with defect definitions developed to specify defects which would interrupt the cuttings. Yield in percent clear veneer for each grade could be specified. This limitation weakens the statistical analysis by introducing error in the dependent variable - price per square foot of the veneer.

b. Pricing. There is sufficient evidence to conclude that the study firm's marketing inexperience is seriously limiting its profit potential. Cumulative frequency distribution curves of unit veneer price of the sample data taken from the study firm and inventory data from a competitive firm are shown in Figure 31. There is an obvious difference in these price distributions. It should be noted here that information from the competitor firm became available after the study was completed. The veneer price range for the study firm is 1.0 to 8.0 cents per square foot; while the competitor price range is 3.0 to 60.0 cents. The data also identifies significant differences in price distribution at the higher value levels. The top 10 percent of unit veneer

Figure 31. Cumulative frequency distribution of veneer price, study firm vrs. competitor firm.

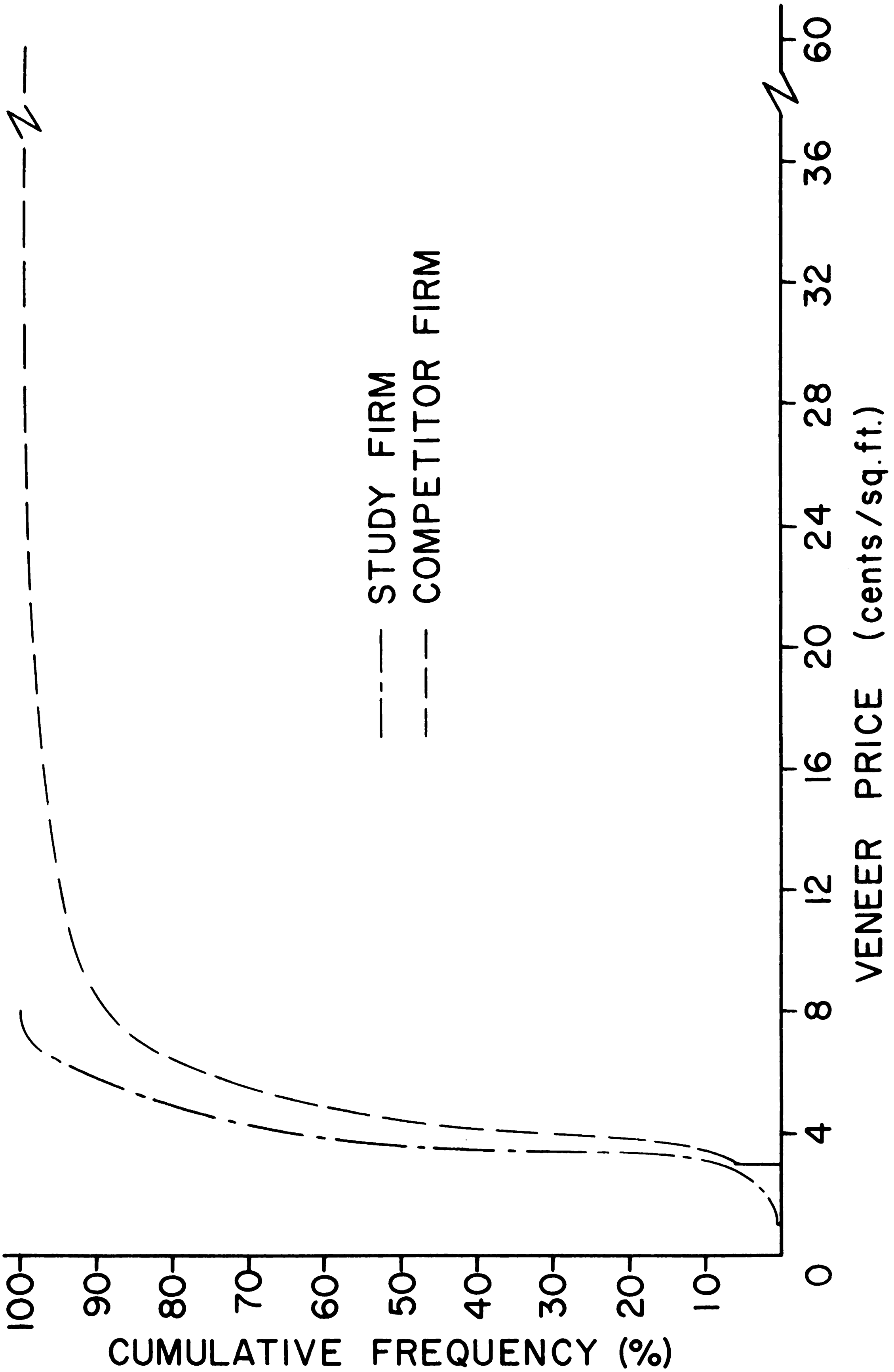

STUDY FIRM
COMPETITOR FIRM
CUMULATIVE FREQUENCY (%)
0
10
20
30
40
50
60
70
80
90
100
4
8
12
16
20
24
28
32
36
60
VENEER PRICE (cents/sq.ft.)

Table 7. A comparison of the differential pricing policies of the study firm and a competitor. (20,000,000 S.F./year production)

Quality Class	Study Firm		Competitor	
	average price (¢/SF)	yearly income (dollars)	average price (¢/SF)	yearly income (dollars)
All Walnut Veneer	4.10	820,000	6.16	1,231,200
Top 10% of Quality	6.12	122,400	17.29	345,980

prices range from 5.8 to 8.0 cents for the study firm; the competitor firm from 8.0 to 60.0 cents per square foot.

This evidence identifies possible causes for failure of the regression models. One could not expect the model to explain price variation from independent variables if unit price differentials were present but not identified in the dependent variable. That is, the log characteristics (independent variables) may have been at such levels that 15 cents per square foot veneer (dependent variable) would have been predicted; the veneer may have been of that value, but was incorrectly priced at eight cents. Under these conditions it is obvious that mathematical models would fail.

The effect on yearly income generation of this price differentiation is presented in Table 7. Annual income for the equivalent production (20 MM square feet) by the competitor is $411,200 greater than that of the study firm. The raw material acquisition cost is not available for the competitor. These costs can not be expected to vary greatly; for both function in the same purchasing environment. Real income differences are evident when the top 10 percent of the price ranges are analyzed. The income increment from this portion of production for the competitor is over

$223,000 - more than one-fourth the projected annual income of the study firm.

c. Specialized Markets. In addition to imperfect pricing, the study firm lacks general marketing expertise. It has identified very few specialized markets; lacks the experience to identify these veneers; and fails to hold uniquely figured flitches in inventory to meet market opportunities. For example, a furniture company in North Carolina has designed a bedroom suite with highly figured walnut veneer. This unique grain figure is caused by pin knots. A limited number of pin knots generally result in degrade of otherwise high quality veneer. However, when pin knots appear in excessive numbers highly figured veneer results. Without knowledge of this specialized market, veneer with numerous pin knots may be priced as low quality rather than high quality and may not be inventoried for this specialized market.

Value determination of domestic veneer should be the basis for value estimation of domestic veneer logs (Figure 2). Impinging upon this valuation process is, however, competition from export veneer markets and lumber conversion markets. The real competition for domestic logs is the export veneer log market. Why is this so? Apparently the Europeans obtain more value from the products of the logs than do domestic producers. It would seem a logical move by the study firm to determine what product or products the European veneer mills produce and take steps to obtain a share of this market. Domestic firms would have certain competitive advantages. Transportation costs would be one, for water lost in drying and conversion residue would be a significant weight factor. Knowledge of walnut timber sources, supply, quality and market alternatives would be others.

d. Supply-Demand Disruptions. There are additional influences of the competition from the export veneer log market on domestic veneer log purchasing systems. Until the export market developed for walnut logs the supply-demand-price relationship was in balance. The veneer conversion industry was generally assured a "fair" profit or return on their investment. When the export market for logs developed, the supply-demand-price equilibrium was disturbed. The length of time taken to restore equilibrium has been prolonged by: (1) the temporary export limit on logs in 1964 (2) the inconsistent action of foreign buyers in the market place (3) the lack of innovative action by domestic veneer production and marketing units to meet this challenge (4) a somewhat erratic demand for domestic walnut veneer products since 1968.

e. Innovative Action. With system improvement our goal, the custom of marketing domestic veneer flitches intact should also be questioned. This practice has direct influence on marketing efficiency and raw material evaluation. The key to the general concept is in this fact of processing: at each stage a single input unit is transformed into two or more output units. Each output unit may be a different product or different grade. The output units can be evaluated more precisely than can the input unit because they are one step nearer final use and can be inspected more completely. This concept suggests the study firm investigate the alternative of processing individual flitches into products. Veneer should be allocated to that market which would maximize its dollar return. Certain flitches would be marketed intact; others divided into two or more products. This output information from an improved processing and marketing system could be used to improve the raw material evaluation and log-costing system.

2. Buying System Limitations

a. Grading Half-logs. There are certain buying system improvements that warrant consideration if system improvement is our goal. Application of grading rules to half-logs should warrant consideration. Processing and

marketing is based on half-log flitches. Why, then, limit evaluation to full logs? Evidence from this study indicates there are but two domestic veneer log quality classes. If half-logs were graded, four, rather than two, unit price levels could be established for each log.

b. Buyer Training. Other system controls that warrant investigation are more thorough training of log buyers and developing an incentive plan based on profit from logs purchased by the individual log buyers.

LITERATURE CITED

LITERATURE CITED

1) Quigley, K. L. and R. D. Lindmark, A Look at Black Walnut. U.S. For. Serv., Northeastern For. Exp. Sta. Resource Bulletin NE-4, 28 pp., 1967.

2) Hair, D. and A. H. Ulrich, The Demand and Price Situation for Forest Products 1969-70. U.S. For. Serv. Division of Forest Economics and Marketing Research, Misc. Pub. No. 1165, 79 pp., 1970.

3) Chapman, H. H. and W. H. Meyer, Forest Mensuration, McGraw Hill Book Co., Inc., New York, N.Y., 522 pp., 1949.

4) Forest Products Laboratory, Overall Work Plan for Development of Log and Bolt Grades for Hardwoods, U.S. For. Serv., For. Prod. Lab., Report TGUR-16, 62 pp., 1958.

5) Ostrander, M. D., A Guide to Hardwood Log Grading (Revised), U.S. For. Serv., NE. For. Exp. Sta., 50 pp., 1965.

6) Newport, Carl, C. R. Lockard and L. Vaughan, Log and Tree Grading as a Means of Measuring Quality, U.S. For. Serv. (Limited Distribution), 45 pp., 1958.

7) Anon., Hardwood and Decorative Plywood, NBS Voluntory Product Standard PS51-71, U.S. Dept. of Com., 16 pp., 1971.

8) Stayton, C. L., R. M. Morden, R. G. Buchman, Exterior Defects Indicators and Their Associated Interior Defects in Sugar Maple, Forest Products Journal, Vol 20, No. 2, pp. 55-58, Feb., 1970.

9) Lane, P. H., Evaluating Log and Tree Quality for Wood Products, Forest Products Journal, Vol. 13, No. 3, pp. 89-93, March, 1963.

10) Gaines, E. M., Log and Tree Quality Concepts in the Computer Age, Society of American Foresters, Proceedings, 1965.

11) _____________, Analytical Methods for Studying Timber Quality From Tree to End Product, Proceeding IUFRO, Section 41, Oct., 1965.

12) Henley, J. W., E. H. Bulgrin, H. H. Haskell and R. O. Woodfin, Jr., Work Plan For Hardwood Veneer Log and Bolt Grade Development, U.S. For. Serv., For. Prod. Lab. (Limited Distribution Copy), 13 pp., 1963.

13) Bulgrin, Erwin H., Hardwood Tree Diagramming Manual, U.S. For. Serv., Central States For. Exp. Sta., Manual No. 1, 48 pp., 1964.

14) Moslemi, Ali A., Wood Color Evaluation: Some Tools and Considerations, School of Agriculture Publication No. 30, Southern Illinois University, Carbondale, Ill., 19 pp., 1967.

15) Draper, N. R. and H. Smith, Applied Regression Analysis, John Wiley & Sons, Inc., New York, N.Y., 1966.

16) Freese, Frank, Linear Regression Methods for Forest Research, U.S. For. Serv., Research Paper FPL 17, Madison, Wis., 1964.

17) Ezekial, M. and K. A. Fox, Methods of Correlation and Regression Analysis, Ed. 3, John Wiley & Sons, New York, N.Y., 1959.

18) Anon., Least Squares-Multiple Regression, Ag. Exp. Sta., Library Prog. No. 7, Mich. State Univ. East Lansing, Mich., 128 pp., 1967.

19) _____, Least Squares-Multiple Regression Variable Deletion, Ag. Exp. Sta., Library Prog. No. 8, Mich. State Univ., East Lansing, Mich., 38 pp., 1967.

20) _____, Least Squares-Multiple Regression Variable Addition, Ag. Exp. Sta., Library Prog. No. 9, Mich. State Univ., East Lansing, Mich., 32 pp., 1967.

21) Sokal, Robert R. and F. James Rohf, Biometry: The Principles and Practice of Statistics in Biological Research, W. H. Freeman and Company, San Francisco, Calif., 776 pp., 1969.

APPENDICES

APPENDIX I

Input variable number, description, measurement unit, code and format of program LOGAN.

No.	DESCRIPTION	UNITS	CODE	COL-UMNS	FORMAT
1	Unique individual half-log number	---	IHLN	1-3	I3
2	Flitch number	---	IFLN	4-8	I5
3	Disposition of other half-log	Coded	IDHLT	9	I1
4	Other half-log unique number	---	IQHL	10-12	I3
5	Log type (butt or upper)	Coded	LTP	13	I1
6	Stain level	Coded	ISTAIN	14	I1
7	Grain contrast level	Coded	ICON	15	I1
8	Color level	Coded	ICOLOR	16	I1
9	Annual ring pattern	Coded	IRPAT	17	I1
10	Log freshness	Coded	IFRESH	18	I1
11	Log length	Tenths feet	ALLEN	19-21	F3.1
12	Amount of log sweep	Tenths inches	ASWEEP	23-24	F2.1
13	Direction of sweep	Coded	DSWEEP1	25	F1.0
14	Direction of sweep	Coded	DSWEEP2	26	F1.0

APPENDIX I (cont'd.)

No.	DESCRIPTION	UNITS	CODE	COLUMNS	FORMAT
15	Amount of crook	Tenths inches	ACROOK	27-28	F2.1
16	Distance crook from small end	Tenths feet	ACROOK	29-31	F3.1
17	Direction of crook	Coded	DCROOK1	32	F1.0
18	Direction of crook	Coded	DCROOK2	33	F1.0
19	Spiral grain	Tenths inches	SPRGR	34-35	F2.1
20	Pin knots visible	#/S.F.	PINK	36-37	F2.1
21	Diameter - Small End	Tenths inches	DIAS	38-40	F3.1
22	Sap thickness - Small End	Tenths inches	SAPTS	41-42	F2.1
23	Bark thickness - Small End	Tenths inches	BARKTS	43-44	F2.1
24	Pith displacement, SE	Tenths inches	AHCS	45-46	F2.1
25	Direction pith displacement, SE	Coded	DHCS1	47	F1.0
26	Direction pith displacement, SE	Coded	DHCS2	48	F1.0
27	Diameter - Large End	Tenths inches	DIAL	49-51	F3.1
28	Sap thickness - Large End	Tenths inches	SAPTL	52-53	F2.1

APPENDIX I (cont'd.)

No.	DESCRIPTION	UNITS	CODE	COL-UMNS	FORMAT
29	Bark thickness - Large End	Tenths inches	BARKTL	54-55	F2.1
30	Pith displacement, LE	Tenths inches	AHCL	56-57	F2.1
31	Direction pith displacement, LE	Coded	DHCL1	58	F1.0
32	Direction pith displacement, LE	Coded	DHCL2	59	F1.0
33	Growth rate uniformity	Coded	IRING	60	F1
34	Visibility of new bark growth	Coded	BARKNV	61	F1.0
35	New bark color	Coded	BARKNC	62	F1.0
36	Old bark vigor (weathering)	Coded	BARKOW	63	F1.0
37	Length, receiving	Full foot	RLENG	64-65	F2.0
38	Diameter, receiving	Full inch	RDIA	66-67	F2.0
39	Log grade, receiving	Grade	RGRADE	68	R1
40	Log grade, buyer	Grade	BGRADE	69	R1
41	Log buyers identification number	Coded	IBUY	70-71	I2
42	Buyer assigned lot number	---	ILOT	72-74	I3
43	Geographical log source	Coded	IAREA	75-77	I3

APPENDIX I (cont'd.)

No.	DESCRIPTION	UNITS	CODE	COL-UMNS	FORMAT
44	Flitch volume	Actual Bd.Ft.	FLFOOT	78-80	F3.0
45	Bird Peck	#/S.F.	IBPECK	22	I1
		SECOND DATA CARD			
46	No. 1 Repeated	---	IHLN	1-3	I3
47	Log cost, actual dollars	$ & ¢	PRICEL	4-8	F5.2
48	Veneer length	Tenths feet	VLEN	9-11	F3.1
49	Footage, veneer	Sq.Ft.	VFTAGE	12-15	F4.0
50	Veneer price	¢/S.F.	VPRIC	16-17	F2.3
51	Veneer grade	---	VGRAD	18-19	R2
52	Number log defects	---	NUMD	20	I1
53	<u>Sector</u> of defect location*	---	ISECT	21	I1
54	Beginning <u>section</u> of defect	---	IBEG	22-23	I2
55	Ending <u>section</u> of defect	---	IEND	24-25	I2
56	Defect severity level	---	ILEV	26	I2

*Defect information in columns 21 to 26 repeated nine times to accept up to ten defect specifications.

APPENDIX II

Variable classification and measurement unit of field data.

Continuous:

Variable	Measurement Unit
Length	0.1 ft.
Sweep	0.1 in.
Crook	0.1 in.
Crook-distance from small end	0.1 ft.
Diameter-small end	0.1 in.
Sapwood thickness-small end	0.1 in.
Bark thickness-small end	0.1 in.
Pith displacement-small end	0.1 in.
Diameter-large end	0.1 in.
Sapwood thickness-large end	0.1 in.
Pith displacement-large end	0.1 in.

Discontinuous:

Log defects	number

Ranked:

	Level
Stain	5
Grain contrast	5
Color	5
Annual ring pattern	4
Log freshness	3
Bird peck	3
Bark growth visibility	3
New bark color	3
Old bark vigor	3

APPENDIX II (cont'd.)

Attribute:

	Level
Log type	2
Growth rate uniformity	2
Sweep direction	sector
Crook direction	sector
Pith displacement direction-small end	sector
Pith displacement direction-large end	sector
Defect location	sector
Defect location, beginning	section
Defect location, ending	section
Defect severity, level	2
Geographical log source	419

Computed:

	Measurement Unit
Pin knots	#/SF
Spiral grain	0.1 inches in 2 ft.

Veneer Yield Data:

Length	0.1 ft.
Area	sq. ft.
Unit price	¢/sq. ft.

APPENDIX III

Magnitude boundaries of ranked variables.

Stain (Evaluated after end trim):

1 = None
2 = Evidence to 2% end area
3 = More than 2% to 10%
4 = More than 10% to 50%
5 = More than 50%

Grain contrast level:

Grain contrast is defined as the distinct shading of the annual rings that makes a grain pattern apparent.

1 = Uniform color of growth rings except it is several shades darker at the summerwood boundary. Desirable.

2 = (a) Only slight shading of summerwood boundary resulting in faintly apparent annual rings, or,

(b) Dark summerwood boundary area resulting in pronounced annual ring appearance.

3 = (a) Lack of darkening of summerwood boundary resulting in uniform shade of annual rings.

(b) Very dark late summerwood boundary resulting in extremely pronounced annual ring appearance.

4 = Distinct bands of several annual rings alternating light and dark shades with gradual shade transition. Little or no annual ring appearance.

5 = Distinct bands of several annual rings of alternating light and dark shades and transition abrupt. Includes abrupt shade change between and along annual ring.

APPENDIX III (cont'd.)

Color level:

0 = Masked by pathological stain.
1 = Grey to light brown.
2 = Light brown to medium brown.
3 = Medium brown to dark brown with slight purple and reds.
4 = Range of colors, heavy to purple and reds.

Annual ring pattern:

1 = Uniform - ring width, concentric pattern.
2 = Slight - from distinguishable variation to 1/3 ring width variation. Slight variation from normal concentricity (to 1/4 inch per inch diameter).
3 = Medium - up to 100% variation of average ring width along and between annual rings. Medium variation from concentricity (1/4 to 3/4 inch per inch diameter).
4 = Wild - greater than medium limit in either or both characteristics.

Log freshness:

1 = No sign of stain or weathering.
2 = Slight indication of presence of stain and weathering.
3 = Heavy presence of stain, weathering and checking of log end.

Bird peck:

0 = None - no visible indication of occurance.
1 = Slight - any indication of occurance in an area not greater than 0.5 square foot.
2 = Heavy - any indication of occurance in more than one location or one area greater than 0.5 square foot.

Visibility of new bark growth:

1 = Not visible.
2 = Slightly visible.
3 = Distinctly visible.

APPENDIX III (cont'd.)

New bark color:

1 = Bright
2 = Medium
3 = Dull

Old bark vigor:

1 = Fissures long, shallow, sharply edged
2 = Fissures broken, deep, eroded edges
3 = Fissures short, bark cross broken

Geographical log source:

111 to 999, First digit identifies state, second, groups of counties within state and third identifies individual counties with group. Classified study corporation information.

APPENDIX IV

Output variable number, description, measurement unit, code and format of program LOGAN.

No.	DESCRIPTION	UNITS	CODE	COL-UMNS	FORMAT
1	Unique individual half-log number	---	N	2-4	I3
2	Minimum length of cutting allowed	---	CUT	5-6	F2.0
3	Number section, cutting width	---	NS	7	I1
4	Log type	Coded	LTP	8	I1
5	Stain level	Coded	ISTAIN	9	I1
6	Grain contrast level	Coded	ICON	10	I1
7	Color level	Coded	ICOLOR	11	I1
8	Annual ring pattern	Coded	IRPAT	12	I1
9	Log freshness	Coded	IFRESH	13	I1
10	Bird peck	Coded	IBPECK	14	I1
11	Growth ring uniformity	Coded	IRING	15	I1
12	Log buyer identification	Coded	IBUY	16-17	I2
13	Geographical log source	Coded	IAREA	18-20	I3
14	Spiral grain	Tenths inches	SPRGR	21-24	F4.1

APPENDIX IV (cont'd.)

No.	DESCRIPTION	UNITS	CODE	COL-UMNS	FORMAT
15	Pin knots visible	#/SF	PINK	25-28	F4.1
16	Average bark vigor rating	Coded	AUBKFA	29-32	F4.1
17	Amount of log sweep	Tenths inches	ASWEEP	33-36	F4.1
18	Amount of log crook	Tenths inches	ACROOK	37-40	F4.1
19	Mean sap thickness	Tenths inches	SAPTA	41-44	F4.1
20	Mean pith displacement	Tenths inches	ANCA	45-48	F4.1
21	Mean bark thickness	Tenths inches	BARKTA	49-52	F4.1
22	Log length	Tenths feet	ALLEN	53-56	F4.1
23	Diameter small end	Tenths inches	DIAS	57-60	F4.1
24	Diameter large end	Tenths inches	DIAS	61-64	F4.1
25	Receiving length	Full foot	RLEN	65-66	F2.0
26	Receiving diameter	Full inch	RDIA	67-68	F2.0
27	Receiving log grade	---	LT	69-70	I2
28	Log cost	Dollars & cents	RLPRIC	71-76	F6.2

APPENDIX IV (cont'd.)

No.	DESCRIPTION	UNITS	CODE	COL-UMNS	FORMAT
	SECOND CARD				
29	Number 1 repeated for identification	---	N	1-3	I3
30	Number 2 repeated for identification	---	CUT	4-5	F2.0
31	Number 3 repeated for identification	---	NS	6	I1
32	Volume half-log	Actual Bd.Ft.	VOL	7-11	F5.1
33	Corrected volume	Actual Bd.Ft.	CVOL	12-16	F5.1
34	Volume clear wood, surface division	Actual Bd.Ft.	CLOUTV	17-21	F5.1
35	Volume clear wood, center division	Actual Bd.Ft.	CLINV	22-26	F5.1
36	Volume clear wood, both divisions	Actual Bd.Ft.	NETCUT	27-31	F5.1
37	Per cent volume, both divisions	Percent	PCL	32-37	F6.1
38	Total clear wood	Actual Bd.Ft.	TCW	38-43	F6.1
39	Number of clear cuts per half-log	---	NCUT	44-45	I2
40	Number of clear cuts surface division	---	NUCUT	46-47	I2

APPENDIX IV (cont'd.)

No.	DESCRIPTION	UNITS	CODE	COL-UMNS	FORMAT
41	Number of clear cuts center division	---	NLCUT	48-49	I2
42	Length of minimum cutting encountered	Tenths feet	CMIN	50-53	F4.1
43	Veneer footage recovered	Sq.Ft.	VCTAGE	54-57	F4.0
44	Veneer price	Cents	VPRIC	58-63	F6.3
45	Veneer grade	---	IVT	64-65	I2
46	Veneer length	Tenths feet	VLEN	66-69	F4.1
47	Veneer value	Dollars ¢ cents	VVALU	70-74	F5.1
48	Weighting factor for sections	---	WT23FAC	75-80	F6.1

APPENDIX V

Variable classification and measurement unit after preliminary computations.

Continuous:

Variable	Measurement Unit
Length	0.1 ft.
Diameter-small end	0.1 in.
Diameter-large end	0.1 in.
Crook	0.1 in.
Sap thickness-mean	0.1 in.
Pith displacement-mean	0.1 in.
Bark thickness-mean	0.1 in.

Discontinuous:

Log defects	number
Clear cuts-half log	number
Clear cuts-surface section	number
Clear cuts-center section	number

Ranked:

	Level
Stain	5
Grain contrast	5
Color	5
Annual ring pattern	4
Log freshness	3
Bird peck	3
Growth rate uniformity	2
Bark vigor	3
Geographical log source	2
Log type	2

APPENDIX V (cont'd.)

Computed:

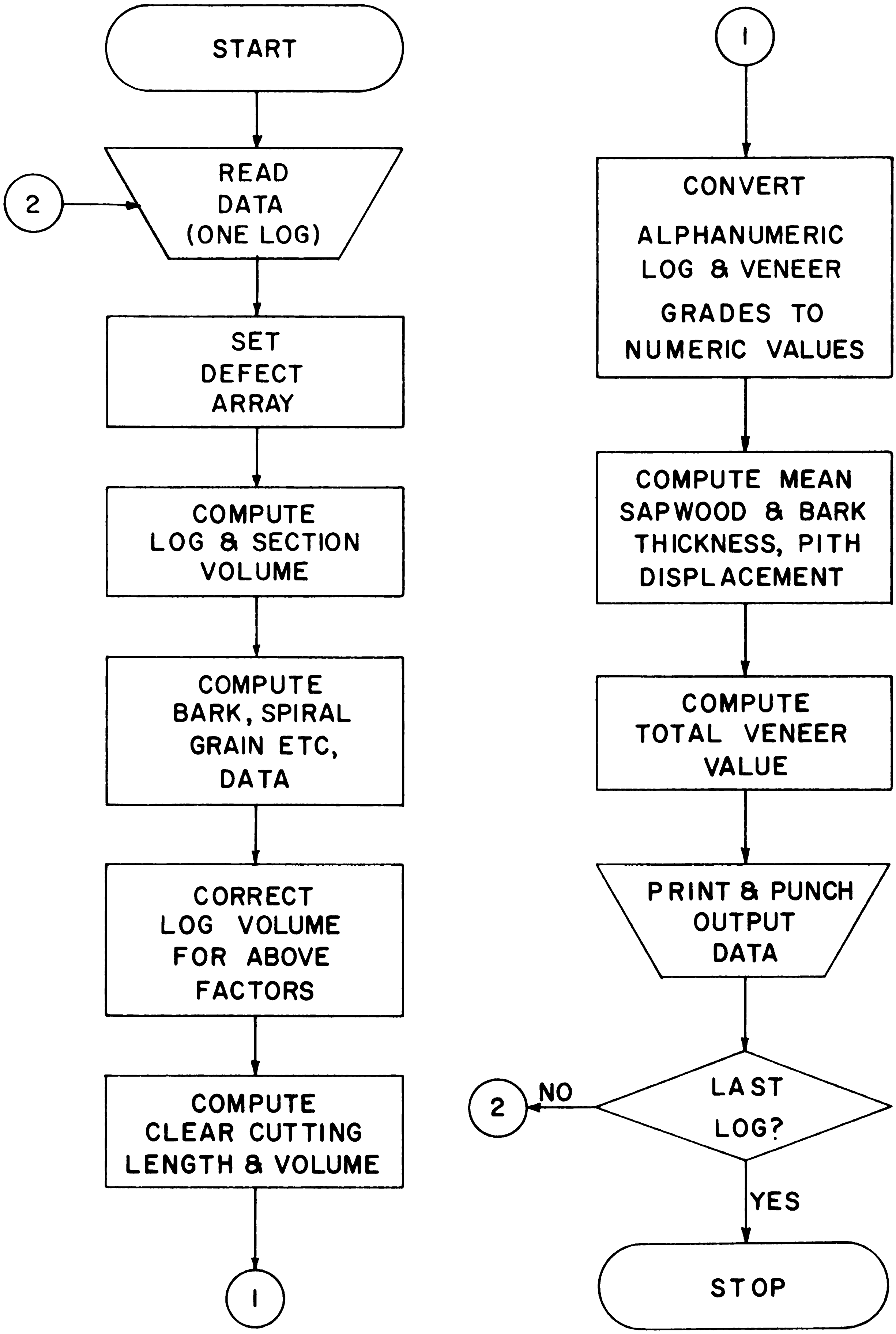
Pin knots	No./Sq. Ft.
Spiral grain	0.1 in./ft.
Sweep	0.1 in./ft.
Volume-corrected	B.F.
Clear wood volume-surface section	B.F.
Clear wood volume-center section	B.F.
Clear wood volume-total	B.F.
Clear wood percentage of total volume	%
Clear wood	B.F.
Clear cutting length-maximum	0.1 ft.
Section weighting factor	Ratio

Veneer Yield Data:

Length	0.1 ft.
Area	Sq. Ft.
Unit price	¢/Sq. Ft.

APPENDIX VI

Flow chart of computer program LOGAN.


START
READ
DATA
(ONE LOG)
2
SET
DEFECT
ARRAY
COMPUTE
LOG & SECTION
VOLUME
COMPUTE
BARK, SPIRAL
GRAIN ETC,
DATA
CORRECT
LOG VOLUME
FOR ABOVE
FACTORS
COMPUTE
CLEAR CUTTING
LENGTH & VOLUME
1
1
CONVERT
ALPHANUMERIC
LOG & VENEER
GRADES TO
NUMERIC VALUES
COMPUTE MEAN
SAPWOOD & BARK
THICKNESS, PITH
DISPLACEMENT
COMPUTE
TOTAL VENEER
VALUE
PRINT & PUNCH
OUTPUT
DATA
LAST
LOG?
NO
2
YES
STOP