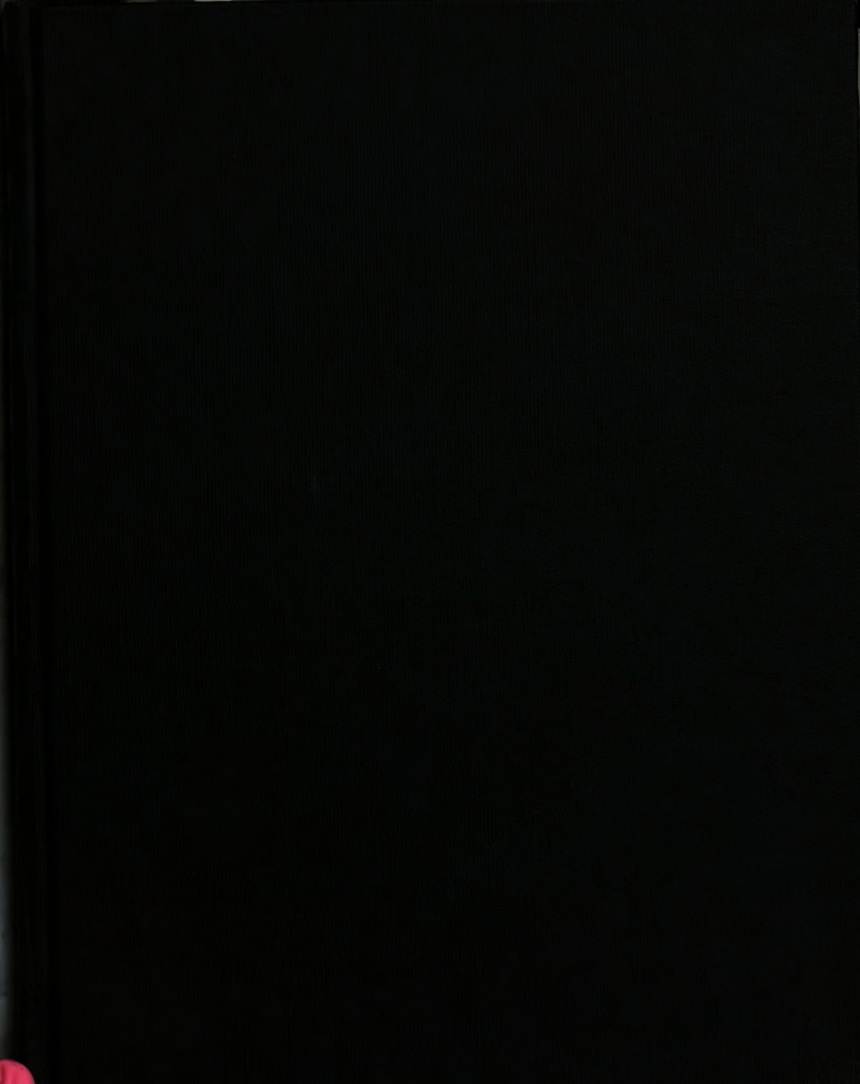
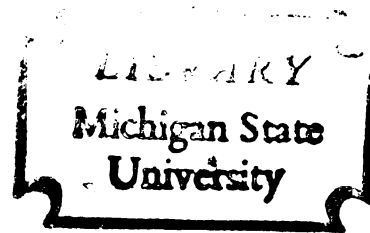






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ANALYSIS OF ROUGH MILL FIELD STUDIES

presented by

Edward King Pepke

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Ph.D. degree in Forestry

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Major professor

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ANALYSIS OF ROUGH MILL FIELD STUDIES

By

Edward King Pepke

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Forestry

1980

ABSTRACT

ANALYSIS OF ROUGH MILL FIELD STUDIES

By
Edward King Pepke

2-11-74 A.S.D.

The analysis of ten rough mill field studies determined that the Optimum Furniture Cutting Computer Program (OFCCP) provides a valuable service in assisting the wood products manufacturing industry in procuring and processing hardwood lumber. The cost and yield studies performed in rough mills of furniture and wood dimension parts manufacturing companies resulted in sufficient information for comparison to the OFCCP's predictions for yields, costs, and grades to process. For all the data combined, the companies' actual yields came to an average weighted by lumber volume of 64.7 percent, 0.6 percent higher than the computer predicted weighted average of 64.1 percent. If the computer program's feature of customizing the yield tables to the individual company's performance needed for specific company applications, was incorporated the computer could simulate both the exact yield and cost for a company.

The OFCCP follows the same basic steps a firm uses when purchasing lumber. Since the steps are the same and yield predictions are accurate, the program can be and is

being used by companies to purchase and process hardwood lumber. The program will output the least cost grade, yields, lumber volumes, costs, and other information for the company's cutting bill piece requirements (part sizes and quantities), and the associated costs of lumber, processing, overhead, and other costs.

The diverse nature of the wood products industry's products, production methods, and raw materials represented in the ten sample companies used in this study precluded the reporting of simple savings figures from use of the OFCCP. The grade mix was examined and the processing efficiency was analyzed to determine if the OFCCP has any effect on lumber usage and rough mill costs. By improving efficiency to the computer program's standards some companies would save substantially--up to \$250,000 in cost and 549 thousand board feet (MBF) annually. These are "potential" savings and might never be fully realized by a company due to limitations of plant design, capacity, labor efficiency, lumber availability, and other factors. However, some of the companies presently perform at or exceed the yield table standards resulting in no savings through improved efficiency.

Similarly, the choice of grades to use (predicted by the computer program) was compared to the grades actually used by the company. The potential cost savings ranged from \$49,000 to \$2,523,000 and from 122 MBF to 1056 MBF annually by using the optimum grade mix for the particular cutting

bill requirements and associated costs. Again, the high value probably would never be reached due to various constraints affecting a specific company's operations. The opportunity for cost and lumber savings does exist in many hardwood lumber processing companies through use of the Optimum Furniture Cutting Computer Program.

ACKNOWLEDGEMENTS

The research for this doctoral dissertation began in March 1977 under a graduate assistantship program jointly sponsored by the Department of Forestry at Michigan State University and the USDA Forest Service, Northeastern Area, State and Private Forestry. While a student at Michigan State University, the advice and teachings of all my professors in forestry and the business management fields provided the basic foundation for my career in forest products technology.

While employed by the USDA Forest Service's Northeastern Area State and Private Forestry, my job duties fortunately correlated well with the ten cost and yield studies necessary for this dissertation. Since the information obtained from the ten studies was needed by the Forest Service, time was provided to perform research for and write this dissertation. The author appreciates the encouragement and support offered by his employer towards obtaining the Ph.D. degree.

The author also appreciates the assistance obtained from his major professor and advisor Dr. Henry A. Huber. The guidance offered by my professors and current committee members Dr. Alan Sliker, Dr. Otto Suchsland, Dr. Stephen Harsh, and Dr. Phillip Carter was essential to completion

of this dissertation and my doctoral degree. The support of my family and friends in pursuit of my goals and interests was crucial to completion of this endeavor.

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CHAPTER I

INTRODUCTION

Hardwood lumber users compose the core of the furniture and dimension (semi-finished wood parts of specific size for remanufacture) industry in the United States. Historically, the supply of high quality lumber for the industry has been readily available at relatively low prices; but in the last few decades, the extensive use of hardwood timber for furniture, pallets, railroad ties, and other purposes has seriously depleted the current resources. Conversion of prime hardwood timber growing land in the United States to pine (softwood) plantations, agriculture, utility and transportation right-of-ways, and urban and industrial development sites threatens the present and future of quality hardwoods. Even with heightened interest in growing quality hardwood timber and in improving management of the present hardwood forests, unfavorable economic conditions will continue to plague lumber consumers.

The economics facing the manufacturer employing hardwood lumber as a basic raw material can best be described graphically. Figure 1.1, "Producer Price Indexes vs. Time", illustrates that the producer price indexes (formerly "wholesale price index") for hardwood lumber,

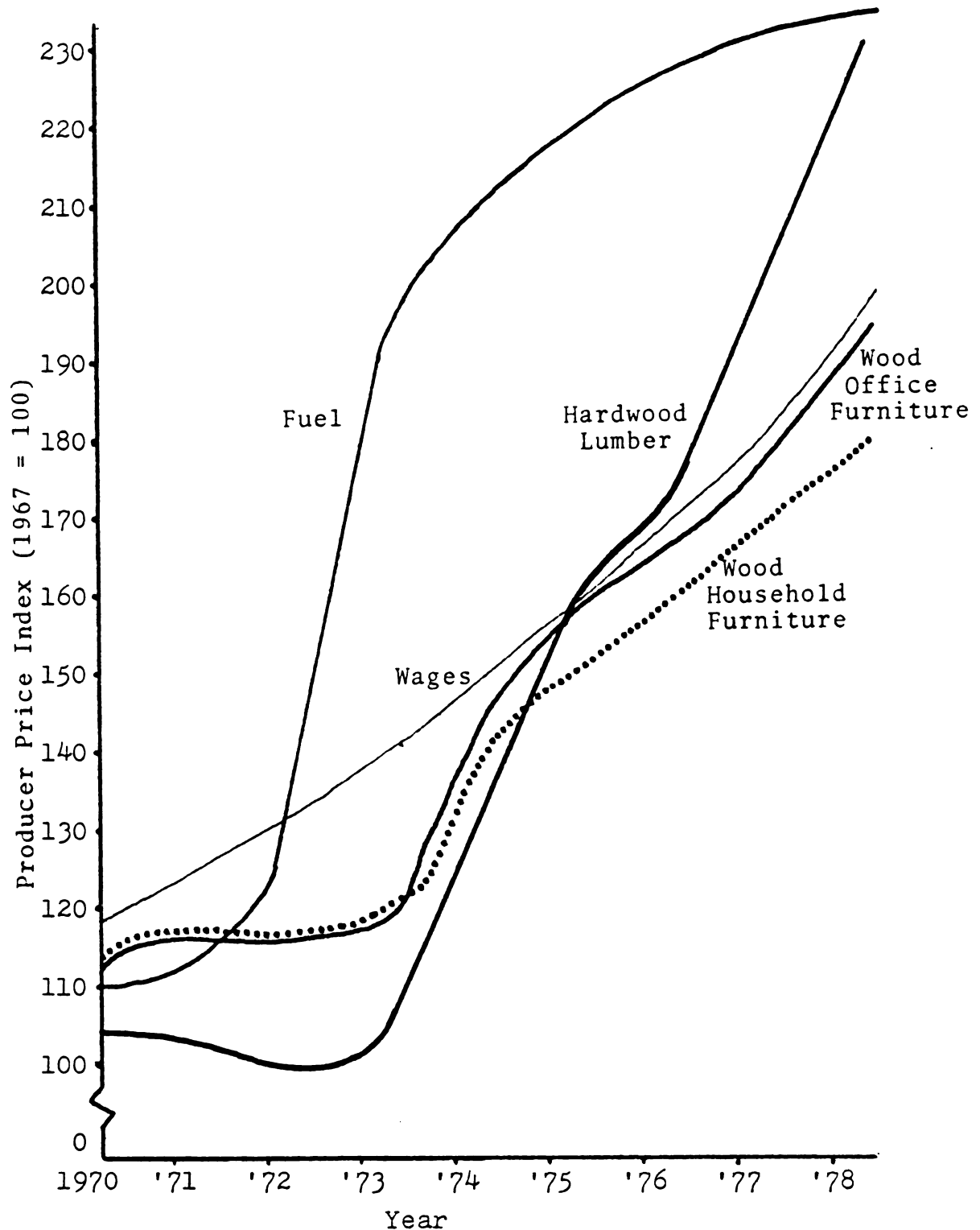


FIGURE 1.1 U.S. PRODUCER PRICE INDEXES VERSUS TIME (1970-1978)

Source: U.S. Bureau of Labor Statistics, Producer Prices and Price Indexes Supplements, 1970 to 1979, Washington, D.C.

U.S. Bureau of Labor Statistics. Handbook of Labor Statistics 1978, June 1979, Bulletin 2000, Washington, D.C.

labor, and fuel are rising much faster than the index of furniture. The manufacturer is financially squeezed when his costs rise faster than the price obtainable for his product. Thirty-five to forty percent of the cost of furniture and fifty percent or more of the cost of dimension parts production are due to lumber alone.¹ Cost reduction has become essential; and, one of the most lucrative areas for savings is in the cost of processing hardwood lumber.

The majority of logs in the hardwood growing stock are grades 3 and 4, the poorest logs for lumber production. Log grades 1 and 2 are the primary grades converted by the sawmill into lumber. From log grade 1, the average yield for the species used by the ten companies in this study came to 32.5 percent FAS ("FAS" is the commonly used abbreviation for "firsts and seconds," the highest lumber grade), 9.2 percent select, 30.0 percent 1 common, 12.7 percent 2 common, and 16.8 percent 3 common (3 common is the lowest yielding lumber grade normally used for furniture and dimension production). For log grade 2 the quantities of FAS, select, 1, 2 and 3 common are 7.7, 5.0, 34.0, 23.5, and 29.9 percent respectively.²

The OFCCP was developed by the USDA Forest Service and Michigan State University to improve the utilization efficiency of hardwood lumber. The specific purpose of the computer program is to enable hardwood lumber users to make purchase decisions using a scientific method for analyzing available grades and species, respective costs, and the firm's

product requirements. The data base comes from the Forest Products Laboratory publication, Charts for Calculating Yields from Hard Maple Lumber, FPL 118.³ See Figure 1.2

"Example Yield Chart for 1 Common Lumber Grade from FPL 118." Black walnut and red alder yield tables may be accessed through the computer program, but were not needed for this research. The program's two basic functions are to predict (1) the best grade mix and (2) the lumber yield for a manufacturer's cutting bill with its associated costs.

The OFCCP's predictions were checked against manually calculated yields using the published yield charts. A satisfactory comparison of manual and computer predictions led to the introduction of the computer program in the hardwood lumber using industry in Michigan and other states. Favorable user feedback inspired more detailed confirmation of the computer program's ability to accurately predict lumber yields, procurement information, and cost predictions.

A series of ten yield and cost studies were performed according to a procedure adaptable to the widely varying conditions encountered at the various companies. Basically, the tests involved monitoring the volume of rough lumber going into a rough mill (a place where rough, unsurfaced, variable-sized lumber is machined to fairly uniform "rough" dimensions). See Figure 1.3 "Rough Mill Layout". The processing of the lumber was observed and timed, and the final net product output was measured and recorded.

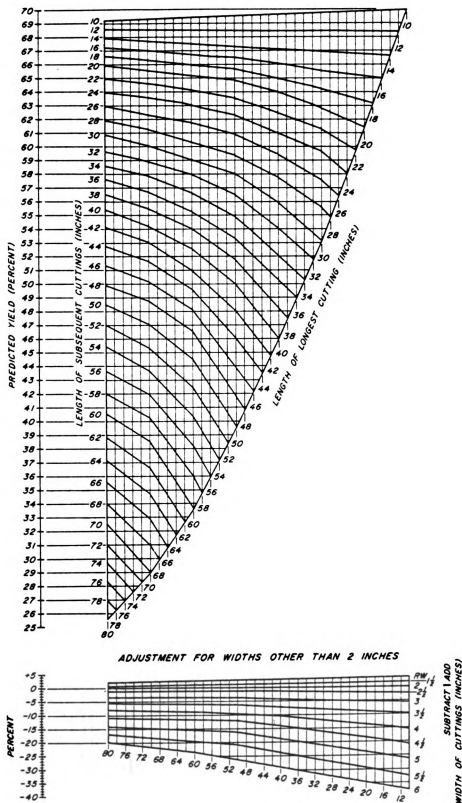


FIGURE 1.2 EXAMPLE YIELD CHART FOR 1 COMMON FROM FPL 118³

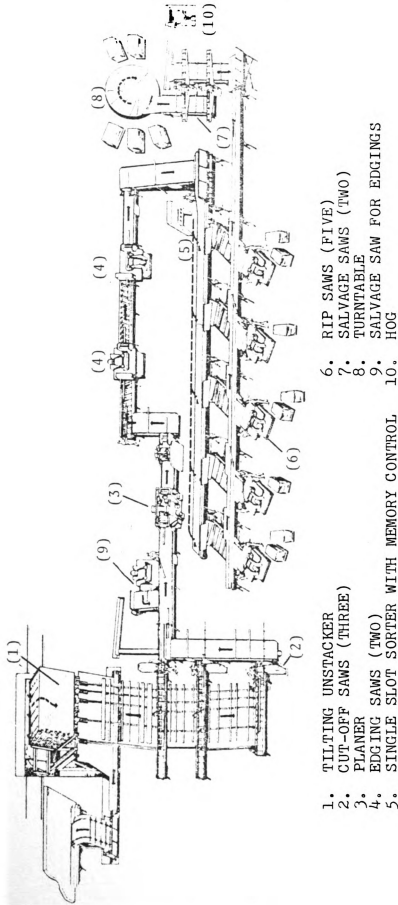


FIGURE 1.3 POSSIBLE ROUGH MILL LAYOUT FOR A CROSSCUT SAW-FIRST SEQUENCE ROUGH MILL.

Source: Irvington-Moore, Inc., Bulletin IM 389, Portland, Oregon.

The volume and time data collected at ten companies were used to calculate the individual firm's costs and yields. Using the OFCCP each company's actual study results were simulated. The computer predictions were compared to the actual study results to determine if the computer program successfully accomplishes this research's objectives (listed in Chapter III).

CHAPTER II

BACKGROUND

The purpose of this chapter is to acquaint the reader with the history and background of research leading to the creation of the Optimum Furniture Cutting Computer Program (OFCCP). The background section will discuss some of the early efficiency pioneers in the hardwood lumber using industry who had foresight to recognize the need before the more popular but wasteful short term sentiment that the quality wood resources would be ever bountiful. Those farsighted men realized that efficient procurement and processing of hardwood lumber could have alleviated the present shortage of the high quality wood resource. While the economic principles of price versus quantity prevail in the free enterprise system of the United States sound ecological consequences will result when hardwood lumber is used most efficiently; reduced waste will lead to extension of the natural resource. While no one chapter could do proper justice to all the people involved in the improvement of hardwood lumber utilization, this chapter will highlight the pertinent developmental steps forming the foundation of the OFCCP.

One man who initiated the momentum in the early 1950's which led to the current interest in lumber use efficiency was C.D. Dosker of Gamble Brothers Incorporated, a wood dimension parts manufacturing company located in Louisville, Kentucky. Besides realizing the economic advantages in efficiently procuring and processing hardwood lumber he visualized the whole scene. Dosker led the industry into a consciousness of the negative consequences resulting from wasteful wood usage. It was directly from Dosker's prodding on the urgency and importance of increasing lumber use efficiency that the USDA Forest Products Laboratory began fundamental research on lumber yields--the same research became the data base for the OFCCP.

Another man who worked closely with Dosker at Gamble Brothers was H.C. Moser. Moser's views are well documented in an early paper presented at a North Carolina State University symposium on lumber yield titled "Potentials for Increased Profits Through Analysis of Yields and Operational Procedures".⁴ Moser put the situation into an illuminating perspective when stating the average ratio of lumber cost to labor cost in the rough mill is 10 to 1. Since this ratio is still extremely lopsided towards lumber the other ideas promoted by Moser maintain validity. Moser's ideas on yield and cost fit well with Dosker's in planning a comprehensive program to save lumber through efficient operations throughout a company. The paper concludes with this statement:

There is a danger that sacrifices of yield to the gods of automation may be false religion. Not only that, it can be poor business.

Along with Moser, Vincent R. Ross, President of Ross Associates a consulting firm headquartered in Ashville, North Carolina, participated in the North Carolina State University Rough Mill Seminars. Ross has unselfishly given of himself in the quest to increase the efficient utilization of hardwood lumber. Ross was a key figure in the movement to make people in the industry aware of the significance of profitably improving lumber yield. While Ross has many presentations and publications to his credit, the one presented at the December 1966 Rough Mill Yield and Operations Seminar entitled "Management's Role in a Program for Yield Optimization" demonstrates his view of the overall picture.³ Ross' point, very true today also, was that without full management support and involvement the success of a yield improvement program will be seriously compromised at best.

At the same time period that North Carolina State University was conducting seminars on rough milling it was also performing basic research on hardwood lumber yields. R.J. Thomas published three volumes, with the first in 1956 on the "Number of Maximum Yield Cuttings per 1000 Board Feet."⁶ The data collection was performed on graded yellow poplar lumber. Unfortunately the North Carolina Yield Tables were cumbersome to use for the commercial firms needing the information most. State extension specialists like W.E.

Keppler and Steven Hanover were instrumental in initiating their acceptance along with industry consultants like Vincent Ross and Ed Shook. The widespread use of these early yield tables was to come later when the information would be computerized by Sandy Mullin in the Barr-Mullin Company, producers of the Mini-Max lumber yield improvement computers.

Thomas also worked with Keppler to push the use of the lumber yield information by means of open rough mill seminars, company demonstrations,⁷ and trade journal articles. The questions posed in two of Keppler and Thomas' articles in Wood and Wood Products in 1965 entitled "New Two-Way System Predicts Lumber Yield"⁸ and "How to Predict Costs by Using New Yield Data"⁹ are valid today and indicate the need for the OFCCP:

- "1. What utilization or yield can be expected when a certain grade of lumber is used to produce a given number of rough cuttings of various dimensions?
2. If a special type of cutting must be produced how does this affect overall yield?
3. What is the optimum combination of grades to use to produce a required number of different cuttings?
4. How shall stock of lumber be allocated to various products?
5. What are reasonable costs for such allocations?"

The articles by Keppler and Thomas explained how the North Carolina State University yield tables could solve these problems. By special type of cutting in question 2 above,

Keppler and Thomas were referring to an extraordinary length, width, and/or quantity requirement which might adversely affect overall yield.

Dosker's impetus led the USDA Forest Service into developing yield tables to provide similar information as the North Carolina State University research. Much of the original work was performed at the Forest Products Laboratory in Madison, Wisconsin and the Forestry Sciences Laboratory in Carbondale, Illinois. The research performed led to many publications by such people as Daniel E. Dunmire and George H. Englerth in their publication "Programming for Lumber Yield."¹⁰ In the introduction of the above Forest Products Journal article Dunmire and Englerth set the stage with these words:

To a considerable extent this project was developed and conducted as a result of the interest displayed by Dosker. C.D. Dosker, for many years a leader in the hardwood industry, stated the problem thus: 'Wood is missing out as a raw material in thousands of usages simply because the industry has no information on which a designer, or a user, can determine in advance what the refining costs of wood as a raw material will be'.

Dunmire and Englerth's article and procedure for the computer prediction of lumber yield drew on some basic computer programming performed in the early 1960's. At the Forest Products Laboratory a computer program was designed to determine the dimension and number of cuttings obtained from a board whose size and defects had been entered into the computer. The program was detailed in a publication by

Claudia Wodzinski and Eldona Hahm titled A Computer Program to Determine Yields of Lumber.¹¹ Their computer program had flexibility and became the basic tool in development of yield charts.

A year later, 1967, Dunmire and Englerth published another Research Paper (NC-15) Development of a Computer Method for Predicting Lumber Cutting Yields.¹² At this same time David R. Schumann in conjunction with the other above named authors at the Forest Products Laboratory published some of the first functional yield tables for hard maple lumber^{13,14} (and therefore all similarly graded species of lumber), black walnut,¹⁵ and alder.¹⁶ The black walnut charts were a more refined update of research began in the early 1950's by the American Walnut Manufacturers Association in their publication "Walnut Yields".¹⁷ Basic data collection and research for black walnut was performed at this same time by J.W. Creighton, W.G. Stump, and W.F. Hutchins in their 1952 publication "Correlation of Walnut Furniture Cutting Requirements with Grade Yield."¹⁸

With the basic foundation laid in the above cited publications, the next step was verification of the data and demonstration of its application to the wood using industry in order to achieve the original goals of efficient utilization of the hardwood resource. Various popular trade journal articles were devoted to explanation of the usefulness of the yield table predictions. One such article appeared in the March 1968 Wood and Wood Products titled "New

Yield Data for Cutting Hardwood Dimension Stock".¹⁹ Confirmation of yield table accuracy was performed in numerous studies like Henry A. Huber and David R. Schumann's "Comparison of Predicted and Actual Yields of Dimension in the Grand Rapids, Michigan Area".²⁰ Huber and George Vasiliou, Extension Specialists in Forest Products at Michigan State University's Forest Products Department performed and published on other cost and yield studies in "Cost Analysis in Wood Products Manufacturing".²¹ Later Huber again used the Forest Products Laboratory data and computer program in his publication "In the Rough Mill Should You Rip or Crosscut First?".²²

Attempts to increase processing efficiency continued with Forest Products Laboratory developed yield tables in the 1960's and early 1970's but the need for a more comprehensive computer program was apparent. Robert Nevel and associates at the USDA Forest Service's Princeton, West Virginia Forest Products Marketing Laboratory developed OPTIGRAMI. The nomographs from Englerth's FPL 118 Research Paper Charts for Calculating Dimension Yield for Hard Maple Lumber were the basis of OPTIGRAMI once they had been computerized. The yield information was combined with a linear program to predict the OPTimum GRade MIX (hence OPTIGRAMI) for any given cutting bill (a parts list of specific quantities and dimensions to be produced) and the associated processing and procurement costs. OPTIGRAMI is designed to use punched card data input which makes the program unwieldy

to use on site in the field. At the time of this writing OPTIGRAMI has not been published although much of the work has been completed.

To overcome some of the limitations of OPTIGRAMI the USDA Forest Service, Northeastern Area State and Private Forestry, entered into a cooperative agreement with Michigan State University's Department of Forestry through Professor Henry Huber. Stephen Harsh, Professor of Agricultural Economics at Michigan State University, performed most of the computer programming for what was to become the "Optimum Furniture Cutting Computer Program". The computerized yield data of FPL 118 Charts for Calculating Dimension Yield for Hard Maple Lumber from the OPTIGRAMI program was combined with a cost minimization linear program. The resulting program was designed to be accessible by remote data terminal linked to the main computer over ordinary telephone lines. The ease of access enabled the OFCCP to be used immediately within a company any time information is needed.

Validation of the OFCCP was performed by manually calculating cutting bills through the FPL 118 hard maple nomographs and comparing the results to the computer predicted yields at Michigan State University. Further checking of the functionality of the computer program was done through a series of demonstrations in Michigan. Results were favorable in that computer predictions came close to actual industry experience.

The USDA Forest Service realized the imposing necessities of using the hardwood resource to its maximum efficiency. Through the efforts of many of the forenamed men the Northeastern Area, State and Private Forestry branch of the Service established RIP, the Rough-mill Improvement Program. The author was hired in June 1977 to implement savings in the 20 state Northeastern Area and coordinate efforts in the remaining states to improve the utilization standards of the hardwood resources.

Most of the emphasis of the RIP program has been to help the secondary (in this case lumber to semi-finished or finished goods) wood manufacturing industry improve lumber yields thereby reducing wood waste and reducing costs. The OFCCP has been the main tool used in conduction the RIP work. Various publications aimed at the industry processing hardwood lumber have appeared in trade journals.^{23,24,25,26}

As a result of RIP the OFCCP has been used to help over 200 companies in the United States and a few outside the United States.

Trade journal articles plus shorter press releases for trade journals and trade associations new letters resulted in more demands for on site demonstration by individual companies and by secondary processing industry groups. Since the computer program was developed it has been presented to: Grand Rapids Furniture Manufacturer's Association, National and Regional Forest Products Research Society

meetings, National Association of Furniture Manufacturers, Southern Furniture Manufacturers Association, Hardwood Dimension Manufacturers Association, Keystone Kiln Drying Association, New England Kiln Drying Association, Northeastern Dimension Manufacturers Association, and various school groups. Typically each presentation would result in a few invitations for in-plant demonstrations at individual furniture and dimension manufacturing companies.

Each presentation or demonstration was performed with the knowledge of or actually with local and regional forest products utilization specialists involved. The utilization specialists were federal, state or extension specialists or industry consultants. These people often carried the program to their constituents. In the past three years the versatility and many applications (from shoe heels, stairs and piano keys to the most expensive high quality wood furniture) of the RIP program has been of assistance to the industry. The necessity of in-depth cost and yield studies at some manufacturing plants enabled the gathering of data for the ten scientific tests described in the next chapters.

CHAPTER III

POSSIBLE SOURCES OF ERROR

While it was the intent of this research to be as objective and unbiased as possible, certain sources of errors were unavoidable. The expressed intent of the cost and yield studies was to monitor each company's "normal" operations. Unfortunately, some uncontrollable variables were present; since these potential sources of error could affect the study results, an explanation is required.

When an observer watches employees engaged in their routine tasks, his presence may influence a worker to alter the rate and the method in which the job is done. To eliminate or alleviate this source of error in the present study, the employees and foremen were briefed in advance about the purpose of the observers. To minimize the possibility that workers might alter their production rates, they were informed that the study staff was only measuring the capacity of the machinery, not the worker's individual production rates. However, since the workers control the rough mill machinery (not vice-versa), the explanation of the study purpose was misleading; in actuality, the workers' production rates were

being measured. At some companies, employees either accepted the explanation that the machinery's capacity was being measured, or they did not care enough to alter their normal production rates. In other companies, a deviation from standard work rates was observed during the first portion of the study.

If workers thought the research team was establishing labor rate standards for the company, the rough mill workers might have tried to intentionally slow their speed to set a low, easily exceeded, production rate. On the other hand, some workers might have tried to increase their work rate to obtain a favorable report with supervisors.

Several times during a study, when the researcher suspected the workers were performing at rates above or below the company's normal production level, the supervisory personnel were questioned about relative production rates. In some instances, the supervisor confirmed that a worker was performing faster or slower than normal. But in every case when a change in usual work rates was initially identified, management later confirmed that the workers had slipped back to more typical rates. If time to perform a study was unlimited, the "study effect" could have been reduced by disregarding the initial data collected, favoring the less biased data which followed. The potential error caused by changes in normal methods and in normal rates probably did not significantly affect the ten studies. The researchers' initial concern for changes in the normal tasks

performed due to observers' presence was not confirmed by supervisory personnel.

Another source of error introduced by the study procedure was the change from a company's typically mixed grade packages to distinctly graded lumber packages. In order to scientifically monitor yield and production rates for each grade, the company was requested to have a National Hardwood Lumber Association Inspector grade and measure the volume of the study's lumber. None of the ten companies normally segregated all of their lumber into distinctly graded packages before processing it through the rough mills; several companies did purchase lumber grade mixtures oriented towards specific grades, either high or low, for their desired cutting schedules.

The grades were physically separated before the start of the study to preclude disruption of the rough mill routine. Usually processing of distinct grade packages went uninterrupted because it was possible to closely monitor the time when the next grade would be processed and to record the relevant volume measurements. In several plants, however, it was impossible to make accurate measurements of each grade due to a continuous production line linking the ripaws and crosscut saws; accurate measurement required completely purging the rough mill line of one grade before beginning to process the next grade. These alterations of normal production practices were effectively eliminated by not recording the time incurred in change of grades for study

purposes. The researcher was able to distinguish between time delays due to a change of grade to meet the study purposes and routine time delays due to bringing more lumber into production when the supply had been depleted. To avoid any influence on the measured production rates, the delays due to conducting the study were not included.

Processing individual grades was a possible source of error when the cutting bill lengths were not arranged by grade. For example, a company may have normally processed mixed grade cutting bills having a variety of lengths, from long to short, and a variety of widths, from wide to narrow, from a mixture of higher grades, 1 common, select, and FAS; low yields could result when the company attempted to cut the same length and width pieces from a single grade at a time. To alleviate this source of abnormally low yields, the companies were requested to process their own typical cutting bills during the study. Since the target volume for each field test (20,000 board feet) occasionally exceeded the volume of one cutting bill's lumber requirements, several cutting bills were combined to utilize all the study's lumber. When combination cutting bills were processed, they were treated as a single cutting bill by the computer simulation.

The companies processed cutting bills in the accustomed manner. Introducing individual grades presented a problem to some rough mills when they had no available

knowledge of the most efficient means of scheduling the appropriate cuttings from the correct grade. The researchers abstained from assisting the firms to determine which cuttings to produce from each grade. Since most companies used their normal cutting bill from their normally available grades, this presented no large source of error. In other cases, the loss in yield due to cutting lengths not matched to the grade being processed was evident. While the effect on yield due to grade segregation was observed to be minimal, the net result cannot be accurately estimated. The magnitude of this source of error was not measured, but its potential presence must be acknowledged.

The effect on yield due to a company's cutting bill requirements has been mentioned in Chapter II. Accurate matching of the cutting bill's lengths, widths, and piece requirements is essential to obtaining maximum cutting yields. Since the ten field study company's yields will undoubtedly be compared, the reader is cautioned that the cutting bills produced and the lumber used were not the same for each company. When a company processes high grades of lumber it will obtain better yields for a given cutting bill than when it uses a lower grade. The cutting sizes and the grades processed by each company are listed in Table 3.1 on the next page.

TABLE 3.1 RANGE OF CUTTING BILL SIZES BY COMPANY AND LUMBER GRADES

Com- pany	Lumber Grade Processed	Range of Length		Range of Widths		
		Minimum (inches)	Maximum (inches)	Minimum (inches)	Maximum (inches)	Random Width for Glued Panels
1	FAS	13	43	N/A	N/A	yes
	Select	13	52	N/A	N/A	yes
	1 Common	13	48	N/A	N/A	yes
	2 Common	13	52	N/A	N/A	yes
	3 Common	13	43	N/A	N/A	yes
2	FAS+Select	13	66	1½	6½	no
	1 Common	13	66	1½	6½	no
	2 Common	13	64	1½	6½	no
3	FAS	11	81	1 3/4	1 3/4	no
	Select	11	81	1 3/4	1 3/4	no
	1 Common	11	81	1 3/4	1 3/4	no
	2 Common	11	81	1 3/4	1 3/4	no
4	FAS+Select	14	101	2½	5	no
	1 Common	13	96	2½	5	no
	2 Common	13	40	2½	2½	no
	3A Common	13	28	2½	2½	no
5	FAS	15	80	N/A	N/A	yes
	Select	15	61	N/A	N/A	yes
	1 Common	15	56	N/A	N/A	yes
	2 Common	15	56	N/A	N/A	yes
	3 Common	15	56	N/A	N/A	yes
6	FAS+Select	18	58	N/A	N/A	yes
	1 Common	18	58	N/A	N/A	yes
	2 Common	18	58	N/A	N/A	yes
7	1 Common	17	52	2½	2½	no
	2 Common	17	52	2½	2½	no
8	Select	17	81	1 5/8	3½	no
	1 Common	17	81	1 5/8	3½	no
	2 Common	20	81	1 5/8	3½	no
9	FAS	14	71	1½	5½	no
	Select	15	71	1½	3½	no
	1 Common	13	60	2½	2½	no
	2 Common	13	60	2½	2½	no
10	1 Common	12	80	N/A	N/A	yes
	2 Common	12	36	N/A	N/A	yes
	3 Common	12	36	N/A	N/A	yes

N/A = Not Applicable (No specific minimum or maximum width)

Source: Ten rough mill field studies performed 1977-1979 in the Eastern United States.

Another uncontrollable variable was a company's production sequence, i.e., whether the firm crosscut or ripped the lumber first. Theoretically, the companies process the lumber in such a way to maximize product yield. For example, flooring manufacturers rip-saw lumber before crosscutting to length because their product is long and narrow. Conversely, furniture cabinetry manufacturers initially crosscut incoming lumber to length to obtain the wide widths necessary to meet their product requirements.

The computer's data bank, derived from FPL 118 is based on crosscut first lumber processing. The yield tables are being successfully used by a number of rip-first lumber processors; however, different production sequences could affect the study results. To minimize variability from this source, yield summaries for companies with different production sequences will show results for each individual sequence before combining them together.

While lumber grading can be mathematically explained, human judgement will always be involved because wood is a heterogeneous substance. Since an inspector's subjective judgement is involved, some margin of error is possible. A fairly well accepted standard is that any given lot of lumber may be within five percent of the designated grade. Gordon Bullard, Chief Lumber Inspector of the National Hardwood Lumber Association, confirmed that a five percent range was "a pretty fair yardstick".²⁸ Bullard stated that grade

variance will occur because profit demands rapid lumber inspection and inspector judgement varies about the extent of knots, wane, stain, surface checks, and honeycomb.

Because of potential legal consequences, the "five percent rule" has never been documented; however, Rules for the Measurement and Inspection of Hardwood and Cypress Lumber²⁷ makes a provision for deviation in grade called "the four percent money clause." This clause is used to determine whether or not a discrepancy in grade exists when a lumber buyer believes the quality of lumber received differs significantly from the quality listed on the invoice. When a buyer requests a formal inspection of the lumber by the National Hardwood Lumber Association, the four percent money clause is used. The clause is documented in the following passage from the National Hardwood Sales Code, Article X -- Inspection Section 5:

Should this original official inspection result in not more than 4% deductible difference in money value from the gross amount of the invoice, the buyer is to pay all expenses of the inspection, accept all lumber and honor the seller's invoice in full. If the deductible difference be more than 4% money value, the seller is to pay all expenses of the NHLA inspection and labor charges at actual cost or at the rate of \$4.00 per M feet, whichever is less, the seller to issue an invoice for the items reported on the inspection certificate.²⁹

The clause is also used as a standard during reinspections as illustrated in this portion of the National Reinspections Regulations and Guarantee:

V. If the reinspection results in a difference in favor of the party complaining, of more than four percent in money value based on the total gross value of all stock included in the inspection, the party complaining may receive the amount of such difference directly from the Association by sending to the secretary an itemized statement showing in detail the items and amounts as shown on the original certificate and reinspection certificate.³⁰

The intention of this chapter was to investigate potential sources of error which might influence results of the ten rough mill studies. While the researcher attempted to minimize error in the study, he was unable to totally control the ten companies operating in a competitive business environment. Regardless of the long range benefits resulting from the cost and yield studies performed at a company's plant, higher priority is given to short range obligations (production schedules, shipment deadlines, profits, and others). No firm can forego its obligations in order to participate in a study. The ten studies were performed in as controlled an environment as possible to minimize the possible sources of error. However, the reader should be aware of these sources of variation and should interpret the results of these rough mill studies accordingly.

CHAPTER IV

OBJECTIVES

The objectives of this research are:

1. To analyze the capability of the Optimum Furniture Cutting Computer Program for predicting lumber yields, given information on lumber grade requirements, associated costs, and cutting bill needs.
2. To determine if the Optimum Furniture Cutting Computer Program can be used by the wood products manufacturing industry for the purchasing of lumber on a scientific, factual basis.
3. To determine whether or not the opportunity for monetary and lumber savings exists in the secondary wood processing industry through use of the Optimum Furniture Cutting Computer Program.

CHAPTER V

THE OPTIMUM FURNITURE CUTTING COMPUTER PROGRAM

The Optimum Furniture Cutting Computer Program (OFCCP) was developed by the USDA Forest Service and Michigan State University to increase efficiency in the utilization of hardwood lumber. The program was specifically designed to enable purchasing and processing of lumber on a scientific basis while taking into account the available grades and species, with their respective costs, in conjunction with a firm's product requirements.

The computer program contains two main steps; the first being an analysis of the maximum yield for the firms cutting bill requirements for each available grade. The second step combines the relative costs of lumber, labor, and overhead for various production steps (preceeding and including the rough mill operation) with yield information in a cost minimization linear program.

The inputs to the computer program are listed in Figure 5.1, "Data Inputs to the Optimum Furniture Cutting Computer Program". These values are usually written on a blank worksheet like the one in Figure 5.2. Figure 5.3 is an example of a completed worksheet ready for computer entry.

Lumber Species
Lumber Thickness
Delivery Cost
Drying Cost
Percent Drying Shrinkage
Interest Rate
Average Inventory Period
Stacking & Handling Cost
Gluing Cost
Lumber Cost by Grade
Processing and Overhead Cost by Grade
Plant Efficiency Level by Grade
Cutting Bill
Salvage Lumber Value
Salvage Lumber Size
Salvage Lumber Usage
Other Costs

FIGURE 5.1 DATA INPUT TO THE OPTIMUM FURNITURE CUTTING
COMPUTER PROGRAM.

WORKSHEET

Optimum Furniture Cutting Computer Program

Date: _____
 Bill #: _____
 File #: _____

GENERAL AND COMMON COST INFORMATION

1	State _____	01	} Enter all data with a " " underneath.
	Company _____		
2	Species _____		
	Thickness in 1/4's	.02	
	Delivery Cost in \$/MBF		
3	Drying Cost in \$/MBF	.03	
	Shrinkage in %		
4	Interest Rate Percentage	.04	
	Average Number of Days in Inventory		
5	Stacking & Handling Costs for the highest grade of lumber used \$/MBF	.05	}
	Gluing Cost \$/MBF		
6	Other Costs	.06	

LUMBER AND PROCESSING COSTS AND EFFICIENCY BY GRADE

7	FAS Cost \$/MBF	.07	} **
	Cutting labor & overhead cost \$/MBF		
8	Plant yield adjustment percentage	.08	}
	% plant yield adjustment for lengths over 40"		
9	SEL Cost \$/MBF	.09	} **
	Cutting labor & overhead cost \$/MBF		
10	Plant yield adjustment percentage	.10	}
	% plant yield adjustment for lengths over 40"		
11	1C Cost \$/MBF	.11	} **
	Cutting labor & overhead cost \$/MBF		
12	Plant yield adjustment percentage	.12	}
	% plant yield adjustment for lengths over 40"		
13	2C Cost \$/MBF	.13	} **
	Cutting labor & overhead cost \$/MBF		
14	Plant yield adjustment percentage	.14	}
	% plant yield adjustment for lengths over 40"		
15	3AC Cost \$/MBF	.15	} **
	Cutting labor & overhead cost \$/MBF		
16	Plant yield adjustment percentage	.16	}
	% plant yield adjustment for lengths over 40"		
17	1C and Better \$/MBF	.17	} **
	Cutting labor & overhead cost \$/MBF		
18	Plant yield adjustment percentage	.18	}
	% plant yield adjustment for lengths over 40"		

FIGURE 5.2 BLANK WORKSHEET FOR THE OPTIMUM FURNITURE
CUTTING COMPUTER PROGRAM

CUTTING BILL

L I N E	C O D E	NUMBER PIECES	L I N E	LENGTH INCHES	1/8"	WIDTH INCHES	1/8"	ENTER: 0 = Random 1 = Specified
19	0 1	---	20	---	---	---	---	---
21	0 2	---	22	---	---	---	---	---
23	0 3	---	24	---	---	---	---	---
25	0 4	---	26	---	---	---	---	---
27	0 5	---	28	---	---	---	---	---
29	0 6	---	30	---	---	---	---	---
31	0 7	---	32	---	---	---	---	---
33	0 8	---	34	---	---	---	---	---
35	0 9	---	36	---	---	---	---	---
37	1 0	---	38	---	---	---	---	---
39	1 1	---	40	---	---	---	---	---
41	1 2	---	42	---	---	---	---	---
43	1 3	---	44	---	---	---	---	---
45	1 4	---	46	---	---	---	---	---
47	1 5	---	48	---	---	---	---	---
49	1 6	---	50	---	---	---	---	---
51	1 7	---	52	---	---	---	---	---
53	1 8	---	54	---	---	---	---	---
55	1 9	---	56	---	---	---	---	---
57	2 0	---	58	---	---	---	---	---
59	2 1	---	60	---	---	---	---	---
61	2 2	---	62	---	---	---	---	---
63	2 3	---	64	---	---	---	---	---
65	2 4	---	66	---	---	---	---	---
67	2 5	---	68	---	---	---	---	---
69	2 6	---	70	---	---	---	---	---
71	2 7	---	72	---	---	---	---	---
73	2 8	---	74	---	---	---	---	---
75	2 9	---	76	---	---	---	---	---
77	3 0	---	78	---	---	---	---	---

SALVAGE LUMBER INFORMATION

79 Value in \$/MBF (less than lumber cost) . . . { ---
 Length in inches (less than cutting bill) 79 { ---
 Amount actually used in % { ---

SPECIFICATION OF DESIRED GRADE USAGE

80 Specification Code * 80 { ---
 Grade ** 80 { ---
 Specification level (BF or %) { ---
 81 Specification Code * 81 { ---
 Grade ** 81 { ---
 Specification level (BF or %) { ---
 82 Specification Code * 82 { ---
 Grade ** 82 { ---
 Specification level (BF or %) { ---
 83 Specification Code * 83 { ---
 Grade ** 83 { ---
 Specification level (BF or %) { ---

* 1 = Maximum amount; 2 = Actual amount; 3 = Minimum amount; 4 = % of Grade
 ** 1 = FAS; 2 = SEL; 3 = 1C; 4 = 2C; 5 = 3AC; 6 = 1C and Btr

OUTPUT OPTIONS

Output in addition to basic cutting summary. (1 = yes; 0 = no)

84 Details on boards cut from each grade {
 Marginal cost and board feet needed from each board . . . 84 {
 Break-even grade information {

1/79

FIGURE 5.2 (Continued)

WORKSHEET

Optimum Furniture Cutting Computer Program

Date: _____
 Bill #: 1
 File #: 3

GENERAL AND COMMON COST INFORMATION

1 State <u>MICHIGAN</u>			
Company <u>SAMUEL WOOD PRODUCTS</u>	01	{ 31 100	Enter all data with a " " underneath.
2 Species <u>RED OAK</u>			
Thickness in 1/4's	02	{ 21 01	
Delivery Cost in \$/MBF			000
3 Drying Cost in \$/MBF	03	{ 74	7.0
Shrinkage in %			
4 Interest Rate Percentage	04	{ 10.0	100
Average Number of Days in Inventory			
5 Stacking & Handling Costs for the highest grade of lumber used \$/MBF	05	{ 0	7.0
Gluing Cost \$/MBF			
6 Other Costs	06	{ 8	

LUMBER AND PROCESSING COSTS AND EFFICIENCY BY GRADE

7 FAS Cost \$/MBF	07	{ 1 700	7.0
Cutting labor & overhead cost \$/MBF			
8 Plant yield adjustment percentage	08	{ 95	100
% plant yield adjustment for lengths over 40"			
9 SEL Cost \$/MBF	09	{ 2 690	8.0
Cutting labor & overhead cost \$/MBF			
10 Plant yield adjustment percentage	10	{ 95	100
% plant yield adjustment for lengths over 40"			
11 1C Cost \$/MBF	11	{ 3 489	8.0
Cutting labor & overhead cost \$/MBF			
12 Plant yield adjustment percentage	12	{ 95	100
% plant yield adjustment for lengths over 40"			
13 2C Cost \$/MBF	13	{ 4 246	10.0
Cutting labor & overhead cost \$/MBF			
14 Plant yield adjustment percentage	14	{ 95	100
% plant yield adjustment for lengths over 40"			
15 3AC Cost \$/MBF	15	{ 5 326	12.0
Cutting labor & overhead cost \$/MBF			
16 Plant yield adjustment percentage	16	{ 95	100
% plant yield adjustment for lengths over 40"			
17 1C and Better \$/MBF	17	{ 0	
Cutting labor & overhead cost \$/MBF			
18 Plant yield adjustment percentage	18	{	
% plant yield adjustment for lengths over 40"			

FIGURE 5.3 SAMPLE OF COMPLETED WORKSHEET FOR THE
 OPTIMUM FURNITURE CUTTING COMPUTER PROGRAM

CUTTING BILL

L I N E	C O D E	NUMBER PIECES	L I N E	LENGTH		WIDTH		ENTER: 0 = Random 1 = Specified
				INCHES	1/8"	INCHES	1/8"	
19	0 1	6 2 5	20	4 6	0	2	4	1
21	0 2	1 8 0 0	22	3 0	2	2	4	1
23	0 3	1 8 0 0	24	2 3	3	2	4	1
25	0 4	1 0 0 0	26	1 8	1	2	4	1
27	0 5	4 0 0 0	28	1 6	3	2	4	1
29	0 6	2 0 0 0	30	1 3	3	2	4	1
31	0 7	—	32	—	—	—	—	—
33	0 8	—	34	—	—	—	—	—
35	0 9	—	36	—	—	—	—	—
37	1 0	—	38	—	—	—	—	—
39	1 1	—	40	—	—	—	—	—
41	1 2	—	42	—	—	—	—	—
43	1 3	—	44	—	—	—	—	—
45	1 4	—	46	—	—	—	—	—
47	1 5	—	48	—	—	—	—	—
49	1 6	—	50	—	—	—	—	—
51	1 7	—	52	—	—	—	—	—
53	1 8	—	54	—	—	—	—	—
55	1 9	—	56	—	—	—	—	—
57	2 0	—	58	—	—	—	—	—
59	2 1	—	60	—	—	—	—	—
61	2 2	—	62	—	—	—	—	—
63	2 3	—	64	—	—	—	—	—
65	2 4	—	66	—	—	—	—	—
67	2 5	—	68	—	—	—	—	—
69	2 6	—	70	—	—	—	—	—
71	2 7	—	72	—	—	—	—	—
73	2 8	—	74	—	—	—	—	—
75	2 9	—	76	—	—	—	—	—
77	3 0	—	78	—	—	—	—	—

SALVAGE LUMBER INFORMATION

79 Value in \$/BF (less than lumber cost) . . . { - 50
 Length in inches (less than cutting bill) 79 { 10
 Amount actually used in % 100

SPECIFICATION OF DESIRED GRADE USAGE

80 Specification Code * { 0
 Grade ** 80 { —
 Specification level (BF or Z) —
 81 Specification Code * { —
 Grade ** 81 { —
 Specification level (BF or Z) —
 82 Specification Code * { —
 Grade ** 82 { —
 Specification level (BF or Z) —
 83 Specification Code * { —
 Grade ** 83 { —
 Specification level (BF or Z) —

* 1 = Maximum amount; 2 = Actual amount; 3 = Minimum amount; 4 = % of Grade
 ** 1 = FAS; 2 = SEL; 3 = 1C; 4 = 2C; 5 = 3AC; 6 = 1C and Btr

OUTPUT OPTIONS

Output in addition to basic cutting summary. (1 = yes; 0 = no)

84 Details on boards cut from each grade { 1
 Marginal cost and board feet needed from each board . . . 84 { 1
 Break-even grade information 1

1/79

FIGURE 5.3 (Continued)

Some of the inputs listed in Figure 5.1 are self-explanatory, but others require an explanation. The "Delivery Cost" for the lumber is the charge paid to transport the lumber to the rough mill. Often this cost is included in lumber price and would not be entered separately for the computer program.

The "Drying Cost" represents the costs associated with air and kiln drying of green lumber. If the lumber is purchased dry, no cost would be entered for drying. The "Percent Drying Shrinkage" incurred in drying provides a better estimate of the quantity of lumber to purchase knowing that the wood volume after drying will be less. The "Stacking and Handling Cost" for the highest grade of lumber used normally covers the labor expense to stack and sticker the lumber piles. Sticker is a common practice in stacking lumber wherein each successive course of boards is separated from the next by sticks--usually 1 to 2 inch wide boards about 8 feet in length. Since stacking costs vary by grade, the computer program makes these adjustments based on the raw data for FPL 118 (shown in Table 5.1):

TABLE 5.1 STACKING COSTS' ADJUSTMENT FACTORS FOR THE OPTIMUM FURNITURE CUTTING COMPUTER PROGRAM

GRADE	FACTOR
FAS	1.00
Select	1.10
1 Common	1.18
2 Common	1.25
3 Common	1.30

Source: Harsh, Stephen, Henry Huber, Ed Pepke, and Paula Johnson. Optimum Furniture Cutting Program, A Tel-plan Program, User's Manual. Department of Agricultural Economics, Michigan State University, East Lansing, Michigan, 1977.

These factors will increase the cost of stacking and handling for lower grades; the adjustment is necessary because lower grades have relatively smaller, more numerous boards per unit volume which require increased labor to stack.

The "Interest Rate" is used to evaluate the inventory which necessitates a value for the "Average Inventory Period". Thus the program includes the inventory carrying charge incurred when a company purchases lumber and keeps it through various production stages.

The "Gluing Cost" should include the cost of the glue and overhead along with the labor involved in gluing. The gluing process is used to join random width boards to specific panel dimensions. If the company intends to glue some of the pieces in the cutting bill the cost for gluing should be input. The computer program automatically anticipates more glue joints for lower lumber grades and adjusts the costs accordingly (See Table 5.2 below). These adjustment factors were derived from FPL 118 raw data on hard maple cutting yields.

TABLE 5.2 GLUING COSTS' ADJUSTMENT FACTORS FOR THE OPTIMUM FURNITURE CUTTING COMPUTER PROGRAM

GRADE	FACTOR
FAS	1.00
Select	1.10
1 Common	1.18
2 Common	1.25
3 Common	1.30

Source: Harsh, Stephen, Henry Huber, Ed Pepke, and Paula Johnson. Optimum Furniture Cutting Program, a Telplan Program, User's Manual. Department of Agricultural Economics, Michigan State University, East Lansing, Michigan, 1977.

The remaining costs in Figure 5.1 are more specific, i.e., "Lumber Cost by Grade". The cost of processing the lumber (with overhead applied) must be input for each grade. "Plant Efficiency Level by Grade" commonly termed plant yield adjustment is entered for each grade to customize the yield table predictions for the company. The exact application of the plant yield adjustment will be discussed later.

The "Cutting Bill" includes the number and sizes of pieces to be processed. Usually a company will save the lumber which is too small to meet the current cutting bill requirements but which may be used in some future cutting bill. The volume of pieces, called "salvage" or "offal", can be estimated by the OFCCP after inputting the minimum length saved, the value of a thousand board feet of that length, and the percentage that will actually be used. To permit comparisons between companies in the ten rough mill field tests of this study, salvage production and value was disregarded.

The costs and information described above comprise the inputs to the computer program. Another data input space is available for a program user to insert any other cost specific to the company being examined.

Once the basic cost data and cutting bill requirements have been input to the program the analysis begins. The computer program flowchart appears in Figure 5.4.

The output information from the OFCCP is listed in 5.5. A sample printout appears in Figure 5.6. The first

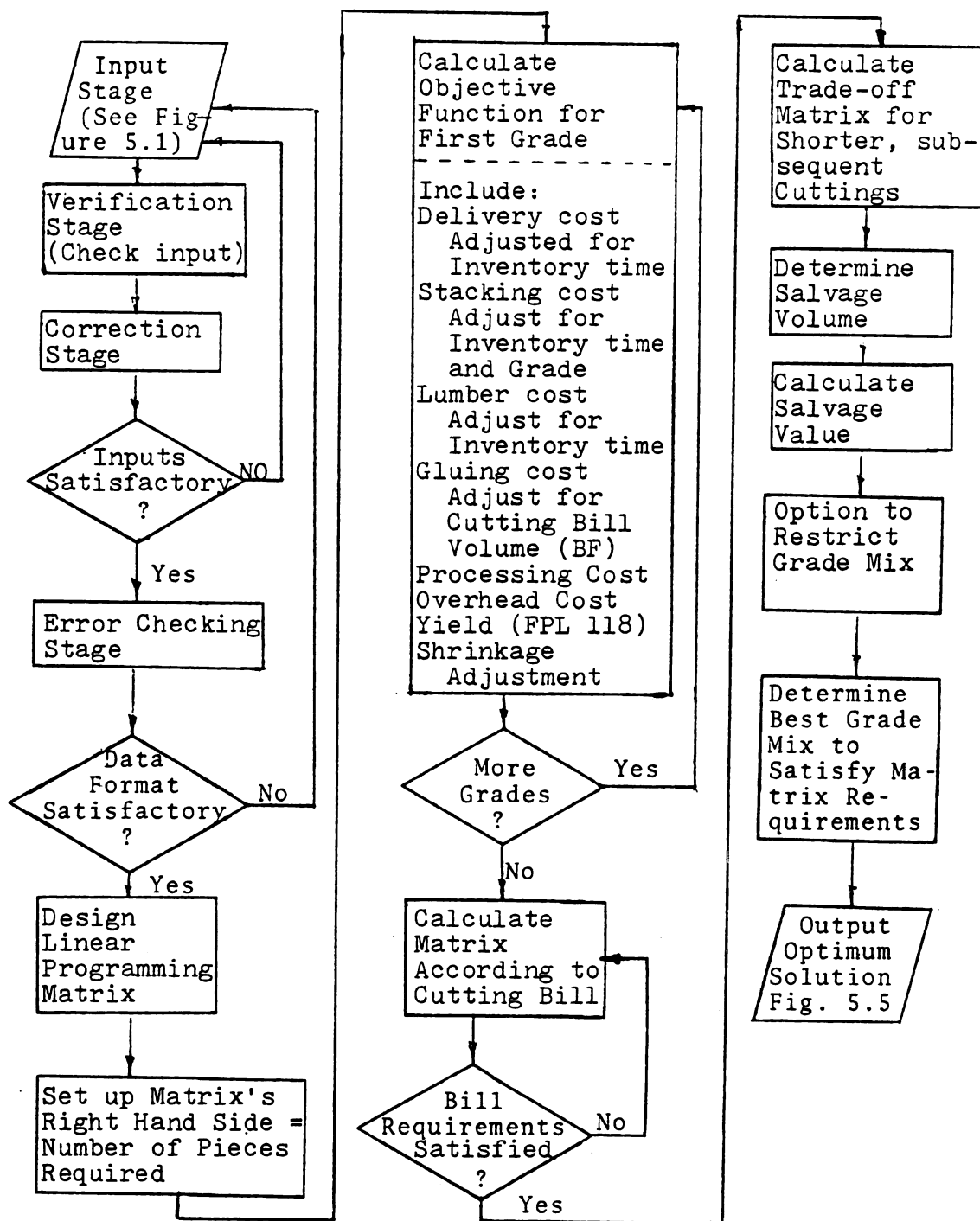


FIGURE 5.4 GENERAL FLOWCHART FOR THE OPTIMUM FURNITURE CUTTING COMPUTER PROGRAM

Net Cost of Cutting Bill
Which Grades to Process
Volume of each grade to purchase
Volume to process (after shrinkage)
Expected yield of parts
Yield of salvage
Cost of materials and processing each grade
Parts to obtain from each grade
Critical cuts
Cost per piece
Volume per piece
Volume in each cutting size
Net volume of cutting bill
Percent of total cutting bill represented in each size
Total amount of lumber to be processed
Overall yield
Overall salvage yield
Value of salvage pieces
Breakeven grade and costs

FIGURE 5.5 OUTPUT INFORMATION FROM THE OPTIMUM FURNITURE CUTTING COMPUTER PROGRAM

◆◆◆ OPTIMUM FURNITURE CUTTING COMPUTER PROGRAM ◆◆◆

SPECIES = RED OAK -- 4/4 THICKNESS

◆ COST SUMMARY ◆

NET COST OF CUTTING BILL \$ 2684.

◆ GRADE UTILIZATION SUMMARY ◆

AMOUNT OF GRADE 1 COM TO BE PURCHASED = 1514. BF

AMOUNT TO BE CUT IN MILL = 1408. BF

PERCENT YIELD FROM GRADE = 61.8

SALVAGE YIELD FROM GRADE = 7.3

COST = \$ 997.

CODE	LENGTH	WIDTH	R/S	C C	NO. CUT
1	48 0/8	2 4/8	0	YES	625.
2	30 2/8	2 4/8	0		411.
3	23 3/8	2 4/8	0		154.
4	18 7/8	2 4/8	0		114.
5	16 3/8	2 4/8	0		54.
6	13 3/8	2 4/8	0		80.
9999	10 0/8	3 0/8	R		531.

AMOUNT OF GRADE 2 COM TO BE PURCHASED = 4000. BF

AMOUNT TO BE CUT IN MILL = 3720. BF

PERCENT YIELD FROM GRADE = 48.8

SALVAGE YIELD FROM GRADE = 12.7

COST = \$ 1716.

CODE	LENGTH	WIDTH	R/S	C C	NO. CUT
2	30 2/8	2 4/8	0	YES	1389.
3	23 3/8	2 4/8	0	YES	1646.
4	18 7/8	2 4/8	0	YES	886.
5	16 3/8	2 4/8	0	YES	346.
6	13 3/8	2 4/8	0		120.
9999	10 0/8	3 0/8	R		2265.

◆ COST AND BOARD FEET INFORMATION ◆

CODE	COST/PC	BF/PC	TOTAL BF	% BF
1	1.09	0.83	521.	15.2
2	0.43	0.53	945.	28.9
3	0.39	0.41	730.	22.4
4	0.32	0.33	328.	10.0
5	0.28	0.28	114.	3.5
6	0.01	0.23	46.	1.4
9999	0.01	0.21	582.	17.8
TOTALS			3267.	100.0

◆ TOTAL YIELD AND SALVAGE INFORMATION ◆

TOTAL AMOUNT TO BE CUT = 5128. BF

PERCENT YIELD FROM ALL GRADES = 52.3

SALVAGE YIELD FROM ALL GRADES = 11.4

VALUE OF SALVAGE PIECES = \$ 29.

◆ BREAK-EVEN GRADE INFORMATION ◆

GRADE	BE COST
FAS	596.29
SELECT	531.63
3H COM	78.27

FIGURE 5.6 OPTIMUM FURNITURE CUTTING COMPUTER PROGRAM SAMPLE PRINTOUT

value output is the "Net Cost of the Cutting Bill" which includes lumber, processing, and overhead costs of producing the cuttings. This cost is termed "net" since it is the total cost reduced by any salvage value. Again, in this study, salvage was not included in any of the costs for the ten rough mill studies.

Next, the program output shows the grades to cut according to the various conditions involved in the model. For each grade, the volume to purchase is shown along with the volume to cut, i.e., the purchase amount reduced by shrinkage. The grade's yield is shown both for primary parts and for salvage. The cost of lumber, processing, and overhead are combined into a single cost for each grade.

After displaying the cost and yield information for each grade, the computer lists the length, width, and number of pieces it processed during simulated cutting of the lumber. The widths are coded "R" for random widths to be produced by gluing boards into panels or "S" for solid widths. If a "YES" appears under the "CC", critical cut heading, the computer had to obtain lumber to produce some or all of the pieces of that size. A manufacturer would be aware that the critical cuts are the more difficult pieces to obtain.

Following "Cost and Board Feet Information" heading, the marginal "Cost per Piece" is listed. The marginal cost would be the incremental cost incurred to produce one additional unit. For example, if the cutting bill called for 625 pieces of part number one, the cost of material, labor,

and overhead for the 626th piece would be the marginal cost.

The size of each piece and its relative importance (expressed in percent of the total bill) is listed. Totaling the volume per part gives the net board foot volume produced. The computer program also totals the amount of lumber to cut from each grade into a single overall lumber consumption value. The yields for the individual grades are combined by a weighted average into a single overall yield. The salvage yields per grade are similarly averaged. The salvage yield from all grades is computed along with the salvage value. The salvage value is used to reduce the total cutting bill's cost to give the "net cost of cutting bill" discussed earlier.

Last, the available grades not selected by the computer in the current analysis are listed along with the "Break-Even Costs." The break-even cost is the price at which the company would have to purchase the lumber to have that grade become one of the program's chosen grades.

This section has described the inputs, function and outputs of the OFCCP. The program is basically a tool to permit analysis of rough mill operations. The interpretation of the results must be made by the user to maximize the program's value. The use of the Optimum Furniture Cutting Computer Program for analyzing ten rough mill field studies will be discussed below.

CHAPTER VI

PROCEDURE

In order to accomplish the forestated objectives, ten rough mill field studies were performed. The Optimum Furniture Cutting Computer Program (OFCCP) described in Chapter III was used to evaluate the information gathered in ten yield and cost studies. Before enlisting the aid of the OFCCP its yield predictions had to be compared and validated with the Charts for Calculating Yields of Hard Maple Lumber, FPL 118.³

Manual Verification of the Optimum Furniture Cutting Computer Program

The basis for the OFCCP is the USDA Forest Products Laboratory yield tables (nomograms) published in FPL 118. The nomograms were computerized and then made accessible through the Optimum Furniture Cutting Computer Program. To check both the computerization of the yield tables and the total interface between program user and the computer program's data bank, manual calculations were performed. Comparisons were made between manual use of the nomograms and the computer's results from the same nomograms.

Manual verification began with the simplest cutting bill possible: one piece of given length at the standard width (2 inches, for other widths an adjustment is necessary from the standard). Originally, only four hard maple grades, FAS, select, 1 common and 2 common were checked; further program modifications entailed checking 3A common, black walnut grades, and alder grades. Black walnut and alder were added to the program because the National Hardwood Lumber Association inspection rules are significantly different for these species. Most other commercially used hardwood lumber species follow the same rules as hard maple.

The results of manual verification of the OFCCP stem from calculations of single piece cutting bills and multiple piece cutting bills. Using FPL 118, the yields for length and width combinations could be calculated and compared to computer predictions.

The results of comparisons on one piece cutting bills between the FPL 118 publication and the computer's prediction were satisfactory; the computer prediction fell within one percent of the manually calculated prediction. This was true whether computer predictions were compared to the charts in FPL 118 or to larger scale blueprints. Regardless of whether the five percent "rule of thumb" or the four percent "money clause" discussed in Chapter VI is used, the difference between computer predictions and FPL 118 predictions is within grading rule tolerance; the difference

in yield percentages could also be due to rounding and transcribing error.

When more than one piece of a particular size is in a cutting bill, the FPL 118 publication is not designed to determine yields (unless the additional quantities are proportionally equal, i.e., 50 pieces of each size or 10,000 pieces of each size, etc.). The linear program portion of the OFCCP becomes important when various quantities of multiple cutting bill sizes are required. Linear programming uses the various quantity requirements as constraints to work around, to achieve an optimal solution. However, it was always possible to arrange the quantities required of various sizes in the cutting bill so that computer program predictions would exactly equal FPL 118 predictions.

Based on the comparisons between computer yield predictions described above the author gained confidence in the abilities of the OFCCP. Addition of black walnut yield charts and red alder yield tables dictated additional manual verification by the same methods used for hard maple (FPL 118). Both species' computer predictions compared satisfactorily with the respective species' yield tables and width adjustment tables.

Field Testing of the Optimum Furniture Cutting Computer Program

Once the accuracy of the computerized nomograms had been established, the OFCCP was demonstrated to several

woodworking companies. As a result of these manufacturers' suggestions, minor revisions and additions were made to the output format to allow easier interpretation. The stage was now set for formal field tests at ten companies requesting, i.e., volunteering for, rough mill studies.

A field test followed a standardized procedure to investigate the processing of lumber in a rough mill (see Figure 6.1, "Flowchart of a Rough Mill Field Study"). Each study or test was targeted for 20,000 board feet equally distributed among the separate grades. Some companies production rates were so low that two weeks or more would have been necessary to completely process 20,000 board feet. While a three day limit was placed on each study, it was sometimes exceeded by a day to complete a study.

The company was requested to have a National Hardwood Lumber Association certified inspector grade and measure the volume (scale) of the incoming lumber. To eliminate potential drying degrade, it would have been preferable to have all the lumber graded when dry but, this was not always possible. All lumber was scaled dry to eliminate estimates of volume shrinkage incurred during drying operations. Lumber was segregated into distinct packages by grade (with a few exceptions where FAS and select were combined). While it would have been preferable to have each normal hardwood lumber grade (FAS, select, 1 common, 2 common, and 3A common) equally represented at each mill, it was impossible to interrupt the corporations' production operations. Some

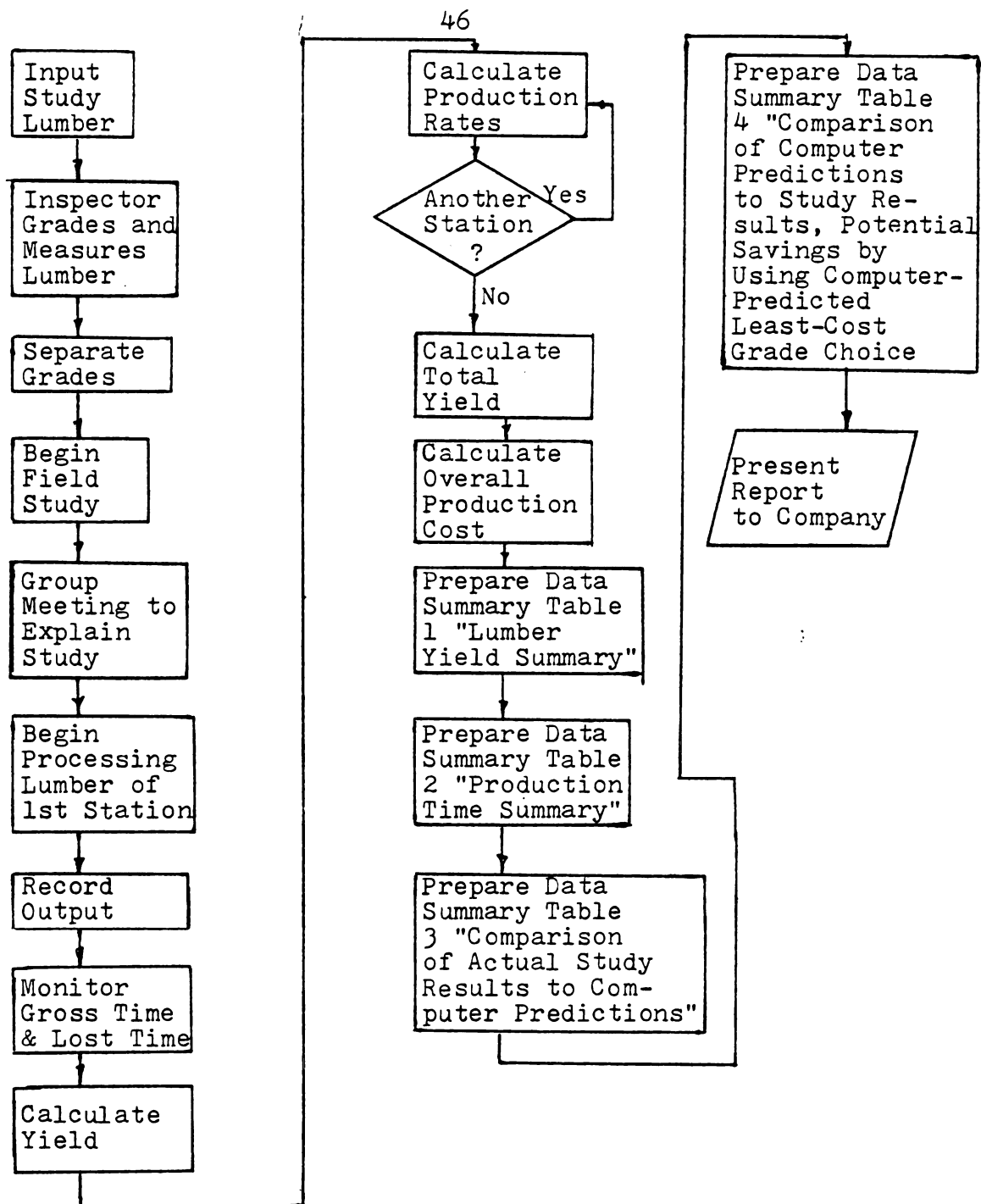


FIGURE 6.1 FLOWCHART OF A ROUGH MILL FIELD STUDY

companies had no need for the extreme high or low grades, therefore only 1 and 2 common were available at these mills.

Individual groups of graded and scaled lumber were processed normally through each rough mill. The company's typical grade mix was processed except when a company desired to know their production efficiency and production rates for alternative lumber grades. Because of production demands, some companies ran more than one thickness during the study; it was necessary to analyze each thickness separately during the field study and by computer simulation.

Once the lumber was prepared, processing began by the company's typical production sequence. Most companies first crosscut the random length and width lumber to their cutting bill requirements though this was not always the first cutting operation. The saw for cutting lumber to length was variously called a crosscut saw, X-C saw, or chop saw. At the first operation and at successive operations the usable primary product, i.e., the "cutput," was measured by tape measure to the nearest 1/8th inch; the computer program's finest increment is also 1/8th inch. In crosscut-first operations, where wood pieces are stacked on a skid, hand truck, or pallet, the volume was bulk measured because the width of individual pieces varied greatly. Gross volume was calculated via:

Formula:

$$\text{Gross Volume in Board Feet} = \frac{\text{Length} \times \text{Width} \times \text{Height of the Stack in inches}}{144 \text{ cubic inches per board foot}}$$

Example:

$$787.5 \text{ board feet} = \frac{54" \times 35" \times 60"}{144 \text{ cubic inches}} \quad (" = \text{inches})$$

To compensate for air space in loosely piled stacks, the air space volume was calculated as follows:

Formula:

$$\text{Air space volume in board feet} = \frac{\text{Length of cuttings X Cumulative width of air space X Nominal lumber thickness in inches}}{144 \text{ Cubic inches per board foot}}$$

Example:

$$47.6 \text{ board feet of air space} = \frac{54" \times 127" \times 1"}{144 \text{ cubic inches}}$$

Gross volume minus air space volume gave the actual output lumber volume from the crosscut operation:

Example:

$$\begin{array}{l} 739.9 \text{ board feet} \\ \text{actual volume cut} \end{array} = 787.5 \text{ board feet} - 47.6 \text{ board feet}$$

Once the volume of lumber into the saw and the output volume were known the yield could be calculated:

Formula:

$$\text{yield in \%} = \frac{\text{Output product volume in board feet}}{\text{Incoming lumber volume in board feet}} \times 100$$

Example:

$$65.0\% \text{ yield} = \frac{739.9 \text{ board feet}}{1138.3 \text{ board feet}} \times 100$$

Crosscutting yield data and the production rate information were gathered simultaneously according to standard industrial engineering practices.^{33,34,35} The start of gross (overall) time was defined as the instant the saw-blade made the first cut. This point in time was chosen because it was both audible and visible to the researcher. The stopping time was the instant of the first saw cut in the next grade or the end of the work shift, whichever occurred first. Both the start time and the stop time were defined to preclude judgement by the data collector. Gross time or overall time was calculated by the following:

Formula:

$$\text{Gross time in hours} = \text{Stop time in hours} - \text{Start Time in Hours}$$

Example:

$$2.23 \text{ hours (total or gross)} = 3.23 \text{ hours (stopped)} - 1.00 \text{ hours (started)}$$

The actual production rate was calculated based upon inbound lumber volume for the first operation as normally done in the industry:

Formula:

$$\begin{array}{l} \text{Actual Production Rate} \\ \text{board feet/hour per saw} = \frac{\text{Input in board feet}}{\text{Gross time in hours}} \\ \text{(assuming one saw)} \end{array}$$

Example:

$$510.5 \text{ board feet/hour/saw} = \frac{1138.3 \text{ board feet}}{2.23 \text{ hours}}$$

Production rates are stated "per saw" to enable comparison between the study companies having various numbers of saws.

Since every plant had a different amount of non-productive time (down time, or lost time) the idle machine time was monitored closely by stopwatch. Down time was recorded for any paid period of time greater than one minute during which the operator was not sawing. Corporate managers and floor supervisors were concerned about the quantity of non-production time. After determining the total down time and the causes, the net time was obtained as follows:

Formula:

$$\begin{array}{l} \text{Net time in hours} = \text{non-production time in hours} - \\ \text{gross time in hours.} \end{array}$$

Example:

$$\begin{array}{l} 2.08 \text{ hours net time} = 2.23 \text{ hours gross time} - \\ 0.15 \text{ hours down time} \end{array}$$

The net time and the lumber footage incoming to the machine and these calculations give the potential production rate:

Formula:

$$\text{Potential production rate} = \frac{\text{Lumber input in board feet/}}{\text{in board feet/hour/saw}} = \frac{\text{Net time in hours/Number of}}{\text{crosscut saws}}$$

Example:

$$547.26 \text{ board feet} = 1138.3 \text{ board feet} / 2.08 \text{ hours} / 1 \text{ saw per hour per saw}$$

This rate is termed "potential" since it would only be obtained if a company had zero down time. Every company has a certain amount of paid down time when maintenance is performed, rest breaks are taken, jobs are changed, and set-ups are altered. But these mandatory non-productive times vary from firm to firm and must be considered to calculate comparable production rates.

Similar data was collected on the rip-saws; a rip-saw saws a board to the desired width by ripping lengthwise along the grain. If rip-sawing was the second operation, the lumber volume into the rip-saws usually equalled the crosscut saw's product. The product was counted by the piece since each piece had the same dimensions. Differentiation between lumber grades was possible because after crosscutting the ends of the boards were spray painted with a distinctive color for each grade. In the case of a rip-first operation or a continuous production line, the line was purged of all of the previous grade before a new grade was processed. Yields were calculated for each grade, cumulatively for all grades, and combined to produce an overall yield of both

cross-cutting and ripping. Production rates were timed by the same method as the crosscut saw rates.

Analysis of the Data Generated
From a Rough Mill Field Study

Most companies easily computed their processing cost per hour in the rough mill by adding hourly wage rates for each rough mill employee and direct supervision cost per hour; also added into rough mill costs were the overhead costs of power, maintenance, repair, worker benefits (if not included in wages), depreciation of rough mill equipment, supplies, insurance, and any other rough mill expenses. Factory burden was not be include selling and administration costs. Once a total cost per hour was known, the cost of processing each grade was determined as follows:

Formula:

$$\begin{array}{l} \text{Number of hours to} \\ \text{process 1000 board} \\ \text{feet (MBF)} \end{array} = \frac{\text{1000 Board Feet}}{\text{Production volume} \\ \text{output per hour}}$$

$$\begin{array}{l} \text{Cost of processing} \\ \text{1 MBF} \end{array} = \begin{array}{l} \text{Number of hours} \\ \text{to process 1 MBF} \end{array} \times \begin{array}{l} \text{Cost per hour} \\ \text{for labor and} \\ \text{overhead} \end{array}$$

Example:

$$1.8 \text{ hours/MBF} = \frac{1000 \text{ Board feet}}{547.26 \text{ Board feet/hour}}$$

$$\$72 \text{ per MBF} = 1.8 \text{ hours/MBF} (\$40/\text{hour for labor and overhead})$$

In this example, \$72 represents the costs of crosscutting, ripping, stacking, sorting, and overhead for one thousand board feet of a specific lumber grade in a hypothetical rough mill. The costs of rough mill processing were used in computer analyses.

All of the ten companies used in this study incorporated some form of salvage operation to retrieve usable wood parts after an initial pass through the crosscut and ripaws. Not all of the salvage operations were performed during the study due to time limitations or a particular company's production sequence. However, when possible the salvage operation was monitored. In the case of a crosscut first operation, the spray painted board ends enabled determination of the volume of salvage recovered by grade. Salvage operation yield could not be calculated since the exact quantity of wood entering the station was undeterminable. The increased production (due to salvage production) by grade was easily measured; this figure was then used to calculate overall yield.

Because complete salvage operations in each study could not be monitored, the effect of salvage could not be evaluated in this dissertation even though some data are included. Thus, the salvage saw was not timed, salvage production rates were not computed, and costs of the salvage operation were not determined.

After each in-plant study, data was prepared and summarized in four tables for individual company reports.

These tables, which may be found in the appendix by company number became the raw data for Chapter VII "Results". "Data Summary Table 1 Lumber Yield Summary" displays data for each saw type by grade of lumber. "Data Summary Table 2 Production Time Summary" is also divided into machining operations and displays the time data and production rates for each grade. The OFCCP was used to prepare "Data Summary Table 3, Comparison of Actual Study Results to Computer Predictions". The last of each company's raw data tables is "Data Summary Table 4, Comparison of Computer Predictions to Study Results, Potential Savings by Using Computer-Predicted Least-Cost Grade Choice".

CHAPTER VII

RESULTS AND ANALYSIS

The result of ten cost and yield studies where production time and lumber input and output measurements were taken are summarized below in tabular form. The purpose of these tables is to support the forestated objectives: to decide whether the Optimum Furniture Cutting Computer Program (OFCCP) can produce cost and material savings when used to predict lumber yields and to aid in lumber procurement. Every company studied had their own particular product mix which dictated a cutting bill. The costs of processing and materials were obtained from each company's cost accountants and from the time studies. The cutting bill requirements and associated costs were used as input information to the OFCCP.

Analysis of the Optimum Furniture Cutting Computer Program's Yield Predictions

One of the major values of the OFCCP could come from its ability to simulate and predict lumber yields. The yield for each company (output volume divided by input volume) was tabulated for each grade processed (See Table 7.1).

Because different processing sequences directly affect each station's yield, the company's production method is indicated as a rip-first (RIP) or crosscut saw-first (X-C). For each grade the yield in the table, is presented for the crosscut saw(s), rip-saw(s), and salvage saw.

Table 7.2, "Summary of Actual Lumber Yields," lists the cumulative yield after crosscutting, ripping, and salvage operation by company and by grade. Each company was different and produced its own particular products. Seven companies crosscut-first, one company ripped-first, and two companies had separate lines for crosscut or rip-first.

Normally furniture and dimension stock producers procure their grade mix to complement their product specifications. Once the lumber is in inventory, it must be matched to the cutting bill. Failure to coordinate cutting bill requirements with the most economical lumber grade reduces yield and increases cost. The most dramatic illustration of this situation occurred in Company Number Eight's 2 common processing. Because the production of long lengths ($80\frac{1}{2}$, $58\frac{1}{2}$ and $52\frac{1}{2}$ inches) was low the rough mill foreman instructed the crosscut saw operator to cut more long lengths. The crosscut saw operator began cutting the long lengths regardless of defects; the crosscut saw yield was 94.3 percent. However, due to the lack of defect-free rippings, the rip-saws only obtained a 36.0 percent yield. Together the yield from 2 common was 29.3 percent. While this is an extreme example of lack of coordination between cutting bill

TABLE 7-2 SUMMARY OF ACTUAL LUMBER YIELDS OBSERVED AT TEN ROUGH MILL FIELD STUDIES

Com- pany	Rip or X-C First	FAS Yield %	FAS Volume BF	Select Yield %	Select Volume BF	1 C Yield %	1 C Volume BF	2C Yield %	2C Volume BF	3A Yield %	3A Volume BF	Total Volume BF	Weighted Average Overall Yield %
1	X-C	78.6	1040	71.5	1782	73.6	5765	63.1	3956	42.3	1622	14,165	67.2
2	X-C	68.8 ¹	6024 ²	68.8 ¹	6024 ²	65.7	5087	38.8	2476	N/A	N/A	19,611	64.2
3	Rip	70.5	378	71.2	1247	46.4	4563	54.8	3928	N/A	N/A	11,116	62.3
4	X-C	70.6 ¹	1920	70.6 ¹	4275	60.6	6000	N/A	N/A	N/A	N/A	12,195	65.7
	Rip	N/A	N/A	N/A	N/A	73.8	1956	67.8	6906	50.9	2885	11,747	64.7
5	X-C	80.8	2163	77.8	2880	67.0	4932	55.8	3349	45.3	1898	15,222	65.8
6	X-C	80.4 ¹	2413 ²	80.4 ¹	2413 ²	72.7	4107	65.1	7223	N/A	N/A	16,156	71.5
7	X-C	N/A	N/A	N/A	N/A	68.3	685	59.1	3336	N/A	N/A	4,021	60.6
8	X-C	N/A	N/A	53.0	1162	70.1	4816	36.0	931	N/A	N/A	6,909	62.7
9	X-C	90.0	1807	71.4	2636	61.4	3196	77.3	1194	N/A	N/A	8,833	72.4
10	X-C	N/A	N/A	N/A	N/A	N/A	N/A	50.7	3912	35.5	3991	7,903	43.1
	Rip	N/A	N/A	N/A	N/A	63.5	7817	N/A	N/A	N/A	N/A	7,817	63.5
Total	X-C	15,367	21,172			34,588		26,377		7,511	105,015		
Total	Rip	378	1,247			14,336		10,834		2,885	29,680		
Total	Both	15,745	22,419			48,924		37,211		10,396	134,695		
Wtd.Avg.	X-C	75.7	71.4			67.4		57.8		39.4			65.0
Wtd.Avg.	Rip	70.5	71.2			59.5		63.1		50.9			63.6
Wtd.Avg.	Both	75.6	71.4			65.1		59.3		42.6			64.7
Standard	Deviation	7.6	8.1			7.8		12.7		6.4			7.4

¹FAS and select processed together² $\frac{1}{2}$ of FAS and select mix

1C = 1 common, 2C = 2 common, 3AC = 3A common Rip = Ripsaw

X-C = Crosscut saw BF = Board Feet Both = Combination of both ripsaw and crosscut saw first

Wtd. Avg. = Weighted Average by volume processed

SOURCE: Ten rough mill field studies for hardwood lumber users in Eastern United States, 1977-1979

requirements and rough lumber grades, other companies also suffered from the same problem to various lesser degrees.

The difficulty of matching cutting bills with grades of lumber available to be cut resulted in a distortion of the anticipated patterns of highest yields for highest grades for the rip-first lines. Based on the National Hardwood Lumber Association's grading rules,²⁷ the yields should have been closer to the following:

TABLE 7.3 NATIONAL HARDWOOD LUMBER ASSOCIATION MINIMUM YIELDS FOR EACH GRADE ACCORDING TO GRADING RULES

Grade	Minimum Yield (%)
FAS	83.3
Select	66.7
1 Common	66.7
2 Common	50.0
3A Common	33.3

But the actual average yields, when weighted by volume of lumber processed, of the ten studies were as follows:

TABLE 7.4 ACTUAL AVERAGE YIELDS BY VOLUME OF LUMBER PROCESSED FOR TEN STUDY COMPANIES (Abstracted from Table 7.2).

Grade	Crosscut- First Yield (%)	Rip-first Yield (%)	Combined Production Processes Yield (%)
FAS	75.7	70.5	75.6
Select	71.4	71.2	71.4
1 Common	67.4	59.5	65.1
2 Common	57.8	63.1	59.3
3A Common	39.4	50.9	42.6
Weighted Average	65.0	63.6	64.7 s = 6.3

In order to reduce potential error in the above yields due to small sample size, the weighted average by lumber volume processed data from Table 7.2 was used to extract the above information. Most companies crosscut lumber first, which explains why the "Combined Production Processes Yield" is similar to "Crosscut-first Yield". While the crosscut-first yields and the combined production processes yields followed the anticipated pattern of higher yields for higher grades, the rip-first yields did not follow such a logical pattern. If more than two or three plants were studied for a grade, the researcher assumes the normal correlation between descending grade and decending yield pattern would have been observed for the rip-first production sequence as well.

Table 7.5 shows the OFCCP's yields when the computer was restricted to the same grades processed during the field

TABLE 7.5 SUMMARY OF OPTIMUM FURNITURE CUTTING COMPUTER PROGRAM PREDICTED YIELDS FOR CUTTING BILLS PROCESSED AT TEN ROUGH MILL FIELD STUDIES

Com- pany	Rip or X-C First	FAS Yield %	FAS Volume BF	Select Yield %	Select Volume BF	1 C Yield %	1C Volume BF	2C Yield %	2C Volume BF	3AC Yield %	3AC Volume BF	Total Volume BF	Overall Weighted Average Yield %
1	X-C	77.1	1461	74.0	2448	71.6	6956	61.4	4929	45.3	2272	18,066	66.3
2	X-C	68.4 ¹	6094 ²	68.4 ¹	6094 ²	50.1	6003	N/A	N/A	N/A	N/A	19,311	60.7
3	Rip	75.2	354	70.8	1253	69.7	3036	56.2	3594	N/A	N/A	8,737	64.3
4	{X-C Rip}	73.6 ¹	1594	73.6 ¹	3549	69.9	5209	N/A	N/A	N/A	N/A	10,312	72.0
		N/A	N/A	N/A	N/A	64.4	2249	53.7	8550	36.8	3851	14,465	51.5
5	X-C	76.9	2106	71.7	3041	67.8	4328	N/A	N/A	N/A	N/A	9,475	71.1
6	X-C	73.1 ¹	2631 ²	73.1 ¹	2631 ²	68.5	4293	N/A	N/A	N/A	N/A	9,555	71.0
7	X-C	N/A	N/A	N/A	N/A	72.8	1612	63.7	7869	N/A	N/A	9,481	65.3
8	X-C	N/A	N/A	71.5	866	69.0	4592	N/A	N/A	N/A	N/A	5,458	69.4
9	X-C	66.2	1613	61.9	1920	66.0	1129	56.4	882	N/A	N/A	5,544	63.1
10	{X-C Rip}	N/A	N/A	N/A	N/A	N/A	N/A	61.8	3038	46.7	2959	5,988	54.3
		N/A	N/A	N/A	N/A	65.8	6512	N/A	N/A	N/A	N/A	6,512	65.8
Total X-C			15,499		20,549		34,122		16,718		5,231	93,190	
Total Rip			354		1,253		11,797		12,144		3,851	29,714	
Total Both			15,853		21,802		45,919		28,682		9,082	122,904	
Wtd.Avg. X-C		71.5		70.6		66.2		62.3		46.1			65.9
Wtd.Avg. Rip		75.2		70.8		66.5		54.4		36.8			58.4
Wtd.Avg. Both		71.6		70.6		66.3		59.0		42.2			64.1
Standard Deviation		4.2		2.7		6.1		4.0		5.4			6.5

¹FAS and select run together ² $\frac{1}{2}$ of FAS and select mix

Rip = Ripsaw X-C = Crosscut saw BF = Board Feet Both = Combination of both ripsaw and crosscut saw-first

Wtd. avg.=Weighted average by volume processed

SOURCE: Ten rough mill field studies for hardwood lumber users in Eastern United States.

study. The computer predicted the logical pattern of decreasing yield as grade is reduced.

TABLE 7.6 OPTIMUM FURNITURE CUTTING COMPUTER PROGRAM PREDICTED YIELDS. AVERAGES OF TEN STUDY COMPANIES WEIGHTED BY VOLUME PROCESSED (Abstracted from Table 7.5)

Grade	Crosscut- First Yield (%)	Rip-first Yield (%)	Combined Production Processes Yield (%)
FAS	71.5	75.2	71.6
Select	70.6	70.8	70.6
1 Common	66.2	66.5	66.3
2 Common	62.3	54.4	59.0
3A Common	46.1	36.8	42.2
Combined	65.9	58.4	64.1

As in Table 7.2, the above average yields were weighted by the quantity of lumber required to produce the cutting bill. The board footage volumes were taken from the computer output in Table 7.5, rather than from the volume values based on the actual volumes processed in Table 7.2.

While individual company values differed between Table 7.2 and Table 7.5, the weighted averages of the two tables are remarkably close (See Figure 7.1). Considering the five percent "allowable" error accepted in lumber grading, the basic yield table predictions were correct.

If the computer program's plant yield adjustment is used, the actual practices of almost any company processing

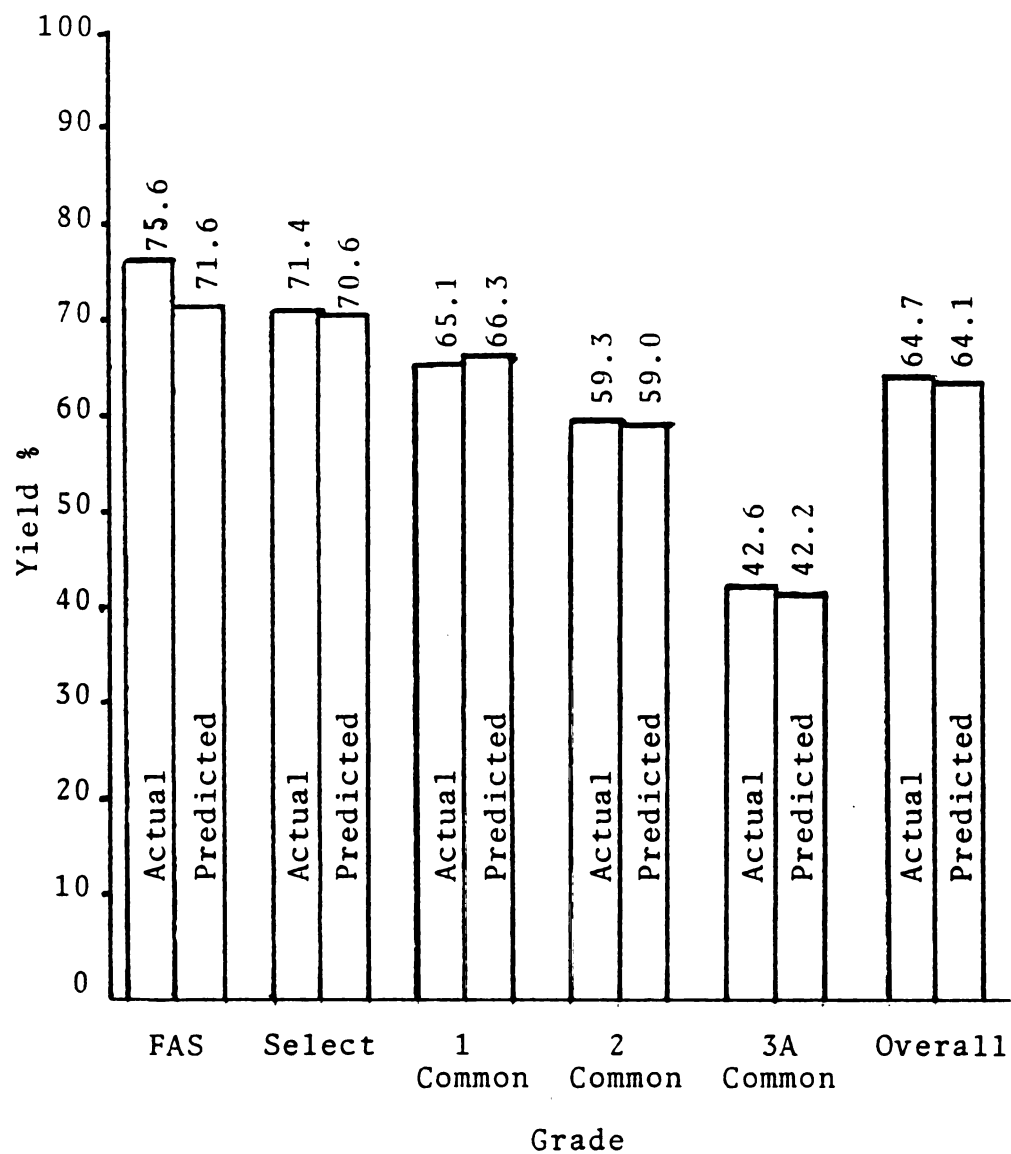


FIGURE 7.1 COMPARISON OF WEIGHTED AVERAGE ACTUAL LUMBER YIELDS OBSERVED AT TEN ROUGH MILL FIELD STUDIES (From Table 7.2) TO WEIGHTED AVERAGE OPTIMUM FURNITURE CUTTING COMPUTER PROGRAM PREDICTED LUMBER YIELDS FOR CUTTING BILLS PROCESSED DURING THE SAME FIELD STUDIES (From Table 7.5)

National Hardwood Lumber Association's standard graded lumber can be simulated to within a few board feet, or to within a one percent yield. Therefore, while the averages discussed above are based on the unaltered yields from FPL 118, the individual cutting bills produced by each company from the various grades could be simulated exactly (within one percent, or a few board feet).

The correlation between higher yield and higher grades (select yields equal 1 common yields when producing clear cuttings on two faces) was anticipated, since processing the highest grades efficiently requires less skill than trying to obtain desired cuttings from lower grades. At one extreme, an operator can consistently achieve a high yield from relatively clear FAS, if end trim waste is minimal. The other extreme, however, occurred more frequently; this is indicated by the lower plant yield adjustment for 2 and 3A common (discussed shortly), where operators had increased difficulty sawing. Some operators feel it is almost impossible to obtain clear cuttings from the lower grades, especially after being conditioned to using higher grades. The saw operator accustomed to processing large, relatively defect-free boards of FAS and select quality must make a substantial adjustment to efficiently use 2 and 3 common. Ideally, an operator looks for the clear areas of a board in order to capitalize on available cutting opportunities. Often, the sawyer reverses his approach when he sees only the defects; thus, he fails to visualize the potential

cuttings within the piece of lumber. Only when the machinery operators maintain an appropriate perspective are they able to procure their cutting bill requirements and the highest yields from low grade lumber.

The concept above is not as illusive as it might seem superficially. The hardwood lumber grades are based on the clear cuttings on a board, not on the quantity or size of defects. In the education and training of a National Hardwood Lumber Association certified lumber inspector, the importance of visualizing the clear areas of a board is stressed, in contrast to looking for defects. To the untrained eye a board will look like an accumulation of knots, wane, and other defects; on the other hand to the lumber inspector, or efficient rough mill operator, the same board will reveal some clear cutting opportunities. Thus, the importance of perceiving a board from an advantageous clear cutting point of view can and must be learned in order to maximize plant efficiency.

Table 7.7, "Plant Yield Adjustments for Ten Companies by Grade," shows most companies can strive to increase yields towards the FPL 118 standards. Since the objectives of this research do not include identifying methods of yield improvement, the reader is directed to the Rough Mill Operators Guide to Better Cutting Practices³² for suggestions on yield improvement techniques.

The objectives of this research do include analyzing whether the OFCCP can be used to accurately predict lumber

TABLE 7.7 PLANT YIELD ADJUSTMENTS FOR TEN STUDY COMPANIES BY GRADE

Company	FAS Plant Yield Adjustment (%)	Select Plant Yield Adjustment (%)	1 Common Plant Yield Adjustment (%)	2 Common Plant Yield Adjustment (%)	3A Common Plant Yield Adjustment (%)
1	90	79	92	91	73
2	94	94	118	--3	N/A
3	94	101	67	92 ²	N/A
4	96 ¹	96 ¹	115 Rip-first line	126	138
			87 X-C first line		
5	105	108	98	--3	--3
6	110 ¹	110 ¹	106	--3	N/A
7	N/A	N/A	94	93	N/A
8	N/A	73	98	--3	N/A
9	88	73	70	72	N/A
10	N/A	N/A	97	78	74

¹Includes FAS and select grades²Influenced by 12% FAS included to override yield table length limitations of FPL 118 and OFCCP.³Prediction by computer prevented due to yield table length limitations of FPL 118 and OFCCP.

N/A = Not Applicable

SOURCE: Ten rough mill field studies conducted 1977-1979 in Eastern United States for hardwood lumber users.

yields. Without plant yield adjustments (actually 100 percent plant yield adjustments cause no change in FPL 118 predictions), the computer came within two to eight percent of the actual company yields for each grade. With the appropriate plant yield adjustments, each company's yield could be simulated to within one percent accuracy. Since the lumber inspection may easily be up to five percent off-grade, a prediction to within one percent should be satisfactory. Given information on cutting bill requirements, lumber quality (grade) used, and associated costs, the OFCCP can accurately predict lumber yields.

Procurement of Lumber With
Assistance of the Optimum
Furniture Cutting Computer
Program

Since the OFCCP can accurately predict lumber yields it may facilitate the procurement of rough lumber by a secondary manufacturing company. A lumber buyer needs to know both the products' raw material requirement for lumber, usually expressed in board feet, and the expected processing waste. To determine lumber requirements for a product, the buyer works from the product specifications to calculate the board footage volume per unit. Multiplication by the quantity of units to be produced gives the net footage required. For example:

$$12 \text{ board feet/unit} \times 2000 \text{ units} = 24,000 \text{ board feet}$$

Most of the loss in processing lumber occurs in the rough mill; but, the location of waste varies with different

companies and even between products within a company. At one extreme, a dimension producer may have no waste beyond the rough mill since there are no subsequent operations. Conversely, the furniture manufacturer who performs extensive machining after the rough mill (boring, trimming, turning, routing, shaping, sanding, etc.) will incur more unavoidable losses due to removal of wood, set-ups and a certain volume of rejects. The informed lumber buyer has accurate knowledge of where losses occur and how much is lost at each succeeding production step. To calculate the amount of lumber to purchase, the yield is divided into the net footage. To illustrate the above example will be continued and the overall weighted average yield, 64.7 percent, found for the ten companies in the research will be used in the following example:

$$37,094 \text{ BF to buy} = \frac{24,000 \text{ net BF}}{64.7\% \text{ yield}} \quad \text{BF} = \text{board feet}$$

If the company has additional losses before rough milling, normally due to drying shrinkage, the lumber buyer must adjust the volume purchased accordingly. An informed lumber buyer will know the shrinkage volumes for each species of lumber used. The general averages for volumetric shrinkage, depending on inbound and outbound moisture contents in the drying facilities, are published in the Wood Handbook ³⁶ and the Rules for the Measurement and Inspection of Hardwood and Cypress Lumber.²⁷ If an 8 percent shrinkage was anticipated during kiln drying, the example above should be modified as follows:

$$40,320 \text{ BF green lumber to buy} = \frac{37,094 \text{ BF dry lumber needed}}{(1 - 0.08 \text{ kiln shrinkage})}$$

The OFCCP automatically outputs the quantity of lumber to buy based on the cutting bill sizes and quantities, the yields expected from the various grades processed, and the amount of kiln shrinkage input to the program. Actually the volume of lumber to purchase is one of the first lines of output from the program. The partial output format follows:

OPTIMUM FURNITURE CUTTING PROGRAM

SPECIES = HARD MAPLE -- 4/4 THICKNESS

COST SUMMARY

NET COST OF CUTTING BILL \$10577

GRADE UTILIZATION SUMMARY

AMOUNT OF GRADE 1 COM TO BE PURCHASED = 13249. BF

AMOUNT TO BE CUT IN MILL = 12374.BF

PERCENT YIELD FROM GRADE = 71.7

(For a complete sample printout see Figure 5.6)

In the example printout above the net footage required to fill the rough mill's cutting bill requirements is 8872 board feet. The computer program calculates the "Amount of grade...to be purchased" by the same method as the lumber buyer.

Starting with the cutting bill's information on the number of pieces required for each cutting and each cutting's size the computer calculates the net board footage required

to produce the cutting bill. By using the yield anticipated from the grades (chosen by computer or as constrained by the computer operator), the computer program calculates the quantity of lumber "to be cut in mill":

$$12374 \text{ rough board feet} = \frac{8872 \text{ net board feet}}{71.7\% \text{ yield}}$$

This example is from Company Number One where the rough mill acquired its lumber from their integrated, company-owned and run sawmill. To be able to order sufficient green lumber to satisfy rough mill needs from their sawmill the company had to make an allowance for shrinkage during kiln drying. Estimating their lumber shrank an average 6.6 percent during drying Company Number One increased the volume ordered accordingly. To continue the above example:

$$\begin{array}{lcl} 13,249 \text{ board feet} & = & \frac{12,374 \text{ board feet to cut in mill}}{(1 - 0.066 \text{ loss to kiln shrinkage})} \\ \text{to be purchased} & & \end{array}$$

Hence, the computer program logic used is the same as the normal procedure used by the lumber purchaser.

The OFCCP can be used by the secondary wood products manufacturing industry for procurement of lumber on a scientific, factual basis. During the time required to gather and analyze data for this dissertation, many commercial establishments have acquired access rights to the computer program in order to obtain information on which grades of lumber and what quantities to purchase. Therefore, the Optimum Furniture Cutting Computer Program has already been used successfully by companies processing hardwood lumber to procure lumber.

Analysis of Grade Selection

One of the first uses of the Optimum Furniture Cutting Computer Program was to select a grade or grade mixture for a hardwood lumber processor's cutting bill requirements. The computer program analyzes the cutting bill in light of these constraints:

<u>Cutting Bill Requirements</u>	<u>Constraints</u>
Length of Parts	Yield from available grades
Width of Parts	Quantities of lumber available
Number of Parts	Price of each grade
	Processing cost for each grade
	Efficiency of processing each grade (plant yield adjustment percentage)

In order to analyze the possibility for savings through a different grade choice, it is necessary to compare the computer chosen lumber grade(s) to the actual grade(s) of lumber processed during the study. Companies traditionally have not segregated lumber into distinct grade packages, although it is sometimes economically advantageous. To accurately assess the economics involved in grade selection the combined grades and an overall cutting bill must be used. By computing savings or loss resulting from combining lumber grades and cutting bills, a more realistic savings value is obtained; and, the inability of the computer to simulate low grade cutting bills where the lengths cut exceeded yield table values is avoided.

It is very possible for a hardwood lumber processor to cut sizes in excess of the computer's data bank of yield table lengths. If a firm produced rough cuttings from a grade longer than yield table lengths, a computer simulation was impossible. The yield table limits are matched in the table below with the cutting lengths exceeding those limits produced during the study.

TABLE 7.8 MAXIMUM YIELD TABLE LENGTHS FROM FPL 118 VS. MAXIMUM LENGTHS ACTUALLY CUT DURING STUDY

Grade	Maximum Yield Table Length (inches)	Maximum Length Actually Cut During the Study (inches)
FAS	96	101
Select	96	101
1 Common	80	96
2 Common	40	81
3A Common	30	43

Potential savings may be expressed both as volume (thousand board feet or MBF) or as a monetary value (dollars or \$1). The savings may also be expressed as a percentage of improvement over current production practices. Calculation of potential savings due to choice of the most economical grade(s) used came from each company's "Data Summary Table 4", appearing by company in the Appendix.

The potential savings were determined by simulating the actual study results for processing each grade. Once the efficiency level of the company was determined (the plant yield adjustment percent), the values were put into the computer program, enabling it to make a choice of grades for the company's cutting bill. The relative efficiency

level for each grade was determined and is shown in each company's "Data Summary Table 3" in the Appendix.

The computer program enables the user to make two different plant yield adjustments. The purpose of plant yield adjustments is to customize the computer's data base of the FPL 118 yield charts for each grade. In the program, the first plant yield adjustment equally raises or lowers all yields over the entire range of cutting sizes. For example, a plant yield adjustment of 90 percent for FAS would lower the normal 100 percent plant yield predictions by 10 percent for all lengths. Conversely a plant yield adjustment of 110 percent for FAS would raise the computer's normal yield predictions by 10 percent.

The second plant yield adjustment is used to affect only on cutting bill lengths over 40 inches. This adjustment is used in addition to the primary plant yield adjustment. For example, if the FAS plant yield adjustment was 90 percent as in the example above and the plant yield adjustment for longer cutting lengths over 40 inches was 95 percent the result would be a 15 percent total reduction for lengths over 40 inches. This second plant yield adjustment for each grade provides a means for a company experiencing lower than normal yields of their longest cutting bill parts to indicate the exact plant yield adjustment necessary for the computer to accurately predict lumber purchase requirements, yield expectations, production costs, etc.

Plant yield adjustments listed in Table 7.7 display the plant yield adjustment necessary to simulate (to within one percent) the yield of each cutting bill actually produced by a company. Some plant yield adjustments are higher than standard yield table predictions, i.e., greater than 100 percent. Usually when a company achieved yields higher than the yield predicted at 100 percent plant yield adjustment, the company was incorporating a limited amount of defects into their final product. Since FPL 118 is based on a standard of non-defective sides, ends, and one face, a company allowing cutting defects would show a yield higher than normal predictions.

However, most plant yield adjustments fell below 100 percent, indicating the company was not achieving the yield predicted by the computer (based on FPL 118 data) for the particular cutting bill requirements and grade of lumber. The reasons companies failed to reach the standard yield varied between and within companies; failure to obtain the computer-predicted yields did not always indicate a poorly functioning rough mill. While none of the ten companies included in this research followed this practice, other firms place stringest quality control specifications on slope in grain, pin knots, color of wood, sapwood or heartwood, bird peck, gum streaks, grain distortion, etc. When restrictions are more stringent than the grading rule guidelines under which the graphs in FPL 118 were derived, lower yields result. Company Number One did make three separations of their

final hard maple cuttings: normal grain sapwood, normal grain heartwood, and birds-eye (a grain distortion resembling many little birds eyes). Since each final product was combined into one overall production value, Company One's product separations did not affect their yields.

Table 7.9 lists the "Potential Savings Through Optimum Grade Utilization". Column 1 shows each company's annual lumber usage, obtained through discussions with the company's management. The potential percent of volume savings was derived for each company's overall cutting bill by comparing the actual volume of lumber used in the study with the amount of lumber which would satisfy the same cutting bill requirements if the optimum grade mix suggested by the computer had been used. To facilitate comparisons, the various efficiency levels for each company's available grades were set into the program using the plant yield adjustment factors discussed earlier. The potential volume savings ranged from a low to 2.0 to a high of 28.7 percent. The lower values came from companies which already used close to the computer's optimum grade selection. Higher potential savings, of course, were shown for companies which used different lumber grades than the computer recommended.

Since there was such a wide range of savings encountered in the ten rough mill studies, the arithmetic mean of 15.6 percent and potentially unreliable due to a standard deviation of 8.1 percent.

TABLE 7.9 POTENTIAL SAVINGS THROUGH OPTIMUM GRADE UTILIZATION AT TEN STUDY ROUGH MILLS

Company	(1) Annual Consumption MMBF	(2) Potential Volume Savings (%)	(3) Potential Volume Savings Annually (1) x (2)	(4) Volume of Lumber in Study MBF for Costing	(5) Total Cost Savings By Simulation (\$)	(6) Potential Cost Savings (%)	(7) Annual Cost Savings (\$) (1)x(6)+(4)
1	3.9	12.9	503	23,173	1825	14.7	307,000
2	3.0	13.2	396	19,611	2709	12.4	414,000
3	1.4	28.7	402	9,939	1690	31.8	238,000
4	{X-C Rip Both	2.0					
		2.0					
		2.0					
5	11.0	9.6	1056	16,452	560	8.9	374,000
6	10.0	2.0 ²	200 ²	8,933 ²	142 ²	3.6	159,000
7	3.8	20.5	939	4,021	2670	60.4	2,523,000
8	0.8	12.5 ³	122 ³	8,074 ³	490 ³	38.3 ³	49,000
9	0.5	25.0	125	6,896	1284	27.6	93,000
10	{X-C ⁵ Rip ¹ Both	20.1					
		0.0					
		20.1					
			603	7,903	1001	42.4	
				10,001	1717	12.8	
				17,904	2718	55.2	455,000

¹ 1 C Oak only ² FAS, FIF + 1 C only ³ Select + 1 C only ⁴ Column 4 may exclude volumes in study which could not be simulated ⁵ 1, 2, and 3A Common only X-C=crosscut-first line
 Column (2) "Potential Volume Savings (%)="(1-(Lumber required @ Co. Yields/Lumber used))x100
 Column (6) = Cost of study lumber and processing - Cost of lumber and processing opt. grades
 Column (7) = (1-(Cost of lumber+processing opt. grades/Cost of study lbr.+processing))x100
 Rip = Ripsaw-first line Both = X-C and Rip-first combined

To estimate annual lumber savings, the annual lumber usage was multiplied by the potential volume savings percentage. Because the size of the companies ranged from one half million to eleven million board feet per year, an overall average potential lumber savings must be treated with caution. The companies' potential lumber savings were not found to be correlated statistically with either company size (annual consumption) or with potential volume savings percentage (See Table 7.9). The annual lumber savings could be as high as 1,056,000 board feet, as in Company Five; but, realistically, savings will fall below that value.

Prediction of potential savings deserves discussion since the percentages and the volumes are maximums and may not be realistic. There are various constraints which prevent some of the companies from obtaining maximum savings: lumber grade availability, plant design and capacity, and willingness to alter present purchasing procedures.

Company Three, for example, uses a mixture of FAS, select, 1 common and 2 common aspen lumber. While this company realizes now that using all FAS lumber would reduce their cost of raw material per unit of production and increase their production rates, the company cannot purchase any more than their present volume of FAS lumber. The root of the problem is the relatively poor quality of aspen growing stock leading to equally low quality logs and lumber. The company must do the next best alternative: orient its

purchasing procedures to include the maximum amount of FAS available.

The constraints of plant capacity are important when a company cannot take the extra time required to process lower grade lumber to meet their requirements; it takes more time to obtain required cuttings from lower grades with lower yields, more lumber must be processed to meet requirements. Such a conflict was not observed during the study, but it is encountered when a company's production demands dictate rapid processing, when labor shortages exist, or when waste removal is a problem. To complete a rush order, sometimes a manufacturer must minimize production time and increase material costs by processing a less-time-consuming higher grade. If labor shortages or short-run plant capacity restrictions exist, use of the higher grades may increase production. The use of only select and FAS occurs in some lumber processing establishments where waste disposal is a difficult problem, such as in New York City.

The seventh column in Table 7.9, "Annual Cost Savings" was derived as follows:

$$\text{Annual Savings} = \frac{\text{Annual Lumber Consumption (MMBF)} \times \text{Study Cost Savings by Simulation (\$)}}{\text{Volume of Lumber in Study for Costing (MBF)}}$$

Because of the relative importance of the three factors used above to determine annual savings, some companies had high potential savings values. Company Seven had up to \$2,523,000, while the rest had lower values down to \$49,000 per year. An

overall savings average of \$474,500 per year per company could occur, but due to the limited sample size and due to the high standard deviation, \$733,000, the reader is cautioned that the actual value of cost savings through correct grade choice for a company may be extremely different than this mean annual potential savings. It is accurate to state, however, that procurement and processing of the optimum grade mix may lead to thousands of dollars of cost savings for most companies.

Column 6 in Table 7.9 shows each company's potential cost savings (in percent) through optimization of lumber grades. These values were taken from each company's Data Summary Table 4.

The values for potential cost savings were determined as follows:

$$\text{Potential Cost Savings (\%)} = \left(1 - \frac{\text{Cost of Computer's Grade(s) (\$)}}{\text{Cost of Grades Used (\$)}}\right) \times 100$$

Cost includes lumber purchased, processing cost including labor, and overhead;

Cost of Grades Used was determined through computer simulation of the study.

Cost of Computer's Grades was run at each company's efficiency level.

Again a wide range of potential savings was found from 3.6 to 60.4 percent. The wide range stems from the degree to which a company approximated the computer's grade choices.

The overall arithmetic mean of 27.1 percent has a very large standard deviation of 19.4 percent. As before a more valid conclusion is that the opportunity for cost savings exists through use of the OFCCP's grade selection. Actual savings are a function of how close a company presently comes to the computer's grade choice and how close the company can come in the future.

Analysis of Lumber Processing Efficiency

Even prior to publication of FPL 118, progressive lumber processing plants have maintained control of rough mill operations by periodically monitoring yields. Some companies find monthly checks sufficient; others, such as a dimension producer involved in a highly volatile and competitive market, watch yield levels daily. Through comparisons with past yield levels, a company can observe changes in yield levels. If decreasing yields are discovered, remedial steps may be taken to correct the situation.

Past studies, including one mentioned earlier in Chapter II, have found the yield values predicted by Charts for Calculating Yields from Hard Maple Lumber, FPL 118, to be a workable standard which hardwood lumber users can employ to compare their processing efficiency levels. These same FPL 118 yield tables became the OFCCP's data base; the check for accuracy by manual verification was described earlier. Since the computer program output predicts yields

for a cutting bill and associated costs, a manufacturer can use these yield values as a standard equally well.

The yield table standards are based upon cuttings with one clear face; but, some companies' specifications are different. If a company requires all surfaces of a cutting to be clear of defects (knots, bark, grain deviation, etc.), a lower yield than predicted by the computer may be anticipated. Conversely, if the manufacturer allows defects incorporated into the product the yields may exceed the computer predictions.

In the secondary wood products manufacturing industry, wide variability exists among individual companies' products and quality control restrictions. Some of the ten study companies had divergent product specification which might affect their final yield. Therefore, in analyzing potential improvements in efficiency (yield) level, it is necessary to analyze some of the individual company results (See Tables 7.10 and 7.11).

Company Number One used a grade mix which included every normal hard maple grade: FAS, select, 1 common, 2 common, and 3A common. The grade mix was "log run," meaning the firm processed the entire lumber production from the company's captive sawmill located adjacent to the rough mill. When a rough mill buys a log run lumber, it theoretically receives all the lumber produced from the saw logs, i.e., all high and low grade lumber. Company One's rough mill study was part of a sequence of studies which also involved

TABLE 7.10 POTENTIAL VOLUME SAVINGS THROUGH INCREASING EFFICIENCY TO FPL 118 YIELD LEVELS

	(1)	(2)	(3)	(4)	(5)	(6)
Company	Volume Cut in Study (BF) 1	Volume to Cut at 100% FPL 118 (BF)	Potential Volume Savings in Study (BF) (1)-(2)	% of Annual Lumber Consumption in Study	Potential Annual Volume Savings (3)/(4)	Potential Volume Savings (%) $\left[1 - (92)/(1)\right] 100$
1	14,165	18,066	0	0.594	0	0
2	19,611	19,311	300	0.654	46,000	1.5
3	10,116	8,737	1,379	0.723	191,000	13.6
4 {X-C Rip	12,195 11,747	10,312 14,465	1,883 0	1.197 1.197	157,000 0	15.4 0
5	9,975 ²	9,475	500	0.091	549,000	5.0
6	8,933 ²	9,555	0	0.089	0	0
7	4,021	9,481	0	0.106	0	0
8	8,074 ³	5,458	2,616	1.009	259,000	32.4
9	6,896	5,544	1,352	1.379	239,000	37.2
10 {X-C Rip	7,903 6,843	5,988 6,512	1,915 331	0.492 0.492	389,000 67,000	24.2 4.8

1. Volume used to determine savings may be less than total volume in study.
2. FAS, select and 1 common grades only.
3. Select and 1 common only.

SOURCE: Ten rough mill field studies conducted 1977-1979 in Eastern United States for hardwood lumber users.

TABLE 7.11 POTENTIAL COST SAVINGS THROUGH INCREASING EFFICIENCY TO FPL 118 YIELD LEVELS

Company	(1) Cost of Study Lumber (\$) ^{1,2}	(2) Cost at 100% FPL 118 (\$) ^{1,2}	(3) Potential Cost Sav- ings in Study (\$) (1)-(2)	(4) % of Annual Lumber Con- sumption in Study	(5) Potential Annual Cost Sav- ings (\$) (3)/(4)	(6) Potential Cost Savings (%) [1-((2)/(1))0]100
1	11,441	10,216	1,225	0.594	206,000	10.7
2	21,828	21,443	385	0.654	59,000	1.8
3	5,270	4,375	895	0.723	123,790	17.0
4 {X-C [Rip	10,044 8,184	9,211 10,312	833 0	1.197 1.197	70,000 0	8.3 0
5 ³	6,302	6,504	0	0.091	0	0
6 ³	6,759	7,316	0	0.089	0	0
7	4,418	4,153	265	0.106	250,000	6.0
8 ⁴	3,228	3,020	208	1.009	21,000	6.4
9	4,987	3,803	1,184	1.379	86,000	23.7
10 {X-C [Rip	4,974 5,601	3,794 5,433	1,180 168	0.492 0.492	240,000 34,000	23.7 3.0

1. Cost includes lumber+ processing+ overhead, but not salvage value.

2. Obtained by computer simulation of study.

3. FAS + select + 1 common only.

4. Select + 1 common only.

SOURCE: Ten rough mill field studies conducted 1977-1979 in Eastern United States for hardwood lumber users.

studies of the firm's sawmilling and lumber drying efficiency. Because of the method used to measure lumber volume at the plant, the yields were near or above 100 percent after cross-cutting! The firm's production sequence relied heavily on their salvage operation which increased yield by 8.5 percent. Salvage costs, volumes, and yields were deleted from computer simulation as explained in Chapter V. Exclusion of salvage output and erroneously low input volumes caused low processing yields. As a result, Company Number One's efficiency level appears relatively high because little lumber was required to produce their cutting bill requirements compared to the computer predictions. But, Company One's yield level was low because their salvage was not included in the rip-saw product yield. On the one hand, Table 7.10 shows no lumber savings and Table 7.11 shows no cost savings; however, the plant yield adjustments (used to shift the yield tables' predictions higher or lower according to a company's performance level) superficially indicate that the company could improve efficiency:

TABLE 7.12 COMPANY ONE'S PLANT YIELD ADJUSTMENTS BY GRADE

Grade	Plant Yield Adjustment
FAS	90%
Select	79%
1 Common	92%
2 Common	91%
3A Common	73%

Since plant yield adjustments are less than 100 percent, it appears that Company One could improve their processing. If salvage were included for this company which relies so heavily on its salvage operation, the comparison of yields would show these results:

TABLE 7.13 COMPARISON OF ACTUAL YIELDS WITH AND WITHOUT SALVAGE YIELDS INCLUDED TO THE COMPUTER PREDICTED YIELD WITHOUT SALVAGE FOR COMPANY ONE.

Grade	Actual Yield Without Salvage (%)	Actual Yield With Salvage (%)	Computer Predicted Yield Without Salvage (%)
FAS	69.3	78.6	77.1
Select	58.4	71.5	74.0
1 Common	65.6	73.6	71.6
2 Common	56.1	63.1	61.4
3A Common	33.9	42.3	45.3

From the above, it becomes apparent that Company One actually presently performs at a relatively high level of efficiency compared to the OFCCP's standards for yield.

Company Two is a dimension manufacturer processing FAS, select, 1 common and 2 common cherry. The values in Table 7.10, showing "Potential Volume Savings Through Increasing Efficiency to FPL 118 Yield Levels", indicate that the firm has not met the yield table standards. Assuming the manufacturer could increase yields to meet yield table predicted values, a 45,000 board foot reduction in lumber

consumption would be realized annually. Based on the following calculation, a savings of 1.5 percent might be achieved:

$$\frac{\% \text{ Potential Volume Savings}}{= (1 - \frac{\text{Volume to Cut at } 100\% \text{ FPL 118 (BF)}}{\text{Volume Cut in Study (BF)}}) \times 100$$

Table 7.11, "Potential Cost Savings Through Increasing Efficiency to FPL 118 Yield Levels," places dollar values on the savings. For Company Two, the difference between the cost of the study lumber including processing and overhead costs, and the simulated cost (computed at 100 percent FPL 118) is the savings potential during the study. If the study savings are divided by the percentage of annual yield represented in the study the result is potential annual savings:

Equation:

$$\frac{\text{Cost of Study Lumber \& Processing - Cost at 100\% of FPL 118}}{\% \text{ of Annual Lumber Consumption in Study}} = \text{Potential Annual Savings}$$

Example for Company Two:

$$\frac{\$21,828 - 21,443}{0.654\%} = \$59,000$$

While the \$385 potential savings incurred during the study might look small, the savings multiply to larger amounts annually. The potential cost savings, calculated in the same way as percent volume savings, could be 1.8 percent if the firm increased efficiency up to FPL 118 yield standards.

Company Three had similar circumstances as Company Two, with the exception of larger potential savings. Company Four has two production lines: a gang rip first and a crosscut first line. The crosscut first line produced wide furniture parts from a 1 common and better grade mix (FAS and select and 1 common in varying quantities). For the crosscut first line the computer program's predictions on yield, associated costs, and lumber quantities were compared with the actual values observed in the study, indicating the firm may reduce costs and lumber consumption if it increases efficiency to the maximum predictions of FPL 118. The potential savings could be 157,000 board feet annually, or 15.4 percent of lumber consumption. In monetary values, these potential savings through increased efficiency may be as high as \$70,000, or a 8.3 percent savings.

While it appears the crosscut-first line could improve efficiency, the rip-saw-first line achieved yields higher than computer predictions for the same cutting bill and grades (1, 2 and 3A common). No savings are listed on either Table 7.10 or Table 7.11 when the company exceeded yield table predictions.

Company Five came very close to yield table predicted values, and, in fact, exceeded them in their FAS and select grade processing. Unfortunately, the FPL 118 yield tables are not boundless; and, the computer program maintains their accuracy by not extrapolating data values outside the original

yield charts. Company Five cut lengths longer than those covered by tables for 2 and 3A common (their limits are 40 and 30 inches respectively). Thus, calculations to determine potential savings at Company Five focused only on FAS, select and 1 common.

The volume cut at Company Five in the study (9975 board feet) less the volume of lumber required at 100 percent of FPL 118 predictions is 500 board feet. The 500 board feet translate to 549,000 board feet potential annual savings. No cost savings were predicted because the high grade yields and relatively low costs are near the OFCCP predictions.

Company Six performed at a higher level of efficiency than the computer program predictions. This firm incorporated a large number of defects in their piano backframes since they are hidden from view. While no potential savings were predicted, there could be an opportunity for increasing processing efficiency.

Company Seven had a very small sample of 1 common (683 board feet) and another small sample of 2 common (3336 board feet). While the field study design called for 20,000 board feet of one species and of one thickness, this study was terminated after four day's total of 14,053 board feet. By the end of the study, two species and three thicknesses had been processed. In an attempt to reduce the error introduced by different thicknesses and species, the 5/4 oak was chosen for inclusion into this analysis; but, the small sample

size reduced the statistical validity of the field test. While no lumber volume savings would be apparently achieved if the company improved efficiency, the maximum cost savings possible would be 6.0 percent or \$250,000 annually.

Tables 7.10 and 7.11 reveal the opportunity for Companies Eight, Nine, and Ten to achieve both cost and lumber consumption savings if they could improve their current production operations to increase yields closer to computer predictions. Because of the diversity of the sample, and the heterogeneity of the population, an attempt to calculate mean values from the ten field studies would be statistically unsound. The range of savings is reported below:

TABLE 7.14 RANGE OF POTENTIAL SAVINGS THROUGH INCREASED EFFICIENCY. (Values from Tables 7.10 and 7.11)

Parameter	High	Low
Potential Annual Volume Savings (BF)	549,000	0
Potential Volume Savings (%)	37.2	0
Potential Annual Cost Savings (\$)	250,000	0
Potential Cost Savings (%)	23.7	0

The reader is cautioned that the diverse nature of the secondary wood products industry, coupled with the potential sources of error discussed previously, limit general application of these results. Some companies may exceed the potential savings listed above, while others with apparent opportunity to increase efficiency will not obtain the predicted savings.

CHAPTER VIII

PRACTICAL ROUGH MILL EXPERIENCES AND OBSERVATIONS

The purpose of this chapter is to document some of the observations, and some of the practical experiences gained during the ten rough mill studies. While the dissertation objectives revolved around the Optimum Furniture Cutting Computer Program (OFCCP), many of the topics discussed within this chapter may not be related to the computer program. Therefore, the ideas covered herein may be useful for rough mill managers, forest products utilization specialists, and industry consultants, regardless of whether or not the OFCCP is employed. The chapter has two main subdivisions: lumber procurement and lumber processing.

Lumber Procurement

Procuring lumber is a first step towards manufacturing a final product in a rough mill. Usually the lumber buyer has freedom in purchasing lumber, although in some of the ten study rough mills various limitations prevented

procurement liberties (captive sawmills, purchase of lumber by parent corporation, and market supply).

The lumber buyer must have the freedom to purchase the grade, species, and qualities necessary to satisfy requirements of the products' cutting bills. To minimize cost, the buyer must maintain as much flexibility as possible in making purchase decisions. For example, if the species has not been designated by the designers, or several species would be equally acceptable, the buyer could minimize lumber expenses by purchasing the lowest cost species.

A similar philosophy applies to the grade or grades of lumber purchased. Furniture and dimension manufacturers usually have a choice of five lumber grades to purchase (FAS, select, 1 common, 2 common, and 3A common). However, sometimes a premium above the normal lumber price will have to be paid, if only one lumber grade is purchased (such as straight FAS); but, it still may be economically advantageous to pay the premium and process that grade.

The choice of grade is complicated by the varying yields obtainable from each grade. Probably the greatest value of a yield study to a rough mill, is determining the yield percentage from each grade processed. Many variables, other than grade, affecting product yield must be controlled; in order to accurately measure yields for specific grades, the normal conditions should be maintained: processing sequence, operators, cutting bills, and species. Preferably

more than one yield study should be performed to verify that initial yields can be duplicated in future processing. The most cost-conscious rough mill managers perform yield and cost studies at regular intervals: daily, weekly, or monthly.

Armed with the knowledge of their company's obtainable yields, the lumber buyer is in a position to obtain the best available value. If various constraints are present, the buyer must orient his order as close as possible to the desired grade mix. Several examples of purchase constraints, affecting some of the ten field study companies could be helpful in understanding lumber procurement.

The OFCCP predicted that Company Three should purchase only FAS lumber. The company uses aspen, which like some other species such as beech, has a relatively small price differential between the grades. In the computer predictions for the least-cost grade mix for the prevailing conditions, the computer program weighs the anticipated grades' yields against the relevant costs of lumber and processing for each grade. Since the high yield of FAS could be obtained with a relatively small increase in purchase price, and a reduced processing cost (less labor involved), the computer chose FAS. As mentioned earlier FAS aspen lumber is not plentiful; Company Three now orients their grade mix purchases towards FAS.

Table 8.1 compares the OFCCP's grade selections, to the actual grades of lumber used, for the same cutting bills processed during the ten rough mill studies. It becomes apparent from the table, that select grade lumber was never chosen by the program. Select was never predicted because the yield of select grade lumber is near the 1 common grade yield, while the price of select is nearer FAS (usually select is only about \$10 less than the FAS price per thousand board feet). The select example, and the forementioned aspen example, demonstrate the important interaction between lumber cost and the anticipated yield which is intrinsic to knowledgeable lumber procurement.

Another valuable aspect of the rough mill field studies was the identification of the individual grade's processing costs. Introduction of the OFCCP to a company has always renewed management's interest in cost accounting. Often the cost values calculated after a rough mill cost study, differed from the manufacturers previously quoted costs. Precise knowledge of the cost for processing each grade of lumber is a necessity for intelligent lumber purchasing, even if the OFCCP is not used to assist in purchasing decisions.

Once the lumber buyer has determined the grade and species to purchase, the next decision is the quantity of lumber to purchase. Calculation of the lumber volume to buy was covered in the preceeding chapter. If the lumber is green, an additional shrinkage allowance must be included

TABLE 8.1 OPTIMUM FURNITURE CUTTING COMPUTER PROGRAM GRADE CHOICE COMPARED TO ACTUAL GRADES USED IN TEN FIELD STUDY ROUGH MILL

Company	Grade of Lumber Used	Computer Predicted Grade(s) at Company Yield Levels
1	FAS Select 1C 2C 3AC	FAS FAS + 1C 1C + 2C 1C + 2C 1C + 2C
2	FAS + Select 1C 2C	FAS + 2C FAS + 1C FAS + 2C
3	FAS Select 1C 2C	FAS FAS FAS FAS
4	FAS and Select 1C (X-C line) 1C (Rip line) 2C 3AC	FAS and 1C 1C 1C + 2C 2C 2C
5	FAS Select 1C 2C 3C	1C 1C 1C 1C 1C
6	FAS + Select 1C 2C	FAS + 1C + 2C FAS + 1C 1C + 2C
7	1 and 2 C	FAS + 2C
8	Select 1C 2C	FAS FAS FAS
9	FAS Select 1C 2C	FAS FAS + 1C 1C 1C
10	1C 2C 3C	FAS + 1C + 2C 1C 2C

1C = 1 Common 2C = 2 Common 3AC = 3A Common

Source: Ten rough mill field studies conducted for hardwood lumber using rough mills in Eastern United States, 1977-1979

to prevent shortages. Some lumber buyers are forced to purchase lumber inventory to guarantee sufficient raw material stock; others can obtain lumber as needed, usually when the rough mill is integrated with the company's sawmill.

The cost of carrying high inventory volumes must be weighed against the possibility of escaping lumber price increases, common in inflationary periods. Company Nine, for example, had four year old lumber in dry storage. The company claimed to have saved money because the price of lumber had increased greatly in that time; but, the trade-off cost of tying their money in inventory was not considered.

The purchase of the most economical grade mix, species, and quantity in these rapidly fluctuating economic times is a complex procedure. The lumber buyer can no longer be satisfied to simply rely on historic lumber buying practices. Changes in lumber supply, and changes in lumber cost, will force use of lower grades, in contrast to the too frequent consumption of only high grades in the furniture manufacturing industry.

When lumber is received at a furniture or dimension manufacturing plant, it normally is accompanied by an invoice stating, among other information, the quantity of each grade shipped. As each lot of lumber is moved into inventory, maintenance of accurate records of volume, grade, species, inventory control number, and location is essential; with strict inventory control, the lumber can be matched to the cutting bills for which it was intended later in the

rough mill. While most of the ten study firms recorded inventory volumes and grades for cost accounting purposes, coordination was occasionally lacking between these operations: lumber buying, lumber drying, and rough mill processing.

More than one of the study companies discovered the grades' volumes on the invoice did not match the grades' volumes once the lumber was reinspected for the rough mill field study. Therefore, it is important for a secondary wood products company to periodically, if not constantly, grade and scale incoming lumber. When discrepancies between invoice and reinspection are brought to the attention of the sawmill or lumber broker the differences may be reconciled. The rough mills which had lumber grade checks regularly performed, by their company's lumber inspector, rarely were incorrectly billed for their lumber.

Inspection at the company before the rough mill can lead to productive communication and coordination with the sawmill. By reaching an agreement with sawmillers, some rough mill operations have increased their yields. One company visited during the same time period the ten rough mill field studies were performed (but not a study company) had their yields increased by requesting the sawmill not to edge the lumber, i.e., allow waste to remain on the edges. A common sawmill practice to upgrade lumber involves ripping or trimming a board to remove or group defects; while the sawmill's product value is increased, the volume (hence

potential rough mill yield) is reduced. Some rough mills outside of this study have been successful in reaching an agreement with the sawmill to eliminate or reduce extra trimming, edging, and ripping. Companies have acquired sawmills and bolt (less than eight foot long logs) mills to ensure a high quality, reduced cost, and stable supply of hardwood lumber. Company Four discovered that even an integrated corporation sawmill operation might not always ship the grade of lumber as on the invoice.

Coordination with a sawmill or reinspection to the furniture or dimension company can enable sorting of the individual grades during inspection. The OFCCP predicts a grade or grade mix to be processed for a company's product requirements. Since a considerable savings could result by processing the predicted grade(s) the company can easily calculate whether it would be profitable to segregate grades before the rough mill. It suffices to state that some of the largest, most profitable furniture and dimension manufacturers in the United States sort their lumber before processing.

Procurement of lumber is not a simplistic task as it is often treated. The conscious lumber purchaser must coordinate his actions with product designers, industrial engineer's specifications, kiln operators, inventory controllers, and rough mill supervisors. The job has traditionally been performed without computers, but now computers and

computer programs(OFCCP and others) can assist in lumber procurement and inventory control.

Lumber Processing

Following lumber procurement, drying, and inventorying, the rough mill operation begins. While every rough mill is different, they all perform the similar function of converting rough, unsurfaced, variable-sized lumber into semi-finished parts of specified dimensions. Discussion of lumber processing will center on selection of lumber grades, production sequences, operator efficiency, and the salvage operation.

If lumber procurement, inventory, and drying are well coordinated with the rough mill operation, the selection of lumber to process should be relatively simple. However, the more common situation involves the rough mill operators and supervisors making a decision concerning which inventoried lumber to process for the current cutting bill. While the species has been designated in the cutting bill, and extra lumber may be returned to inventory, the choice of grade to process can determine whether or not the rough mill will be profitable. The rough mill must coordinate the grade(s) to be processed with the cutting bill requirements. The advantage of using the OFCCP to assist in lumber procurement was mentioned in Chapter VII; the rough mill may use the OFCCP to choose the grade and quantity of lumber from inventory too.

The sequence of processing in the rough mill is too often viewed as being determined by present plant layout. Actually the sequence should be designed to maximize product yield. Company Four and Company Ten had the flexibility to begin processing by either crosscutting or rip sawing the lumber. Company's Four and Ten are dimension manufacturers, adapting their processing operation to customers' orders. Although the other study companies included both dimension and furniture producers, the product had to be adjusted to the processing sequence; occasionally a higher yield would have resulted by the opposite production line sequence.

The factors influencing the decision of whether to rip or crosscut the lumber first include: product dimensions, lumber, and plant experience. Products which lend themselves to rip-first processing typically have many common, narrow widths such as flooring, moulding, and window and cabinet parts (stiles, rails, and sashes). For wider width products a crosscut-first sequence is generally more advantageous as in furniture casegoods, table, and panel manufacture.

A flexible rough mill may be able to designate individual incoming boards for rip or crosscut-first. A rip-first board might have the majority of defects in a line, pith running the length of the board, or a long split; the product yield could be greater by ripping rather than crosscutting initially.

The plant experience is probably the most valuable factor in deciding whether to crosscut or rip-first. If a company has been successful in obtaining high product yields, from the least-cost grade mix of lumber, by their present production sequence, then a change might only reduce yield. However, sometimes changes in products, raw material lumber quality, species, or a failure to achieve the maximum yield indicates a change in the order of operations should be considered. For more information the reader's attention is drawn to Henry A. Huber's article "In the Rough Mill Should You Rip or Crosscut First?"²² Future modifications of the OFCCP will also permit analysis of whether a particular cutting bill's yield would increase, and cost would be reduced, by ripping or crosscutting-first.

In the course of the ten rough mill field studies the researcher observed a wide range of operator efficiency levels, i.e., production rates, economy of motion, and accuracy. Table 8.2 illustrates the "Potential and Actual Production Rates for Crosscut Saws and Ripsaws by Company and by Grade of Lumber Processed in Ten Rough Mill Field Studies." The reasons why the production rates differed between and within companies are too numerous to detail here; sometimes the reason was not apparent and more studies would be required to obtain an explanation.

TABLE 8.2 POTENTIAL AND ACTUAL PRODUCTION RATES FOR CROSSCUT SAWS AND RIPSAWS BY COMPANY AND BY GRADE OF LUMBER PROCESSED IN TEN ROUGH MILL FIELD STUDIES

Crosscut saws (Based on Input except for Rip-First)								Rip Saws (Based on Output Except for Rip-First)						
Co.	Over All % Down Time	R A T E	FAS Rate BHS	SEL. Rate BHS	1C Rate BHS	2C Rate BHS	3AC Rate BHS	Over All % Down Time	R A T E	FAS Rate BHS	SEL. Rate BHS	1C Rate BHS	2C Rate BHS	3AC Rate BHS
1X-C	14.6	P A	684.2 642.0	1142.3 1142.3	823.6 618.6	553.8 500.6	365.3 333.7	10.4	P A	387.6 383.5	273.1 258.8	388.2 352.7	346.0 316.0	210.0 150.8
2X-C	26.0	P A	411.8 ¹ 283.9 ¹	N/A	342.3 248.9	281.4 217.2	N/A	20.3	P	376.0 ¹ 293.1 ¹	N/A	264.1 210.7	167.4 144.9	N/A
3Rip ²	14.7	P A	253.7 235.8	219.1 209.3	154.0 132.5	161.9 131.8	N/A	41.1	P A	994.7 237.7	1833.8 1619.5	1671.4 1083.9	1761.4 1076.2	N/A
4X-C	32.1	P A	851.0 ¹ 581.1 ¹	N/A	757.6 518.6	N/A	N/A	35.0	P A	235.8 ¹ 156.6 ¹	N/A	240.7 152.5	N/A	N/A
4RIP ²	25.4	P A	N/A	N/A	241.1 166.0	136.2 101.8	99.9 76.7	41.6	P A	N/A	N/A	1157.4 372.6	944.7 627.8	1097.0 786.1
5X-C	10.0	P A	452.7 398.1	496.8 440.8	608.6 553.1	348.1 344.1	293.6 260.0	10.7	P A	430.0 386.0	391.0 355.0	359.0 322.0	270.0 236.0	259.0 219.0
6X-C	16.3	P A	1436.3 ¹ 1318.6 ¹	N/A	1342.2 992.0	711.6 603.2	N/A	14.0	P A	612.9 ¹ 526.9 ¹	N/A	535.5 469.6	358.1 303.9	N/A
7X-C	19.3	P A	N/A	N/A	398.3 295.3	823.7 690.7	N/A	8.4	P A	N/A	N/A	121.1 107.4	146.2 135.1	N/A
8X-C	33.2	P A	N/A	821.3 495.6	708.2 507.6	642.1 338.5	N/A	24.5	P A	N/A	370.4 225.8	223.1 173.8	242.5 193.2	N/A
9RIP ²	42.1	P A	211.7 97.4	198.9 152.4	167.1 97.3	131.0 71.6	N/A	--3	P A	--3	--3	--3	--3	N/A
10X-C	29.9	P A	N/A	N/A	N/A	742.3 562.9	609.3 403.1	20.6	P A	N/A	N/A	N/A	122.8 98.5	102.1 79.7
10RIP ²	33.7	P A	N/A	N/A	237.5 157.5	N/A	N/A	33.7	P A	N/A	N/A	983.4 652.4	N/A	N/A

¹Includes select grade

²Gang rip sawn first; rip saw rates based on input lumber volume, X-C saw rates based on output product volume

³No rip saw rates, automatic line, prevented measurement

P = Potential rate (does not include down time) A = Actual rate BHS = Board feet per Hour per Saw

X-C = Crosscut-first production sequence. Rip = Ripsaw first production sequence

N/A = Not Applicable Sel = Select 1C = 1 Common 2C = 2 Common 3AC = 3A Common

Source: Ten rough mill field studies conducted for Eastern United States hardwood lumber processors, 1977-1979.

Some general causes of variable production rates might be helpful to the readers. One of the major causes of variable production rates is whether the rates were based on input lumber volumes or output product volumes. Table 8.2 is simply a listing of production rates; if comparisons are to be made between companies, the rip-first lines in Company Three, Four, Nine and Ten should be analyzed separately from the crosscut-first lines.

Production rates in Table 8.2 are listed as "P" for potential and "A" for actual; the calculations for these rates were detailed in Chapter VII. The basic difference between the two rates is that actual production rates include the down time (also termed lost time or non-production time). The potential production rate would only occur if the company had zero down time. While an unrealistic value, the potential production rate allows comparisons between companies without the affect of down time.

The "Overall Percent Down Time" listed for both the crosscut saws and rip-saws gives a good indication why some companies actual rates are high. The lowest down time recorded for saws was 8.4 percent, but a more reasonable target would be near ten percent. Unnecessary down time was the major cause of lost production. Some routine maintenance on the machinery will reduce production, but even this could be performed by the millwright after hours. To reduce down time losses, the operator should be allowed to run the

machine, and not be required to bring lumber to the saw, take product away, or perform other duties.

Because of time limitations in the study, accurate measurement of some variables affecting production rates was impossible.

Variables affecting actual production rates include the following:

Operator experience and skill

Operator speed

Machine rate

Product size

Grade of lumber

Board size

Length

Thickness

Width

Down time

Sample size

Condition of work environment

Due to the wide range of values observed for the above list of variables in the ten rough mill field studies, the reader should use caution in interpreting and applying the production rate results in Table 8.2. For specific suggestions on improving operator efficiency the reader is again referred to the Rough Mill Operators Guide to Better Cutting Practices.³²

The final topic to be covered, the salvage operation, is one which was excluded previously to allow equivalent comparisons between the companies. Table 8.3 "Increased Yield From Salvage in Percent by Grade and by Company from Ten Rough Mill Field Studies" is abstracted from Table 7.1 (more complete raw data may be found in the Appendix). Other than when salvage was not processed during the study, denoted by "N/A" and footnote number two, a wide range of salvage yields was observed (0.0 to 34.5 percent).

The main reason for divergent salvage yields is the varying importance placed on the salvage operation by the company. At one extreme, Company Four had no salvage operation. Companies Eight and Nine, on the other hand, placed a higher priority on the salvage operation; therefore, the crosscut and rip saw operators allowed more material to be salvaged into usable parts. Obviously, Company Nine, processing high grades for long lengths can achieve higher added salvage yield than Company Ten, processing low grades for short lengths (assuming equal salvage lengths for both companies). Due to the high value of wood, compared to labor cost, a functional salvage operation significantly increases yields for most companies.

This chapter covered some of the rough mill field study observations and experiences gained indirectly while pursuing the objectives of this research. The chapter may enable understanding some of the variables involved in

lumber procurement and processing. Topics covered in this chapter will not influence Chapters IX and X, "Summary and Conclusions" and "Recommendations" respectively.

CHAPTER IX

SUMMARY AND CONCLUSIONS

Ten rough mill field studies were conducted in furniture and dimension companies in the eastern United States. Data was collected to provide the basis for accomplishing the three study objectives regarding the analysis of the Optimum Furniture Cutting Computer Program (OFCCP) predictions for lumber grade utilization and product yields. Because of the diversity in product, production methods, and raw material used by the hardwood lumber processors, the results in the previous section may or may not be applicable to similar companies.

The first of the three objectives concerns the OFCCP's capability for predicting lumber yields, given information on lumber grade requirements, associated costs, and cutting bill needs. By comparing the computer predicted yields to the actual yields observed in the ten studies the computer's ability to predict yields was analyzed. The OFCCP was found to predict yields for the cutting bills processed by the ten companies within a range of 0.3 to 4.0 percent (on the average) for the five grades (FAS, select, 1 common, 2 common, and 3A common). Overall the computer predicted a yield of 64.1 percent which is only 0.6 percent lower than the actual overall average yield found to be 64.7 percent.

The OFCCP has a feature enabling the company to customize the program's yield table data base to the company's specific yield and lumber volume consumption level. The plant yield adjustment percentage allows the yield table values to be increased, decreased, or to remain at the standard levels as dictated by a company's performance. When the plant yield adjustment customized the data base for a company, the yields predicted were always within one percent of the observed production values.

Overall, the OFCCP accomplishes the objectives of accurately predicting lumber yields, given information on lumber grade requirements, associated costs, and cutting bill needs. The ability to precisely predict yields, easily done using appropriate plant yield adjustment percentages, is essential for procurement of lumber.

Determination of OFCCP's ability to accurately prescribe lumber purchases was the second objective of this research. The program follows the same procedure used by lumber buyers in the secondary wood products manufacturing industry to determine the quantity of lumber to buy. The program's cost minimization linear program combines the company's cost, yield, and product requirements data to select the most economical grade mix for given circumstances. Since the OFCCP follows normal lumber purchasing procedures and predicts accurate lumber yields it can and is actually being used by the secondary wood products manufacturing industry for the procurement of lumber on a scientific basis.

The examination of the opportunity for financial and material savings in the secondary wood processing industry through use of the OFCCP is the final objective of this research. The "potential" savings were analyzed as a result of two separate and distinct changes to be made by a hardwood lumber user. Changed first is the grade mix for a company's cutting bill with its associated costs. The second change analyzed was the improvement of lumber processing efficiency to the maximum level predicted by the program.

Because of the diverse production methods, raw materials, and products of the industry, and of the ten sample companies, the results obtained could not be accurately represented by a mean value. Indeed, the high standard deviations incurred suggest that a range of values would best summarize the data (See Table 9.1).

TABLE 9.1 RANGE OF POTENTIAL SAVINGS INCURRED THROUGH USE OF THE OPTIMUM FURNITURE CUTTING COMPUTER PROGRAM AT TEN FIELD STUDY ROUGH MILLS, 1977-1979. (Abstracted from Tables 7.9, 7.10, and 7.11).

Type of Savings	Low Value	High Value
Optimizing Grade Utilization		
Cost Savings		
%	3.6	60.4
\$ Annually	49,000	2,523,000
Volume Savings		
%	2.0	28.7
MBF Annually	122	1056
Increasing Production Efficiency		
Cost Savings		
%	0	23.7
\$ Annually	0	250,000
Volume Savings		
%	0	37.2
MBF Annually	0	549

Table 9.1 displays the wide range of values obtained in this study. From this information one can conclude that the opportunity for monetary and material savings does exist in some hardwood processing plants. However, specification to the size of such savings is impossible at this time.

CHAPTER X

RECOMMENDATIONS

While the Optimum Furniture Cutting Computer Program (OFCCP) passed its field test demonstration period, the novelty of the program has now worn off. The advertisement of the computer program has recently been limited due to potential competition with a similar private program. Most of the major wood products trade associations have published news releases and have had presentations on the availability of the OFCCP. The program's present status for the USDA Forest Service is that of a tool for use by forest products utilization specialists when servicing their clientele. No comprehensive promotion exists to further implement the OFCCP through the USDA Forest Service, but a growing number of commercial woodworking firms are assessing the computer program made available by the Michigan State University Teleplan System.

For the computer program to reach its maximum potential, a coordinated implementation program would be required. While the USDA Forest Service is in a position to make the computer program available to the entire lumber-user industry,

the lack of manpower and necessary funds plus the fear of competition with the private sector prevents implementation to its fullest degree. Based upon the reception of the computer program by the industry, the need for this tool still exists. The opportunity for an enterprising company or industry consultant to profitably implement the program appears ripe at the present time. Like many developments in the wood industry, the economics of the computer program are presently established; but action may not be taken until the evidence for potential savings becomes overwhelming. General reluctance by the secondary processing industry to accept new production methods or ideas further hinders universal acceptance of the computer program.

Further research on maximizing utilization needs to be performed in all of the sequential steps leading to the lumber processing stage of hardwood conversion. The past, present, and future research must be of a practical nature so that results can be successfully implemented by the wood industry. The various stages which ultimately may have an impact on hardwood lumber yields are the timber growing, logging, sawmilling, grading, drying, marketing, and lumber processing.

Tree growing must be performed with the objective of profitably producing the highest quality timber in the minimum amount of time. Research and implementation of research on growing and harvesting (to provide information on maximizing the forest timber resources) must be continued.

Recent improvements in logging due to new methods, such as the USDA Forest Services "Felling and Bucking" (FAS) procedures analysis, ultimately boost lumber yields.

The improvements possible in sawmilling have been initiated through research and implementation of research. New mechanization has generated increased precision in log conversion. Improvements in production facilities or "tightening-up" are being carried out by public and private industry consultants. Again, increased efficiency in sawmilling should lead to increased volume production and maximum grade production of hardwood lumber.

While grading is fairly universally based on the National Hardwood Lumber Association's Rules for the Measurement and Inspection of Hardwood and Cypress Lumber,²⁷ the application of the grading rules in sawmilling, marketing (buying and selling), and processing of lumber should be improved. Processor's needs with lumber grade availability must be coordinated to maximize lumber utilization.

Research along with implementation of the findings for lumber drying practices can reduce degrade incurred during drying. One program used by the USDA Forest Service, State and Private Forestry is the Improved Drying Program (IDP). The IDP, as an analysis tool, is used to measure the amount of drying degrade and then make recommendations to decrease the losses. The IDP program is a good example of implementation of research since the user bases recommendations on findings of earlier research in the lumber drying field.

The USDA Forest Service's RIP (Rough-Mill Improvement Program) is another program implementing research on manufacturing techniques to improve lumber yields, decrease manufacturing costs, reduce waste, and extend the hardwood resource. As the particular stage under analysis moves closer to the final product, the increases in efficiency become increasingly important. For example, a small percentage increase in rough mill yields will have ramifications (theoretically) back through the successive stages leading to lumber processing; a small savings in the rough mill could mean less lumber to dry, less to produce for the company, and an extension of the hardwood lumber resource. Integration of the research and research implementation for all the various stages leading to hardwood lumber processing in the rough mill would maximize effectiveness.

APPENDIX

FOUR DATA SUMMARY TABLES FOR EACH
PRODUCTION LINE BY COMPANY NUMBER

COMPANY 1

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 1

LUMBER YIELD SUMMARY

Cross Cut Saws

(1) Grade	(2) Input (BF)	(3) Output (BF)	(4) Yield (%) $(3) \div (2) \times 100$
FAS	1040	1062.3	102.1
Select	1782	1809.1	101.5
1 Common	5765	5642.8	97.9
2 Common	3956	3670.0	92.8
3A Common	<u>1622</u>	<u>1435.0</u>	88.5
Total	14,165	13,619.2	96.1

Rip Saws

(5) Grade	(6)=(3) Input (BF)	(7) Output (BF)	(8) Yield (%) $(2) / (6) \times 100$	(9) Cumulative Yield (%) $(7) / (2) \times 100$
FAS	1062.3	720.9	67.9	69.3
Select	1809.1	1040.3	57.5	58.4
1 Common	5642.8	3781.0	67.0	65.6
2 Common	3670.0	2218.3	60.4	56.1
3A Common	<u>1435.0</u>	<u>550.3</u>	38.3	33.9
Total	13,619.2	8310.3	61.0	58.7

COMPANY 1

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 2

PRODUCTION TIME SUMMARY

Cross Cut Saw (Based on Total Input BF)

(1) Grade	(2) Gross Time (hr)	(3) Down Time (hr)	(4) % Down Time (3)÷(2)	(5) Net Time (2)-(3) (hr)	(6) Input (BF)	(7) Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	(8) Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	(9) % Change Between Next Highest Grade
FAS	0.81	0.05	6.2	0.76	1040	684.2	642.0	-----
Select	0.78	0.00	0.0	0.78	1782	1142.3	1142.3	+43.8
1 Common	4.66	1.16	24.9	3.50	5765	823.6	618.6	-45.9
2 Common	3.96	0.38	10.3	3.58	3956	553.8	500.6	-19.1
3A Common	2.43	0.21	8.6	2.22	1622	365.3	333.7	-33.3
Total	12.64	1.80	14.6	10.84	14,165	653.4	560.3	----

Rip Saws (Based Upon Total Output BF)

Grade	Gross Time (hr)	Down Time (hr)	% Down Time (3)÷(2)	Net Time (2)-(3)	Output (BF)	Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	% Change Between Next Highest Grade
FAS	1.88	0.03	1.6	1.85	720.9	387.6	383.5	-----
Select	4.02	0.21	5.2	3.81	1040.3	273.1	258.8	-32.5
1 Common	10.72	0.98	9.1	9.74	3781.0	388.2	352.7	+26.6
2 Common	7.02	0.61	8.7	6.41	2218.3	346.0	316.0	-10.4
3A Common	3.65	1.02	27.9	2.63	550.3	210.0	150.8	-52.3
Total	27.29	2.85	10.4	24.44	8310.8	340.1	304.5	----

COMPANY 1

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 3

COMPARISON OF ACTUAL STUDY RESULTS TO COMPUTER PREDICTIONS

Actual Study Results		Computer Predictions									
		Study Simulation									
Grades Used by Company	Quantity Actually Cut (BF)	Yield Actually Obtained (%)	Grades Used by Company	Quantity to Cut (BF)	Yield at 100% FPL 118 (%)	Cost (\$)	Plant Yield Adj't (%)	Quantity to Cut (BF)	Yield to Obtain (%)	Cost (\$)	
FAS	1040	69.3	FAS	1461	77.1	1006	90	1624	69.4	1117	
Select	1782	58.4	Select	2448	74.0	1636	79	3098	58.5	2071	
1 Common	5765	65.6	1 Common	6956	71.6	3996	92	7561	65.8	4343	1/
2 Common	3956	56.1	2 Common	4929	61.4	2411	91	5242	55.9	2552	1/
3A Common	1622	33.9	3A Common	2272	45.3	1167	73	3108	34.0	1358	2/

1/ Includes 35% 1 Common required to override computer program's 2 Common length limitations.

2/ Includes 33% 1 common required to override computer program's 2 common length limitations.

COMPANY 1

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 4

COMPARISON OF COMPUTER PREDICTIONS TO STUDY RESULTS

POTENTIAL SAVINGS BY USING COMPUTER-PREDICTED LEAST-COST GRADE CHOICE

Computer Predicted Grade(s)	(1) Lumber Required (BF)	(2) Cost (\$)	Grade Used in Plant	(3) Lumber ^{1/} Used (BF)	(4) Simulation Cost (\$)	(5) Potential \$ Savings [1-(2)/(4)] x100	(6) Potential BF Savings [1-(1)/(3)] x100
FAS	1461	1006	FAS	1624	1117	9.9%	10.0%
FAS	1004	1519	Select	3098	2071	26.7%	21.1%
1 Common	1441						
1 Common	3879	3819	1 Common	7561	4343	12.1%	1.7%
2 Common	3557						
1 Common	1709	2411	2 Common	5242	2552 ^{2/}	5.6%	6.0%
2 Common	3219						
1 Common	445	1069	3A Common	3108	1368 ^{3/}	21.3%	22.7%
2 Common	1956						
1 Common	12,374	10,577	All Above	23,173	12,402	14.7%	12.9%
2 Common	7814						

1/ Do not match actual footage values used since only yield percentages were simulated.

2/ Included 35% 1 common to override yield table length limitations.

3/ Included 33% 1 common to override yield table length limitations.

COMPANY 2

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 1

LUMBER YIELD SUMMARY

Cross Cut Saws

(1) Grade	(2) Input (BF)	(3) Output (BF)	(4) Yield (%) $(3) \div (2) \times 100$
FAS and Select	12,048	11,281.3	93.6
1 Common	5,087	5,482.2	N/A
2 Common	<u>2,476</u>	<u>1,928.5</u>	77.9
Total	19,611	18,692.0	95.3

Rip Saws

(5) Grade	(6)=(3) Input (BF)	(7) Output (BF)	(8) Yield (%) $(2) / (6) \times 100$	(9) Cumulative Yield (%) $(7) / (2) \times 100$
FAS+Select	11281,3	7741,9	68,6	64.3
1 Common	5482.2	3008,2	54,9	59.1
2 Common	<u>1928,5</u>	<u>907,1</u>	47,0	36.6
Total	18,692,0	11,657.2	62.4	59.4

COMPANY 2

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 2

PRODUCTION TIME SUMMARY

Cross Cut Saws (Based Upon Total Input BF)

(1) Grade	(2) Gross Time (hr)	(3) Down Time (hr)	(4) % Down Time (3)÷(2)	(5) Net Time (2)-(3) (hr)	(6) Input (BF)	(7) Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	(8) Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	(9) % Change Between Next Highest Grade
FAS and								
Select	21.2	5.6	26.3	15.6	12,048	411.8	283.9	----
1 Common	10.2	2.8	27.3	7.4	5087	342.3	248.9	-12.3
2 Common	5.7	1.3	22.3	4.4	2476	281.4	217.2	-12.7
Total	37.1	9.7	26.0	27.5	19,611	356.7	264.3	----

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Rip Saws (Based Upon Output BF)

Grade	Gross Time (hr)	Down Time (hr)	% Down Time (3)÷(2)	Net Time (2)-(3)	Output (BF)	Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	% Change Between Next Highest Grade
FAS and								
Select	26.4	5.8	22.0	20.6	7741.9	376.0	293.1	----
1 Common	14.3	2.9	20.2	11.4	3008.2	264.1	210.7	-28.1
2 Common	6.3	0.8	13.4	5.4	907.1	167.4	144.0	-31.2
Total	47.0	9.6	20.3	37.4	11,657.2	311.7	248.3	----

COMPANY 2

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 3

COMPARISON OF ACTUAL STUDY RESULTS TO COMPUTER PREDICTIONS

Actual Study Results			Computer Predictions							
			Study Simulation							
Grades Used by Company	Quantity Actually Cut (BF)	Yield Actually Obtained (%)	Grades Used by Company	Quantity to Cut (BF)	Yield at 100% FPL 118 (%)	Cost (\$)	Plant Yield Adj't (%)	Quantity to Cut (BF)	Yield to Obtain (%)	Cost (\$)
FAS and Select	12,048	64.3	FAS and Select	12,188	68.4	14,985	94	12,966	64.3	15,904
1 Common	5,087	59.1	1 Common	6,008	50.1	6,480	118	5,087	59.1	5,492
2 Common	2,476	36.6	2 Common	Simulation not possible due to yield table limitations.						
Overall Cutting Bill										
All above	19,611	59.4	All above	19,311	60.7	21,443	FAS & Sel=94 1C=110 2C=100	19,660	59.6	21,828

COMPANY 2

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 4

COMPARISON OF COMPUTER PREDICTIONS TO STUDY RESULTS

POTENTIAL SAVINGS BY USING COMPUTER-PREDICTED LEAST-COST GRADE CHOICE

Computer Predicted Grade(s)	(1) Lumber Required (BF)	(2) Cost (\$)	Grade Used in Plant	(3) Lumber ¹ / Used (BF)	(4) Simulation Cost (\$)	(5) Potential \$ Savings [1-(2)/(4)] x100	(6) Potential BF Savings [1-(1)/(3)] x100
FAS+2 Common	11,605	14,245	FAS+Select	12.048	15,940	10.6%	3.7%
FAS+1 Common	4,195	4,965	1 Common	5,087	5,492	17.5%	9.6%
FAS+2 Common	2,272	1,739	2 Common	2,476	Simulation impossible--table limitations		

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OVERALL CUTTING BILL

FAS+2 Common	17,017	19,119	All above	19,611	21,828	12.4%	13.2%
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¹/Do not match actual footage values used since only yield percentages were simulated.

COMPANY 3

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 1

LUMBER YIELD SUMMARY

(1) Grade	(2) Input (BF)	(3) Output (BF)	(4) Yield (%) $(3) \div (2) \times 100$
FAS	378	280.3	74.2
Select	1247	945.2	75.8
1 Common	4563	3891.2	85.3
2 Common	<u>3928</u>	<u>3455.7</u>	88.0
Total	10,116	8572.4	84.7

(5) Grade	(6) = (3) Input (BF)	(7) Output (BF)	(8) Yield (%) $(2) / (6) \times 100$	(9) Cumulative Yield (%) $(7) / (2) \times 100$
FAS	280.3	266.4	95.0	70.5
Select	945.2	887.4	93.9	71.2
1 Common	3891.2	2117.1	54.4	46.4
2 Common	<u>3455.7</u>	<u>2153.1</u>	62.3	54.8
Total	8572.4	5424.0	63.3	53.6

COMPANY 3

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 2

PRODUCTION TIME SUMMARY

Gang Rip Saw (Based Upon Input BF)

(1) Grade	(2) Gross Time (hr)	(3) Down Time (hr)	(4) % Down Time (3) ÷ (2)	(5) Net Time (2) - (3) (hr)	(6) Input (BF)	(7) Production Rate (6) ÷ (5) ÷ (BF/hr/saw) (potential)	(8) Production Rate (6) ÷ (2) ÷ (BF/hr/saw) (actual)	(9) % Change Between Next Highest Grade
FAS	1.59	1.21	76.1	0.38	378	994.7	237.7	---
Select	0.77	0.09	11.7	0.68	1247	1833.8	1619.5	+85.3
1 Common	4.21	1.48	35.2	2.73	4563	1671.4	1083.9	-33.1
2 Common	3.65	1.42	38.9	2.23	3928	1761.4	1076.2	- 0.7
Total	10.22	4.20	41.1	6.02	10,116	1680.4	989.8	---

Chop Saws (Based Upon Output BF)

Grade	Gross Time (hr)	Down Time (hr)	% Down Time (3) ÷ (2)	Net Time (2) - (3)	Output (BF)	Production Rate (6) ÷ (5) ÷ (BF/hr/saw) (potential)	Production Rate (6) ÷ (2) ÷ (BF/hr/saw) (actual)	% Change Between Next Highest Grade
FAS	1.13	0.08	7.1	1.05	266.4	253.7	235.8	---
Select	4.24	0.19	4.5	4.05	887.4	219.1	209.3	-11.2
1 Common	15.98	2.23	14.0	13.75	2117.1	154.0	132.5	-36.7
2 Common	16.34	3.04	18.6	13.30	2153.1	161.9	131.8	- 0.6
Total	37.69	5.54	14.7	32.15	5424.0	168.7	143.9	---

COMPANY 3

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 3

COMPARISON OF ACTUAL STUDY RESULTS TO COMPUTER PREDICTIONS

Actual Study Results			Computer Predictions							
			Study Simulation							
Grades Used by Company	Quantity Actually Cut (BF)	Yield Actually Obtained (%)	Grades Used by Company	Quantity to Cut (BF)	Yield at 100% FPL 118 (%)	Cost (\$)	Plant Yield Adj't (%)	Quantity to Cut (BF)	Yield to Obtain (%)	Cost (\$)
FAS	378	70.5	FAS	354	75.2	181	94	404	70.6	193
Select	1247	71.2	Select	1273	70.8	659	101	1240	71.6	652
1 Common	4563	46.4	1 Common	3036 $\frac{1}{1}$	69.7	1724	67 $\frac{1}{1}$	4531	46.7	2573 $\frac{1}{1}$
2 Common	3928	54.8	2 Common	3594	56.2	1811	92	3676	54.7	1852

1/ Influenced by 12% FAS included to override computer program's 2 Common length limitations.

COMPANY 3

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 4

COMPARISON OF COMPUTER PREDICTIONS TO STUDY RESULTS

POTENTIAL SAVINGS BY USING COMPUTER-PREDICTED LEAST-COST GRADE CHOICE

Computer Predicted Grade(s)	(1) Lumber Required (BF)	(2) Cost (\$)	Grade Used in Plant	(3) Lumber Used (BF)	(4) Simulation Cost (\$)	(5) Potential \$ Savings [1-(2)/(4)] x100	(6) Potential BF Savings [1-(1)/(3)] x100
FAS	354	131	FAS	404	193	6.2%	12.4%
FAS	1269	606	Select	1240	652	7.1%	0.0%
FAS	2991	1427	1 Common	4531	2573	44.5%	34.0%
FAS	2977	1422	2 Common	3676 ^{2/}	1852 ^{2/}	23.2%	19.0%
OVERALL CUTTING BILL							
FAS	7089	3629	All above	9939	5319	31.8%	28.7%

1/ Do not match actual footage values used since only yield percentages were simulated.

2/ Partially influenced by 12% FAS included to override yield table length limitations.

COMPANY 4

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 1

LUMBER YIELD SUMMARY

Cross Cut First Line

Cross Cut and Straight-line Rip Saws

(1) Grade	(2) Input (BF)	(3) Output (BF)	(4) Yield (%) $(3) \div (2) \times 100$
FAS and Select	6195	4370.8	70.6
1 Common	<u>6000</u>	<u>3636.1</u>	60.6
Total	12,195	8007.4	65.7

(5) Grade	(6)=(3) Input	(7) Output	(8) Yield (%) $(2)/(6) \times 100$	(9) Cummulative Yield (%) $(7)/(2) \times 100$
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Continuous line--included above

COMPANY 4

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 2

PRODUCTION TIME SUMMARY

Crosscut First Line--Crosscut Saw (Based upon Input BF)

(1) Grade	(2) Gross Time (hr)	(3) Down Time (hr)	(4) % Down Time (3)÷(2)	(5) Net Time (2)-(3) (hr)	(6) Input (BF)	(7) Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	(8) Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	(9) % Change Between Next Highest Grade
FAS and Select	10.66	3.38	31.3	7.28	6195	851.0	581.1	----
1 Common	<u>11.77</u>	<u>3.85</u>	32.7	<u>7.92</u>	<u>6000</u>	757.6	518.6	-10.8
Total	22.43	7.23	32.1	15.20	12,195	802.3	543.7	----

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Straight-line Ripsaws (Based upon Output BF)

Grade	Gross Time (hr)	Down Time (hr)	% Down Time (3)÷(2)	Net Time (2)-(3)	Output (BF)	Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	% Change Between Next Highest Grade
FAS and Select	27.91	9.37	33.6	18.54	4370.8	235.8	156.6	----
1 Common	<u>23.84</u>	<u>8.73</u>	36.6	<u>15.11</u>	<u>3636.6</u>	240.7	152.5	-2.6
Total	51.75	18.10	35.0	33.65	8007.4	238.0	154.7	----

COMPANY 4

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 3

COMPARISON OF ACTUAL STUDY RESULTS TO COMPUTER PREDICTIONS

Crosscut First Line										
Actual Study Results			Computer Predictions							
			Study Simulation							
Grades Used by Company	Quantity Actually Cut (BF)	Yield Actually Obtained (%)	Grades Used by Company	Quantity to Cut (BF)	Yield at 100% FPL 118 (%)	Cost (\$)	Plant Yield Adj't (%)	Quantity to Cut (BF)	Yield to Obtain (%)	Cost (\$)
FAS and Select	1912 4283	7016	FAS and Select	1594 3549	73.6	5139	96	1661 3697	70.6	5353
1 Common	<u>6000</u>	60.6	1 Common	5209	69.9	4082	87	5988	60.9	4692
All above	12,195	65.7	All above	10,312	72.0	9211	Above 11,245		66.1	10,044

COMPANY 4

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 4

COMPARISON OF COMPUTER PREDICTIONS TO STUDY RESULTS

POTENTIAL SAVINGS BY USING COMPUTER-PREDICTED LEAST-COST GRADE CHOICE

Computer Predicted Grade(s)	Gang Ripsaw First Line						
	(1) Lumber Required (BF)	(2) Cost (\$)	Grade Used in Plant	(3) Lumber Used (BF)	(4) Simulation Cost (\$)	(5) Potential \$ Savings [1-(2)/(4)] x100	(6) Potential BF Savings [1-(1)/(3)] x100
1 Common	1441	1511	1 Common	1956	1533	1.4%	---
2 Common	903						
2 Common	6786	3768	2 Common	6906	3768	0	1.7%
2 Common	2115	1174	3A Common	2885	2049	42.7%	26.7%
OVERALL CUTTING BILL							
1 Common	768	7594	All above	11,747	8760	13.3%	6.4%
2 Common	10,228						

1/Do not match actual footage values used since only yield percentages were simulated.

COMPANY 4

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 1

LUMBER YIELD SUMMARY

Gang Rip Saw First Line -- Gang Rip Saw and Cross Cut Saws

(1) Grade	(2) Input (BF)	(3) Output (BF)	(4) Yield (%) $(3) \div (2) \times 100$
1 Common	1956	1444.4	73.8
2 Common	6906	4684.8	67.8
3A Common	<u>3885</u>	<u>1467.1</u>	50.9
Total	11,747	7596.3	64.7

(5) Grade	(6)=(3) Input	(7) Output	(8) Yield (%) $(2)/(6) \times 100$	(9) Cummulative Yield (%) $(7)/(2) \times 100$
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Continuous line--included above.

COMPANY 4

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 2

PRODUCTION TIME SUMMARY

Gang Ripsaw First Line--Gang Ripsaw (Based Upon Input BF)

(1) Grade	(2) Gross Time (hr)	(3) Down Time (hr)	(4) % Down Time (3)÷(2)	(5) Net Time (2)-(3) (hr)	(6) Input (BF)	(7) Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	(8) Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	(9) % Change Between Next Highest Grade
1 Common	5.25	3.56	67.8	1.69	1956	1157.4	372.6	----
2 Common	11.00	3.69	33.5	7.31	6906	944.7	627.8	+40.7
3A Common	3.67	1.04	28.3	2.63	2885	1097.0	786.1	+20.1
Total	19.92	8.29	41.6	11.63	11,747	1010.1	589.7	----

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Chop Saws (Based Upon Output BF)

Grade	Gross Time (hr)	Down Time (hr)	% Down Time (3)÷(2)	Net Time (2)-(3)	Output (BF)	Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	% Change Between Next Highest Grade
1 Common	8.70	2.71	31.1	5.99	1444.4	241.1	166.0	----
2 Common	46.00	11.59	25.2	34.41	4684.8	136.2	101.8	-38.7
3A Common	19.14	4.46	23.3	14.68	1467.1	99.9	76.7	-24.7
Total	73.84	18.76	25.4	55.08	7596.3	137.9	102.9	----

COMPANY 4

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 3

COMPARISON OF ACTUAL STUDY RESULTS TO COMPUTER PREDICTIONS

Gang Ripsaw First Line

Actual Study Results			Computer Predictions							
Grades Used by Company	Quantity Actually Cut (BF)	Yield Actually Obtained (%)	Grades Used by Company	Quantity to Cut (BF)	Yield at 100% FPL 118 (%)	Cost (\$)	Study Simulation			
							Plant Yield Adj't (%)	Quantity to Cut (BF)	Yield to Obtain (%)	Cost (\$)
1 Common	1956	73.8	1 Common	2249	64.4	1763	115	1955	74.1	1533
2 Common	6906	67.8	2 Common	8550	53.7	4747	126	6786	67.6	3768
3A Common	<u>2885</u>	50.9	3A Common	3851	36.8	2827	138	2790	50.8	2079
All Above	11,747	64.7	All Above	14,465	51.5	10,311	126	11,480	64.9	8184

COMPANY 4

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 4
 COMPARISON OF COMPUTER PREDICTIONS TO STUDY RESULTS
 POTENTIAL SAVINGS BY USING COMPUTER-PREDICTED LEAST-COST GRADE CHOICE

Crosscut First Line							
Computer Predicted Grade(s)	(1) Lumber Required (BF)	(2) Cost (\$)	Grade Used in Plant	(3) Lumber Used (BF)	(4) Simulation Cost (\$)	(5) Potential \$ Savings [1-(2)/(4)] x100	(6) Potential BF Savings [1-(1)/(3)] x100
FAS and 1 Common	866 5188	4946	FAS and Select	1912 4283	5253	5.8%	2.3%
1 Common	5988	4692	1 Common	6000	4692	0	0
OVERALL CUTTING BILL							
FAS and 1 Common	1072 10,881	9613	All above	12,195	10,044	4.3%	2.0%

1/Do not match actual footage values used since only yield percentages were simulated.

COMPANY 5

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 1

LUMBER YIELD SUMMARY

Cross Cut Saws

(1) Grade	(2) Input (BF)	(3) Output (BF)	(4) Yield (%) $(3) \div (2) \times 100$
FAS	2163	2357.1	109.0
Select	2880	3094.4	107.4
1 Common	4932	4955.7	100.5
2 Common	3349	3075.6	91.8
3A Common	1898	1453.1	76.6
3B Common	<u>1230</u>	<u>753.4</u>	61.3
Total	16,452	15,689.3	95.4

Rip Saws

(5) Grade	(6)=(3) Input (BF)	(7) Output (BF)	(8) Yield (%) $(2) / (6) \times 100$	(9) Cumulative Yield (%) $(7) / (2) \times 100$
FAS	2357.1	1592.1	67.5	73.6
Select	3094.4	2061.2	66.6	71.6
1 Common	4955.7	2785.7	56.2	56.5
2 Common	3975.6	1611.2	52.4	48.1
3A Common	1453.1	757.4	52.1	39.9
3B Common	<u>753.4</u>	<u>373.4</u>	49.6	30.4
Total	15,689.3	9181.0	58.5	55.8

COMPANY 5

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 2

PRODUCTION TIME SUMMARY

Crosscut Saws (Based Upon Input BF)

(1) Grade	(2) Gross Time (hr)	(3) Down Time (hr)	(4) % Down Time (3)÷(2)	(5) Net Time (2)-(3) (hr)	(6) Input (BF)	(7) Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	(8) Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	(9) % Change Between Next Highest Grade
FAS	2.72	0.33	12.1	2.39	2163	905.3	796.2	----
Select	3.27	0.37	11.3	2.90	2880	993.6	881.6	+10.7
1 Common	4.45	0.41	9.1	4.05	4932	1217.2	1106.2	+25.4
2 Common	4.87	0.06	1.1	4.81	3349	6.6.1	688.2	-37.8
3A Common	3.65	0.42	11.5	3.23	1898	587.2	520.0	-24.4
3B Common	2.53	0.56	21.9	1.97	1230	621.7	485.5	-6.6
Total	21.49	2.15	10.0	19.35	16,452	850.0	765.5	----

(1) Grade	(2) Gross Time (hr)	(3) Down Time (hr)	(4) % Down Time (3)÷(2)	(5) Net Time (2)-(3) (hr)	(6) Output (BF)	(7) Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	(8) Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	(9) % Change Between Next Highest Grade
FAS	4.13	0.43	10.4	3.70	1592.1	430.3	385.5	----
Select	5.80	0.53	9.1	5.27	2061.2	391.1	355.4	-7.8
1 Common	8.64	0.88	10.2	7.71	2785.7	361.3	322.4	-9.3
2 Common	6.83	0.86	12.5	5.97	1611.2	269.9	235.9	-26.8
3A Common	3.47	0.53	15.5	2.93	757.4	258.5	218.3	-7.5
3B Common	1.97	0.02	0.9	1.95	373.4	191.5	189.5	-13.2
Total	30.84	3.25	10.7	27.53	9181.0	333.5	297.7	----

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 3

COMPARISON OF ACTUAL STUDY RESULTS TO COMPUTER PREDICTIONS

Actual Study Results				Computer Predictions							
Grades Used by Company		Quantity Actually Cut (BF)	Yield Actually Obtained (%)	Grades Used by Company	Quantity to Cut (BF)	Yield at 100% FPL 118 (%)	Cost (\$)	Plant Yield Adj't (%)	Quantity to Cut (BF)	Yield to Obtain (%)	Cost (\$)
FAS		2163	80.8	FAS	2106	76.9	1628	105	2006	80.7	1551
Select		2880	77.8	Select	3041	71.7	2374	108	2816	77.5	2198
1 Common		4932	67.0	1 Common	4328	67.8	2502	98	4416	66.4	2553
2 Common		3349	55.8	2 Common							
3 Common		3128	39.7	3 Common							
Simulation impossible due to yield table limitation											

Simulation impossible due to yield table limitations.

COMPANY 5

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 4

COMPARISON OF COMPUTER PREDICTIONS TO STUDY RESULTS

POTENTIAL SAVINGS BY USING COMPUTER-PREDICTED LEAST-COST GRADE CHOICE

Computer Predicted Grade(s)	(1) Lumber Required (BF)	(2) Cost (\$)	Grade Used in Plant	(3) Lumber Used (BF)	(4) Simulation Cost (\$)	(5) Potential \$ Savings [1-(2)/(4)] x100	(6) Potential BF Savings [1-(1)/(3)] x100
1 Common	2483	1436	FAS	2163	1554	7.6%	0
1 Common	3144	1807	Select	2880	2198	17.8%	0
1 Common	4328	2502	1 Common	4932	2553	2.0%	10.8%
1 Common	2186	1247	2 Common	3349	2/	2/	34.7%
1 Common	2736	1556	3 Common	3123	2/	2/	12.5%
Total	14,877	5745 ^{3/}	All above	16,452	6305 ^{3/}	8.9%	9.6%

1/ Do not match actual footage values used since only yield percentages were simulated.

2/ Simulation impossible due to yield table length limitations.

3/ Computed for FAS, select, and 1 common only.

COMPANY 6

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 1

LUMBER YIELD SUMMARY

Cross Cut Saws

(1) Grade	(2) Input (BF)	(3) Output (BF)	(4) Yield (%) $(3) \div (2) \times 100$
FAS and Select	4826	4715	97.7
1 Common	4107	3763	91.6
2 Common	<u>7223</u>	<u>6320</u>	87.5
Total	16,156	14,798	91.6

Rip Saws

(5) Grade	(6)=(3) Input (BF)	(7) Output (BF)	(8) Yield (%) $(2) / (6) \times 100$	(9) Cummulative Yield (%) $(7) / (2) \times 100$
FAS+Select	4715	3843	81.5	79.6
1 Common	3763	2959	78.6	72.1
2 Common	<u>6320</u>	<u>4643</u>	73.5	64.3
Total	14,798	11,445	77.3	70.8

COMPANY 6

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 2

PRODUCTION TIME SUMMARY

Crosscut Saws (Based Upon Input BF)

(1) Grade	(2) Gross Time (hr)	(3) Down Time (hr)	(4) % Down Time (3) ÷ (2)	(5) Net Time (2) - (3) (hr)	(6) Input (BF)	(7) Production Rate (6) ÷ (5) ÷ (BF/hr/saw) (potential)	(8) Production Rate (6) ÷ (2) ÷ (BF/hr/saw) (actual)	(9) % Change Between Next Highest Grade
FAS and Select	1.83	0.15	8.0	1.68	4826	1436.3	1318.6	----
1 Common	2.07	0.54	26.1	1.53	4107	1342.2	992.0	-24.7
2 Common	<u>4.79</u>	<u>0.73</u>	15.3	<u>4.06</u>	<u>5778</u>	<u>711.6</u> ^{1/}	<u>603.2</u> ^{1/}	-39.2
Total	8.69	1.42	16.3	7.27	14,711	1011.3	846.5	----

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Ripsaws (Based Upon Output BF)

Grade	Gross Time (hr)	Down Time (hr)	% Down Time (3) ÷ (2)	Net Time (2) - (3) (hr)	Output (BF)	Production Rate (6) ÷ (5) ÷ (BF/hr/saw) (potential)	Production Rate (6) ÷ (2) ÷ (BF/hr/saw) (actual)	% Change Between Next Highest Grade
FAS and Select	4.42	0.62	14.0	3.80	2329	612.9	526.9	----
1 Common	1.38	0.17	12.3	1.21	648 ^{1/}	535.5	469.6	-10.9
2 Common	<u>2.05</u>	<u>0.31</u>	15.1	<u>1.74</u>	<u>623</u>	358.1	303.9	-35.3
Total	7.85	1.10	14.0	6.75	3600	533.4	458.6	----

1/ Adjusted downward 80% to 4/4 basis.

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 3

COMPARISON OF ACTUAL STUDY RESULTS TO COMPUTER PREDICTIONS

Actual Study Results			Computer Predictions							
Grades Used by Company	Quantity Actually Cut (BF)	Yield Actually Obtained (%)	Grades Used by Company	Quantity to Cut (BF)	Yield at 100% FPL 118 (%)	Cost (\$)	Study Simulation			
							Plant Yield Adj't (%)	Quantity to Cut (BF)	Yield to Obtain (%)	Cost (\$)
FAS and Select	4826	80.4	FAS and Select	5262	73.1	4325	110	4783	80.4	3925
1 Common	4107	72.2	1 Common	4293	68.5	2991	106	4006	72.2	2834
2 Common	7223	65.1	2 Common	Simulation impossible due to yield table limitation						

COMPANY 6

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 4

COMPARISON OF COMPUTER PREDICTIONS TO STUDY RESULTS

POTENTIAL SAVINGS BY USING COMPUTER-PREDICTED LEAST-COST GRADE CHOICE

Computer Predicted Grade(s)	(1) Lumber Required (BF)	(2) Cost (\$)	Grade Used in Plant	(3) Lumber Used (BF)	(4) Simulation Cost (\$)	(5) Potential \$ Savings [1-(2)/(4)] x100	(6) Potential BF Savings [1-(1)/(3)] x100
FAS and 1+2 Common	4727	3825	FAS+Select	4826	3925	2.1%	2.5%
FAS and 1 Common	3900	2792	1 Common	4107	2834	5.0%	1.5%
1+2 Common	8242	4571	2 Common	7223	Simulation impossible--table limitations.		141
Average						3.6%	2.0%

1/ Do not match actual footage values used since only yield percentages were simulated.

COMPANY 7

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 1

LUMBER YIELD SUMMARY

Cross Cut Saws

(1) Grade	(2) Input (BF)	(3) Output (BF)	(4) Yield (%) $(3) \div (2) \times 100$
1 Common	685	686.7	100.2
2 Common	<u>3336</u>	<u>3144.6</u>	94.3
Totals	4021	3831.3	95.3

Rip Saws

(5) Grade	(6)=(3) Input (BF)	(7) Output (BF)	(8) Yield (%) $(2) / (6) \times 100$	(9) Cummulative Yield (%) $(7) / (2) \times 100$
1 Common	686.7	332.9	48.5	48.6
2 Common	<u>3144.6</u>	<u>1421.4</u>	45.2	42.6
Totals	3831.3	1754.3	45.8	43.6

COMPANY 7

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 2

PRODUCTION TIME SUMMARY

Crosscut Saws (Based Upon Input BF)

(1) Grade	(2) Gross Time (hr)	(3) Down Time (hr)	(4) % Down Time (3) ÷ (2)	(5) Net Time (2) - (3) (hr)	(6) Input (BF)	(7) Production Rate (6) ÷ (5) ÷ (BF/hr/saw) (potential)	(8) Production Rate (6) ÷ (2) ÷ (BF/hr/saw) (actual)	(9) % Change Between Next Highest Grade
1 Common	2.32	0.60	25.9	1.72	685	398.3	295.3	---
2 Common	<u>4.83</u>	<u>0.78</u>	16.1	<u>4.05</u>	<u>3336</u>	823.7	690.7	+57.2
Total	7.15	1.38	19.3	5.77	4021	696.9	562.4	----

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Ripsaws (Based Upon Output BF)

Grade	Gross Time (hr)	Down Time (hr)	% Down Time (3) ÷ (2)	Net Time (2) - (3) (hr)	Output (BF)	Production Rate (6) ÷ (5) ÷ (BF/hr/saw) (potential)	Production Rate (6) ÷ (2) ÷ (BF/hr/saw) (actual)	% Change Between Next Highest Grade
1 Common	3.1	0.35	11.3	2.75	332.9	121.1	107.4	---
2 Common	<u>10.52</u>	<u>0.80</u>	7.6	<u>9.72</u>	<u>1421.4</u>	146.2	135.1	+20.5
Total	13.62	1.15	8.4	12.47	1754.3	140.8	128.8	----

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 3

COMPARISON OF ACTUAL STUDY RESULTS TO COMPUTER PREDICTIONS

Actual Study Results			Computer Predictions							
Grades Used by Company	Quantity Actually Cut (BF)	Yield Actually Obtained (%)	Study Simulation							
			Grades Used by Company	Quantity to Cut (BF)	Yield at 100% FPL 118 (%)	Cost (\$)	Plant Yield Adj't (%)	Quantity to Cut (BF)	Yield to Obtain (%)	Cost (\$)
1 Common	685	68.3	1 Common	1612	72.8	1070	94	1715	68.4	1138
2 Common	3336	59.1	2 Common	7869	63.7	3083	93	8371	59.3	3280

COMPANY 7

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 4

COMPARISON OF COMPUTER PREDICTIONS TO STUDY RESULTS

POTENTIAL SAVINGS BY USING COMPUTER-PREDICTED LEAST-COST GRADE CHOICE

Computer Predicted Grade(s)	(1) Lumber Required (BF)	(2) Cost (\$)	Grade Used in Plant	(3) Lumber Used (BF)	(4) Simulation Cost (\$)	(5) Potential \$ Savings [1-(2)/(4)] x100	(6) Potential BF Savings [1-(1)/(3)] x100
FAS and 2 Common	3196	1748	1+2 Common	4021	4418	60.4%	20.5%

1/ Do not match actual footage values used since only yield percentages were simulated.

COMPANY 8

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 1

LUMBER YIELD SUMMARY

Cross Cut Saws

(1) Grade	(2) Input (BF)	(3) Output (BF)	(4) Yield (%) $(3) \div (2) \times 100$
Select	1700	1667.2	98.1
1 Common	6374	6278.3	98.5
2 Common	<u>931</u>	<u>868.8</u>	93.3
Total	9005	8814.3	97.9

Rip Saws

(5) Grade	(6)=(3) Input (BF)	(7) Output (BF)	(8) Yield (%) $(2) / (6) \times 100$	(9) Cumulative Yield (%) $(7) / (2) \times 100$
Select	1139.1	597.7	52.5	54.4
1 Common	4743.6	3292.9	67.5	69.0
2 Common	<u>887.4</u>	<u>319.5</u>	36.0	42.7
Total	6770.1	4120.1	60.9	63.0

COMPANY 8

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 2

PRODUCTION TIME SUMMARY

(1) Grade	Crosscut Saws (Based Upon Input BF)					(8) Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	(9) % Change Between Next Highest Grade
	(2) Gross Time (hr)	(3) Down Time (hr)	(4) % Down Time (3)÷(2)	(5) Net Time (2)-(3) (hr)	(6) Input (BF)	(7) Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	
Select	3.43	1.86	39.7	2.97	1700	821.3	----
1 Common	12.56	3.56	28.3	9.00	6374	708.2	+2.4
2 Common	<u>2.75</u>	<u>1.30</u>	47.3	<u>1.45</u>	<u>931</u>	642.1	-33.3
Total	18.74	6.22	33.2	12.52	9005	719.3	----

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Ripsaws (Based Upon Output BF)

Grade	Ripsaws (Based Upon Output BF)					(8) Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	(9) % Change Between Next Highest Grade
	(2) Gross Time (hr)	(3) Down Time (hr)	(4) % Down Time (3)÷(2)	(5) Net Time (2)-(3)	(6) Output (BF)	(7) Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	
Select	7.53	2.94	39.0	4.59	597.7	370.4	----
1 Common	36.67	8.09	22.1	28.57	3202.9	223.1	-23.0
2 Common	<u>4.82</u>	<u>0.90</u>	20.3	<u>3.84</u>	<u>319.5</u>	242.5	+11.2
Total	49.02	12.01	24.5	37.00	4120.1	111.4	----

84.1

COMPANY 8

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 3

COMPARISON OF ACTUAL STUDY RESULTS TO COMPUTER PREDICTIONS

Actual Study Results			Computer Predictions							
			Study Simulation							
Grades Used by Company	Quantity Actually Cut (BF)	Yield Actually Obtained (%)	Grades Used by Company	Quantity to Cut (BF)	Yield at 100% FPL 118 (%)	Cost (\$)	Plant Yield Adj't (%)	Quantity to Cut (BF)	Yield to Obtain (%)	Cost (\$)
Select	1700	52.5	Select	866	71.5	419	73	1187	52.2	574
1 Common	6374	67.5	1 Common	4592	69.0	2601	98	4686	67.6	2654
2 Common	981	36	2 Common	Simulation impossible due to yield table limitations.						

COMPANY 8

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 4

COMPARISON OF COMPUTER PREDICTIONS TO STUDY RESULTS

POTENTIAL SAVINGS BY USING COMPUTER-PREDICTED LEAST-COST GRADE CHOICE

Computer Predicted Grade(s)	(1) Lumber Required (BF)	(2) Cost (\$)	Grade Used in Plant	(3) Lumber Used (BF)	(4) Simulation Cost (\$)	(5) Potential \$ Savings [1-(2)/(4)] x100	(6) Potential BF Savings [1-(1)/(3)] x100
FAS	819	381	Select	1700	574	33.6%	51.8%
FAS	4164	2357	1 Common	6374	2654	11.2%	34.7%
FAS	563	265	2 Common	981	2/	2/	39.5%
Total ^{3/}	4983	2738	Select + 1 Common	8074	3228	38.3%	15.2%

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1/ Do not match actual footage values used since only yield percentages were simulated.

2/ Simulation impossible due to yield table limitations.

3/ Computed for select and 1 common only.

COMPANY 9

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 1

LUMBER YIELD SUMMARY

Gang Rip Saw First Line -- Gang Rip Saw and Cross Cut Saw

(1) Grade	(2) Input (BF)	(3) Output (BF)	(4) Yield (%) $(3) \div (2) \times 100$
FAS	1807	1056.4	58.5
Select	2636	1185.3	45.0
1 Common	3196	1488.6	46.6
2 Common	<u>1194</u>	<u>497.7</u>	40.1
Total	8833	4228.0	47.9

(5) Grade	(6)=(3) Input	(7) Output	(8) Yield (%) $(2)/(6) \times 100$	(9) Cumulative Yield (%) $(7)/(2) \times 100$
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Continuous line--included above.

COMPANY 9

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 2

PRODUCTION TIME SUMMARY

Crosscut Saws (Based Upon Input BF)

(1) Grade	(2) Gross Time (hr)	(3) Down Time (hr)	(4) % Down Time (3)÷(2)	(5) Net Time (2)-(3) (hr)	(6) Input (BF)	(7) Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	(8) Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	(9) % Change Between Next Highest Grade
FAS	5.76	3.24	56.3	2.52	1807	717.1	313.7	----
Select	5.53	1.47	26.6	4.06	2636	649.3	476.7	+52.0
1 Common	10.82	3.78	34.9	7.04	3196	454.0	295.4	-38.0
2 Common	3.17	0.67	21.1	2.49	1194	479.5	376.7	-27.5
Total	25.28	9.16	36.2	16.12	8833	548.3	349.4	----

Chop Saws (Based Upon Output BF)

Grade	Gross Time (hr)	Down Time (hr)	% Down Time (3)÷(2)	Net Time (2)-(3)	Output (BF)	Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	% Change Between Next Highest Grade
FAS	10.85	5.86	54.0	4.99	1056.4	211.7	97.4	----
Select	7.78	1.82	23.4	5.96	1185.3	198.9	152.4	+56.5
1 Common	15.80	6.39	41.8	8.91	1488.6	167.1	97.8	-36.2
2 Common	6.95	3.15	45.3	3.80	497.7	131.0	71.6	-26.4
Total	40.88	17.22	42.1	23.66	4228.0	178.7	103.4	----

COMPANY 9

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 3

COMPARISON OF ACTUAL STUDY RESULTS TO COMPUTER PREDICTIONS

Actual Study Results				Computer Predictions			
				Study Simulation			
Grades Used by Company	Quantity Actually Cut (BF)	Yield Actually Obtained (%)	Grades Used by Company	Quantity to Cut (BF)	Yield at 100% FPL 118 (%)	Cost (\$)	Plant Yield Adj't (%)
				to Cut (BF)			Yield to Obtain (%)
							Cost (\$)
FAS	1807	58.5	FAS	1613	66.2	1181	88
							58.2
							1342
Select	2636	45.0	Select	1920	61.9	1364	73
							45.2
							1869
1 Common	3196	46.6	1 Common	1129	66.0	718	70
							46.2
							1025
2 Common	1194	40.1	2 Common	882	56.4	540	72
							40.5
							751

COMPANY 9

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 4

COMPARISON OF COMPUTER PREDICTIONS TO STUDY RESULTS

POTENTIAL SAVINGS BY USING COMPUTER-PREDICTED LEAST-COST GRADE CHOICE

Computer Predicted Grade(s)	(1) Lumber Required (BF)	(2) Cost (\$)	Grade Used in Plant	(3) Lumber Used (BF)	(4) Simulation Cost (\$)	(5) Potential \$ Savings [1-(2)/(4)] x100	(6) Potential BF Savings [1-(1)/(3)] x100
FAS	1631	1181	FAS	1833	1342	12.0%	11.0%
FAS 53% 1 Common 47%	1901	1306	Select	2631	1869	30.1%	27.7%
1 Common	1129	718	1 Common	1612	1025	30.0%	30.0%
1 Common	750	476	2 Common ^{2/}	1228	751	36.6%	35.4%
OVERALL CUTTING BILL							
FAS 16% 1 Common 84%	806 4365	3363	All above	6896	4647	27.6%	25.0%

1/ Do not match actual footage values used since only yield percentages were simulated.

2/ Includes 5% 1 common to override computer's yield table limitations for length.

COMPANY 10

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 1

LUMBER YIELD SUMMARY

Cross Cut First Plant -- Cross Cut Saws

(1) Grade	(2) Input (BF)	(3) Output (BF)	(4) Yield (%) $(3) \div (2) \times 100$
2 Common	3912	2786.8	71.2
3 Common	<u>3991</u>	<u>1971.3</u>	49.4
Total	7903	4758.1	60.2

Rip Saws				
(5) Grade	(6)=(3) Input (BF)	(7) Output (BF)	(8) Yield (%) $(2) / (6) \times 100$	(9) Cumulative Yield (%) $(7) / (2) \times 100$
2 Common	2786.8	1893.7	68.0	48.4
3 Common	<u>1971.3</u>	<u>1380.7</u>	70.0	34.6
Total	4758.1	3274.4	68.8	41.4

COMPANY 10

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 2

PRODUCTION TIME SUMMARY

Crosscut First Line -- Crosscut Saws (Based Upon Input BF)

(1) Grade	(2) Gross Time (hr)	(3) Down Time (hr)	(4) % Down Time (3)÷(2)	(5) Net Time (2)-(3) (hr)	(6) Input (BF)	(7) Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	(8) Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	(9) % Change Between Next Highest Grade
1 Common	6.95	1.68	24.2	5.27	3912	742.32	562.88	----
2 Common	<u>9.90</u>	<u>3.35</u>	33.8	<u>6.55</u>	<u>3991</u>	609.31	403.13	-28.4
Total	16.85	5.03	29.9	11.82	7903	668.61	469.02	----

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Ripsaws (Based Upon Output BF)

Grade	Gross Time (hr)	Down Time (hr)	% Down Time (3)÷(2)	Net Time (2)-(3)	Output (BF)	Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	% Change Between Next Highest Grade
1 Common	14.87	2.94	19.8	11.98	1464.9	122.79	98.51	----
2 Common	<u>9.00</u>	<u>1.97</u>	21.9	<u>7.03</u>	<u>717.6</u>	102.08	79.73	-19.1
Total	23.87	4.91	20.6	18.96	2182.5	115.11	91.43	----

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 3

COMPARISON OF ACTUAL STUDY RESULTS TO COMPUTER PREDICTIONS

Actual Study Results			Crosscut First Line Computer Predictions							
Grades Used by Company	Quantity Actually Cut (BF)	Yield Actually Obtained (%)	Grades Used by Company	Quantity to Cut (BF)	Yield at 100% FPL 118 (%)	Cost (\$)	Study Simulation			
							Plant Yield Adj't (%)	Quantity to Cut (BF)	Yield to Obtain (%)	Cost (\$)
2 Common	3912	48.4	2 Common	3038	61.8	1918	78	3895	48.2	2459
3 Common	3991	34.6	3 Common	2959	46.7	1881	74	3999	34.5	2542
Above	7903	41.4	Above	5988	54.3	3794	Above	7850	41.4	4974

COMPANY 10

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 4

COMPARISON OF COMPUTER PREDICTIONS TO STUDY RESULTS

POTENTIAL SAVINGS BY USING COMPUTER-PREDICTED LEAST-COST GRADE CHOICE

Crosscut First Line							
Computer Predicted Grade(s)	(1) Lumber Required (BF)	(2) Cost (\$)	Grade Used in Plant	(3) Lumber Used (BF)	(4) Simulation Cost (\$)	(5) Potential \$ Savings [1-(2)/(4)] x100	(6) Potential BF Savings [1-(1)/(3)] x100
1 Common	2627	2291	2 Common	3912	2459	6.8%	32.8%
2 Common	2240	1414	3 Common	3991	2542	44.4%	11.9%
OVERALL CUTTING BILL							
1 Common	4554	3973	2+3 Common	7903	4974	42.4%	20.1%

1/ Do not match actual footage values used since only yield percentages were simulated.

COMPANY 10

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 1

LUMBER YIELD SUMMARY

Rip First Plant

(1) Grade	(2) Input (BF)	(3) Output (BF)	(4) Yield (%) $(3) \div (2) \times 100$
Gang Rip Saw			
1 Common	5101	4362	85.5
Straight-line Rip Saw			
1 Common	4900	4394	89.7
Total	10,001	8756	87.6

Chop Saws

(5) Grade	(6)=(3) Input (BF)	(7) Output (BF)	(8) Yield (%) $(2) / (6) \times 100$	(9) Cumulative Yield (%) $(7) / (2) \times 100$
1 Common	6843 ^{1/}	4963	72.5	63.5 ^{2/}

1/ 1913 Board feet of 4 inch or random width was not chopped.

2/ Adjusted for rippings not chopped.

COMPANY 10

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 2

PRODUCTION TIME SUMMARY

Rip First Line

(1) Grade	(2) Gross Time (hr)	(3) Down Time (hr)	(4) % Down Time (3)÷(2)	(5) Net Time (2)-(3) (hr)	(6) Input (BF)	(7) Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	(8) Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	(9) % Change Between Next Highest Grade
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Gang Ripsaw (Based Upon Input BF)

1 Common	7.25	2.79	38.5	4.46	5101	1143.7	703.7	----
----------	------	------	------	------	------	--------	-------	------

Straight-line Ripsaw (Based Upon Input BF)

1 Common	8.08	2.37	29.4	5.70	4900	858.6	606.4	----
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Chop Saws (Based Upon Output BF)

Grade	Gross Time (hr)	Down Time (hr)	% Down Time (3)÷(2)	Net Time (2)-(3) (hr)	Output (BF)	Production Rate (6)÷(5)÷ (BF/hr/saw) (potential)	Production Rate (6)÷(2)÷ (BF/hr/saw) (actual)	% Change Between Next Highest Grade
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1 Common	31.51	10.61	33.7	20.90	4963	237.46	157.50	----
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COMPANY 10

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 3

COMPARISON OF ACTUAL STUDY RESULTS TO COMPUTER PREDICTIONS

Actual Study Results		Rip First Line		Computer Predictions		Study Simulation			
Grades Used by Company	Quantity Actually Cut (BF)	Yield Actually Obtained (%)	Grades Used by Company	Quantity to Cut (BF)	Yield at 100% FPL 118 (%)	Cost (\$)	Plant Yield Adj't (%)	Quantity to Cut (BF)	Yield to Obtain (%)
1 Common	6843	63.5	1 Common	6512	65.8	5433	97	6714	63.8
									5601

COMPANY 10

RIP COST AND YIELD STUDY DATA SUMMARY TABLE 4

COMPARISON OF COMPUTER PREDICTIONS TO STUDY RESULTS

POTENTIAL SAVINGS BY USING COMPUTER-PREDICTED LEAST-COST GRADE CHOICE

Computer Predicted Grade(s)	Rip First Line					
	(1) Lumber Required (BF)	(2) Cost (\$)	Grade Used in Plant	(3) Lumber Used (BF)	(4) Simulation Cost (\$)	(5) Potential \$ Savings [1-(2)/(4)] x100

FAS and
1 Common
and
2 Common

7315 3884

1 Common 6843

5601

12.8%

1/ Do not match actual footage values used since only yield percentages were simulated.

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