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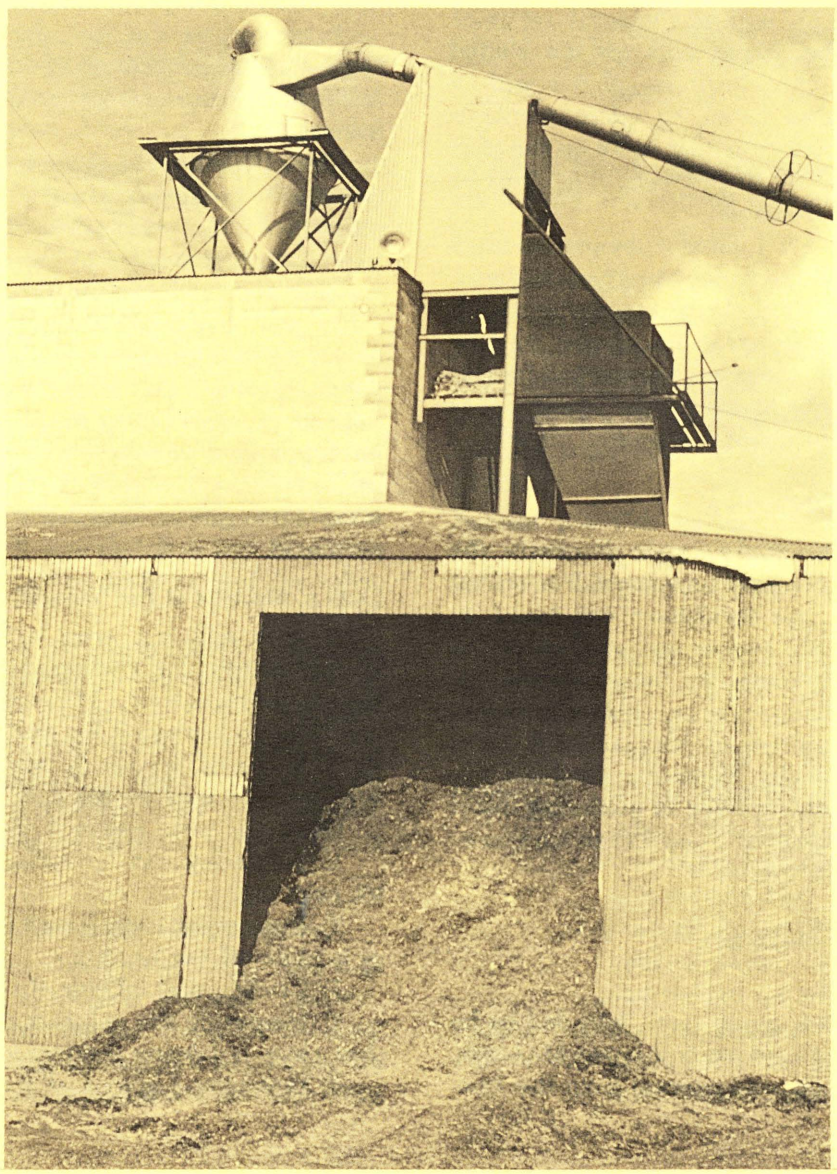

The Internal Cost of Producing Sawmill Residues in Michigan

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Background

Cost information on sawing hardwood lumber based on the lumber value has been calculated and published (4, 5, 14). Studies have been done on yields of lumber and chips from given size logs (1, 3), and concurrent studies have been done on quantities of bark and sawdust produced by different sawing methods and log volumes (3, 8, 15). Financial ratios of pallet and grade lumber plants both for the United States and Michigan have been completed with a breakdown of cost ratios based on sales. A micro-analysis of the component costs that make-up the total sawmill costs allocated to all products, regardless of volume, has not been available.

There have been only limited attempts made to distribute these costs to the various residues produced in hardwood sawmills. It could be reasonably stated that since only the lumber has value, all cost must be allocated to the lumber. However, the method for this study allocated all costs based on the operation as noted without trying to determine mutual benefit.

Objective

The objective of this study was to determine the internal cost structure of operating a sawmill in central lower Michigan. The cost breakdown was based on a combination of sawmill studies and analysis of the financial operating statements for those sawmills.

Confidential information was secured with the understanding that release would be made only as a group and not individually. Particular attention was paid to the average costs involved in producing, moving, handling and disposing of a quantity of bark, sawdust, chips and other residues.

Method

Mill Selection

The sawmills for this study were intended to be representative of the mills in central lower Michigan. A list containing 18 mills was selected from the Sawmill Directory in the geographical area chosen for the study. Of the 18, 12 were studied and an additional two mills were added that were a short distance outside the chosen area for a total of 14 sawmills.

The two mills outside the area had special characteristics. One was the only band mill included in the study and the other was the only agency-run sawmill. They expressed interest by requesting the study.

In general, most of the mills were very cooperative. Only one refusal was given in spite of the sensitive and confidential nature of the financial data requested from the mill.

The sawmills were equally divided between those principally producing graded hardwood lumber and those producing principally pallet material. The two were separated because of inherent differences in raw material and production methods.

In part, the desire to maintain this equality between the two groups eliminated some of the mills in the study area. The falling economy and closing of some of the mills during the study period also created some problems in selection. In general, the 14 mills studied included most of the variations of the mills in lower Michigan as observed by experienced sawmill personnel.

Data Collection at the Sawmill

At each mill, logs were laid out in the mill yard by the operator and numbered sequentially for identification during sawing. They were individually graded according to hardwood log grading rules published by the U.S. Forest Service (9) and scaled using the net rule normally used by the mill.

Observers were assigned the following tasks:

1) Measuring and recording headrig sawing time for each log.

2) Numbering each board sawn, by log number, as it came off the headrig.

3) Grading and tallying the numbered boards.

4) Measuring the volumes of residues, bark, sawdust, chips and coarse residues produced from the logs.

5) Sketching a layout of the mill equipment.

6) Collecting information on equipment type and manufacturer, and the electric motor and horsepower driving the equipment.

7) Obtaining financial information and pertinent cost data from the mill owner.

Cubic-foot volumes of bark, sawdust and coarse residue generated from the study logs were obtained from the residue piles. To facilitate this the area used for residue was cleared or leveled before the study logs were sawn. Chip volumes in the chip van were measured before and after the test logs were processed and the quantity produced for the test was determined.

Sawing the Logs

The headsaw time required to saw each log was recorded to determine the sawing rate of the mill (MBF lumber per hour). Sawn boards were numbered and tallied by log number. To assure that all residue produced by the test logs had cleared the mill, a lag time was allowed after the study logs were sawn. The cubic-foot volume of the residue piles was then measured.

A conversion factor was established for bark, sawdust and chips by averaging the weights of three 1-cubic-foot samples taken from the mill. A sealed sample of each residue type was brought back to the laboratory to determine the percent of moisture. Moisture content was then used to adjust the green-ton residue production cost to the dry-ton cost.

Equipment and Cost Information

The individual pieces of equipment used for conveying and processing bark, sawdust, chips and coarse residue was recorded by manufacturer's name and equipment type. The horse power of each electric motor driving the mill equipment was recorded to determine the cost of power consumed by the equipment. A layout of the sawmill was sketched and all equipment and operation locations were labeled for reference.

Upon completion of the log processing, the mill owner or operator was asked to provide basic cost information to the primary investigator. The mill operating cost per minute was calculated and information on the log hauling costs, labor wages, fuel and oil expenses, and routine maintenance costs was obtained. Also, complete financial statements were obtained when available.

Log, Lumber and Residue weight determination

The total weight for the logs in each study was calcuated so that the weights of the bark, sawdust, chips, coarse residue and lumber could be checked. Actual weighing of the logs at each mill was impossible for this study. Therefore, two alternate methods were used to determine the total weight of logs sawn at each sawmill.

Method 1 — This method utilized the net log scale (BF) of logs sawn in each diameter class to determine total log weights. (It was used for logs with a minimum diameter of 8″.) Timson has developed a table of weight/volume ratios (lbs/BF) for several hardwood species by diameter class (12). Log weights per diameter class were found by multiplying these ratios by the board-foot scale in each diameter class. Diameter class subtotals were added to obtain the total weight of the study logs.

Method 2 — This method was used for small diameter log runs principally in the pallet mills. It utilizes cubic-foot log volume instead of board-feet volume. The cubic-foot volume of logs sawn in the study was directly multiplied by weight/volume ratios (lbs/ft^3) developed by Timson (12). A similar method was available, by Lothner et al. (7) for calculating the weight of aspen logs.

These two methods were used to cross-check each other when overlapping of diameter occurred.

Bark

The weight of bark removed from logs in a mill study was determined by three different methods. The procedure selected was dependent on the species sawn and the possibility of losses that confounded balancing bark weight with the other log components. The three methods were cross-checked with each other where possible.

Method 1 — This method involved estimating the weight of bark removed from logs by using weight/volume ratios compiled by Wartluft (15). Bark weight per average log scale (BF) was extracted from a table and multiplied by the total number of logs sawn in the study. This yielded the total weight of bark removed.

Method 2 — It was used for mills sawing debarked aspen logs. Marden et al. (8) determined that aspen logs consist of an average of 11.8 percent bark by weight. This percentage was multiplied directly by the total calculated weight of logs in a study, and yielded the weight of bark removed.

Method 3 — For this method, a measured truckload of bark was weighed directly on nearby truck scales. Availability of trucks and proximity to scales limited this preferred method.

Sawdust

Three different methods were used to determine the total weight of sawdust produced in a given study. These methods were checked with each other when possible.

Method 1 — This method employed a sawdust weight /log scale ratio developed by Hataja and Hooker (6) and was applied to all mills sawing grade lumber on a circular headrig. The ratio was multiplied by a log scale (BF Scribner) and estimates the tons of sawdust produced per MBF net Scribner log scale.

Method 2 — It employed unpublished weight/lumber tally ratios developed by the Michigan Department of Natural Resources, and applied to mills with a band headrig or greater kerf production gang-mill operations. The ratio was multiplied by lumber tally (BF) and estimates tons of sawdust produced per MBF lumber sawn.

Method 3 — For this method, a measured truckload of sawdust was weighed directly on nearby truck scales. Availability of trucks and proximity to scales limited this preferred method.

Chips

To calculate chip weights, results from actual volume measurements were checked against weights derived from literature. Adams has developed a table of weight/lumber tally ratios (1). These ratios estimate debarked slabwood weight per MBF lumber sawn for an average diameter of a log run.

Average diameter was determined and the corresponding weight ratio was multiplied by the board foot lumber tally. This yielded the ton-weight of slabwood produced. It was assumed there was no significant loss of fines during chipping and, therefore, the weight was used directly as an estimate for chips. Final weights were compared with actual measurements as a cross-check for mills studied.

Coarse Residue

Two methods were used to calculate the weight of coarse residues, principally slabs, produced in the study. The first method was used for mills that produced coarse residue from *debarked* logs. This procedure was identical to that used for chips where calculations were made with literature derived weight ratios, then checked against actual measurements from the study.

The second method was used for mills producing coarse residues from logs *not* debarked before sawing. The theoretical debarked slabwood weight was calculated for these mills using the same formula by Adams (1), and then adjusted upward by 30 percent to account for the bark weight. The adjustment represents findings that an average hardwood log run consists of 30 percent bark by weight (16).

Lumber

The ton-weight of lumber sawed in each study was calculated by the formula:

$$\frac{\text{BF Lumber Tally}}{12\ \text{BF/ft}^3} \times \text{Species Density (lbs/ft}^3) \div 2000\ \text{lbs/ft}^3$$

Species density was taken from the CRC Handbook of Materials Science (10).

Residue Production Costs

The residues examined in this study were bark, chips, sawdust and coarse residue, or slabs. Costs of residue production were separated into six specific cost categories corresponding to the flow of raw material from the logging site through the sawmill.

The categories of costs associated with residue were: 1) external transportation, 2) internal transportation, 3) debarking and bark conveyance, 4) conveyance and processing, 5) sawmill downtime directly caused by residue, and 6) handling and storage. Fixed and variable costs were derived for each residue type in all cost categories. These costs were added for each residue to produce a per hour cost incurred during production, but based on costs attributed to each residue.

Fixed Costs

The fixed sawmill cost was calculated on an annual basis. To determine a per hour charge for the fixed cost, the annual cost was divided by the number of production hours per year. The annual fixed cost had four components.

1) Depreciation — Historical cost of the equipment, including motors and installation, was depreciated over a period of five or eight years. The five year figure was used for mobile equipment, forklift, front-end loaders, etc. While the eight year figure was used for permanently installed equipment. These depreciation figures are in accordance with the Internal Revenue Service (13) useful life estimates.

2) Opportunity Cost — Since the capital used to purchase and install equipment could have been invested to generate income, an opportunity cost of capital available for investment was added to reflect this foregone income. To calculate the capital available for investment (CAI) the following formula was used.

$$CAI = \frac{\sum_{n=i}^{N} \text{Book Value (year end)}}{N}$$

The book value was based on investment figures from the company's books privately obtained and depreciated on a straight line basis. For example, if the depreciable investment is $5,000 and the expected useful life is five years, capital available for investment (CAI) would be

$$CAI = \frac{4000 + 3000 + 2000 + 1000 + 0}{5} = \$2000$$

Capital available for investment was then multiplied by .12 to obtain an estimate of the rate of return at 12 percent that could have been expected had the capital been invested elsewhere at this interest rate.

3) Insurance — Cost of insurance was based on each of the mill's annual insurance premiums for the fixed asset whenever available. In some of the study mills insurance cost was hidden by involvements in other unrelated business and thus not available for the study.

In these cases, an average of 2.5 percent was used as determined by the average from the other mills where the figure was available.

4) Annual Repair — The repair allowance was a provision for repairs and part replacements that fall into no predictable pattern and are often unexpected. Therefore, they cannot be considered as routine maintenance.

For this calculation, the Asset Depreciation Range (13) guidelines were used. For mobile equipment, 10 percent of historical equipment cost was used. For stationary equipment, the rate was 6.5 percent.

Variable Costs

1) Power — Power consumption was computed on the basis of machine operating time and motor horsepower. An average of 8 cents per KWH was used. This 8 cents per KWH represented the current rate charged by the major utility companies for commercial operations in the study areas at the time (1981) of the study.

2) Operator Cost — This was the cost of labor required to operate the machinery associated only with residue production. This cost was made up of base-wage plus additional employer costs for Federal Insurance Contributions Act, workers' compensation, unemployment insurance and employee fringe benefits. These costs were added and charged to the various residues based on actual labor usage during the study period for the amount of residue produced.

3) Maintenance Costs — This was a labor charge to reflect the actual time spent on routine maintenance on a per hour basis for each of the residues. Examples of such costs would be maintaining the debarker, and cleaning and lubricating other machinery directly associated with the residues.

4) Residue Flow Assistance Cost — Often during the course of operations, assistance was needed to keep the various residues moving toward their assigned location. All factors causing extra labor costs were assigned to residues according to the amount of time spent on them during the mill study.

5) Gas, Oil, and Lubrication — Charges for these items were calculated on an hourly basis and allocated as a cost to the residues which caused their use.

External Transportation

The cost of transporting the logs from the logging site to the sawmill was apportioned to the residue based on the calculated weight of the residue. This cost was for a hauling trip as determined by the average distance of the last three hauls for the individual sawmill and based on a cost per loaded mile. The amount of logs (MBF log scale) hauled per load was used as a basis for the calculation, combined with the weight in tons per MBF of scale for that species or mixture.

Internal Transportation

Once the logs are in the mill yard, an additional cost was incurred in transporting whole logs for sorting, grading and scaling before they are sawn. This cost was divided into the fixed hourly equipment cost of the forklift used to move the logs and the variable costs prorated on the residue weight contained in the log.

The annual equipment cost used was the ratio of the time designated for internal transportation to the total productive time for that equipment (the equipment was often used for other work unrelated to residue production). The variable costs were added as a per hour cost based on actual internal operating times. These variable costs were gas and oil, maintenance, and operator wages. The total cost per hour of internal transportation was allocated to the various residues based on the number of tons of residue produced per hour as a percent of total tons of all material produced.

Bark Cost

Of the 14 mills studied, 10 were equipped with debarkers. The fixed component of bark cost included the debarker cost and the conveyors leading to and from the debarker, the motors used to power the debarker and the associated conveyors. The hourly fixed cost of the debarker was allocated to the bark based on bark production in tons per hour.

The variable costs of bark production were power, operator cost and routine maintenance. Power and operator cost were allocated to hourly bark production using the ratio of debarking time to sawing time.

For the mills studied, with one exception, 15 to 20 minutes of debarking would provide the headsaw with one hour's worth of logs. The daily maintenance cost was determined by dividing operating hours per day to produce an hourly maintenance cost.

Conveyance and Processing Cost

The cost incurred from the time the residue was separated from the log until it was deposited outside the sawmill was the conveyance and processing cost. This cost also includes any processing done to the various residues for reasons of marketability or ease of handling.

Each residue class had distinct costs which were calculated separately. The major cost elements were the fixed costs of the equipment, primarily conveyors, chippers, sawdust blowers and the variable cost of the power required to operate this machinery. A high degree of mechanization eliminated most of the operator costs, except in the case of slab residue. Minor variable costs in this category were residue flow assistance and routine maintenance costs.

Each residue was followed as it progressed through the mill, the machinery and operator assistance required to move and process only that residue where noted. The costs associated with this process were then added and allocated to the residue on an hourly basis according to the tonnage of residue produced per hour.

Handling and Storage Costs

Once the residue was in the mill yard, a further cost was incurred in moving it to its assigned location, in stacking and in providing it with a storage vehicle or a designated area of land. The major cost elements in this category were the fixed costs of heavy equipment and the variable costs for the operator, gas and oil.

The land and storage vehicle costs (vans in the case of chips) were minimal. They were usually less than 1 cent per ton of residue. For each residue class, the associated costs were converted to an hourly basis, added and allocated on a per ton basis for the various residues.

Downtime Cost

Occasionally during the course of the day, residue flow bottlenecks or equipment failure related to one of the residues would necessitate a work stoppage of the mill for a few minutes. The residue class that was responsible for this temporary production halt was charged as a downtime cost.

The dollar amount of this operating cost per minute charged was derived from cost schedules provided for us by the mill owner. Operating cost per minute is the sum of all the annual costs for the mill divided by the operating minutes per annum. These costs, during a temporary production halt, with the exception of power, continue to be incurred. They were therefore charged to the cause of the stoppage.

In the future new methods of processing logs will be developed that will reduce the percent of total residue. The balance between value versus production costs for both lumber and residue must be considered if these new developments are to be economically sound. If the fuel value increases are proportionally higher than the lumber cost, there is less incentive to reduce the quantity of the residue.

The value of the fuel will also influence the chip price and the processing method. The primary use for chips in the past has been paper, which demands a clean relatively bark-free material. However, for fuel the bark need not be removed, thus reducing the production cost.

Solve Analysis

SOLVE II and SOLVE III are closely related computerized sawmill analysis techniques developed by the USDA Forest Service's Northeastern Forest Experimental Station and Northeastern Area of State and Private Forestry (NA-S&PF) (2). The SOLVE programs provide sawmill managers with an analytical tool to help gain increased yields from logs and to minimize conversion cost.

Input into the program consists of basic mill data of costs and prices for products and sawlog data. Information provided consists primarily of product yields and breakeven points for purchasing various species and grades of logs.

For the purposes of this study, the SOLVE programs provided the number and diameter distribution of sawlogs, lumber tally yields, cubic-foot log volumes, net log volumes for three different log rules (Internation 1/4, Scribner Decimal C, and Doyle) and average sawing times per log. These programs were used to develop the initial information for the residue study and also provided the individual mill owners with valuable operating data for their mill.

Results

The costs for each specific residue for the six cost components were calculated for all the mills. Conversions were made to obtain an oven dry cost per ton of residue by determining the moisture content on sample quantities at the mills. These figures were then averaged for all the mills to produce six costs for each residue in dollars per ovendry ton.

These six costs were then summed to generate a mean total cost per ton for each residue. Table 1 sum-

Table 1. Residue cost summary—average cost per oven dry ton.

	Residue Type			
Cost Category	Bark (10 Mills)	Sawdust (14 Mills)	Chips (10 Mills)	Coarse Residue (5 Mills)
External Transport	$2.83	$3.80	$3.19	$4.73
Internal Transport	2.05	2.44	2.25	2.75
Debarking & Bark Conveyance	9.48	NA	NA	NA
Processing & Residue Conveyance	NA	2.33	6.60	1.89
Downtime Caused by Residue	.67	.78	.49	.85
Handling & Storage	1.57	2.29	.78	2.34
Mean Total Cost Per Ton Residue				
All Mills (14)	$16.60	$11.64	$13.30	$12.56
Grade Mills (7)	15.42	10.00	14.02	11.71
Pallet Mills (7)	19.39	13.31	11.85	12.81

NA — Not Applicable.

Table 2. Residue cost summary—weighted average cost per oven dry ton.

	Bark	Sawdust	Chips	Coarse Residue
All Mills (14)	$15.35	$10.55	$12.60	$12.24
Grade Mills (7)	14.97	9.84	13.13	11.71
Pallet Mills (7)	16.68	11.98	10.86	12.34

Weighted by Mill Volume.

marizes these component costs and shows total costs per oven dry ton of $16.60, $11.64, $13.30 and $12.56 respectively for bark, sawdust, chips and coarse residue produced by the study mills.

These costs are also divided by pallet and grade mills. Table 2 shows the data from Table 1 weighted by annual lumber production of the mills. These slightly lower costs imply a greater operating efficiency in the larger mills.

Table 3 shows the percentage of total mill costs attributed to each residue type. These figures were derived by adding the total costs for all mills on an hourly basis and dividing by the calculated costs derived from the study.

Table 4 shows the green log weight proportioned by the individual residue and the weight of the lumber. The green or freshly cut wet weight was used and Table 5 gives the average moisture content of the residues. For each mill's residue, moisture content was individually calculated to obtain oven dry weights.

Tables for the 14 mills were used to develop the summary data contained in Tables 1-5 of this report. These individual mill tables are included only in the author's file draft copy. However, a sample of one

Table 3. Percentage of total mill cost attributed to residue.

Bark	8.76%	
Sawdust	7.30%	
Chips	8.50%	
Coarse Residue	4.24%	
Total Costs for Residue	28.8%	of All Mill Costs
Lumber Cost	71.2%	

Table 4. Percentage of total mill log weight by residue (green).

Bark	10.1%
Sawdust	17.0%
Chips	14.6%
Coarse Residue	13.0%
Total Residue Weight	54.7%
Lumber Weight	45.3%
Log Weight	100%

Table 5. Average moisture content by residue.

Bark	56.9%
Sawdust	77.7%
Chips	75.6%
Coarse Residue	76.2%

mill's data is shown in Appendix C to demonstrate the procedure used in calculation.

Appendix A shows the individual mill cost for each residue type, weighted by mill volume (MBF/hour) and unweighted (A-1 through A-4). A-5 shows the background calculations for the percentage of total mill costs attributed to the various residues.

Appendix B shows the individual mill costs for each residue broken down by cost component. These figures were used for Table 1.

Conclusion

The results show the division of costs attributed to four different residues produced at 14 Michigan sawmills. The residue costs are based on the average cost per oven dry ton divided into six cost divisions, external transport, internal transport, debarking and bark conveyance, processing and residue conveyance, mill downtime caused by residue, and handling and storage of the residue.

The highest residue cost per ton was $16.60 for bark. This was due to the considerable cost of the debarking equipment and lower percentage of total log weight represented by this residue.

Sawdust, representing 17 percent of the total log weight, was the lowest cost at $11.64 per ton with the major costs due to transportation and conveyance. Because half of the sawmills were pallet mills, sawing thin pallet material, the sawdust weight ratio may be higher than expected in grade mills.

Chips were produced at 10 of the mills and represented a cost of $13.30 per ton with half of this cost ($6.60) being attributed to the chipper with its associated conveying equipment.

Coarse residue, slabs, were produced at five of the mills and sometimes only intermittently for an average cost per ton of $12.56. The production of slabs occurred usually at the smaller mills and was a more recent innovation caused by a demand for fire wood and reduction in the market for chips. With more efficient equipment and better engineering this cost could be reduced considerably and ready local markets found for this residue.

All the direct costs associated with producing residue in the sawmill are considerably more than would be expected based on sawmill cost information currently available. Previous studies on sawmill costs have used conventional costing procedures based on the assignment of all the sawmill costs to only the saleable products, thus largely ignoring the residue. The argument for this method is valid if used for pricing the lumber. However, it does not help in assigning costs within the mill to various potential products.

Increased mechanization of sawmills resulting in the extensive use of conveyors and mechanical handling methods may also increase the real cost of the residue. With expected future values increasing for both lumber and residue, these residue costs can no longer be neglected as unimportant.

The determination of residue costs is a necessary and valuable tool in future decision making. This paper develops a procedure for determining the residue cost and assigns current values based on 14 sawmills studied.

Literature Cited

1. Adams, E. L. 1970. Value of Chipped Residues Produced from Different Sized Sawlogs. State & Private Forestry. Ext. News Bull. No. 13. NEFES. Upper Darby, PA.
2. Adams, E. L. and D. E. Dunmire. 1977. Solve II — A technique to improve efficiency and solve problems in hardwood sawmills. USDA Forest Ser. Res. Paper NE-382 NE For. Exp. Sta. Upper Darby, PA.
3. Hataja, B. A. and L. W. Hooker. 1965. Mill Residue Survey 1965. Unpublished Michigan mill survey. Inst. Wood Res. Mich. Tech. Univ., Houghton, Mich.
4. Herrick, D. W. and W. W. Christenson. 1967. A Cost Analysis of Chip Manufacture at Hardwood Sawmills. U.S. For. Serv. Res. Pap. NE-69. NE for Exp. Sta. Upper Darby, PA.
5. Huber, H. A. 1969. Sawmill Costs. Mich. State Univ. Coop. Ext. Serv. Publ. Fall Sawmill Clinic. Petoskey, Mich., October 17, 1969.
6. Huber, H. A. 1982. The use of Financial Indicators. Mich. State Univ. Coop. Ext. Bull. E-770. E. Lansing, MI.
7. Lothner, D. C., Marden, R. M. and E. Kallio. 1974. Weight-Volume Relationships of Aspen and Winter-cut Black Spruce Pulpwood in Northern Minnesota. USDA For. Serv. Res. Note NC-174. North Cent. For. Exp. Sta., St. Paul, Minn.
8. Marden, R. M., Lothner, D.C., and E. Kallio. 1975. Wood and Bark Percentages and Moisture Contents of Minnesota Pulpwood Species. USDA For. Serv. Res. Pap. NC-114. 9 p. North Cent. For. Exp. Stat., St. Paul, Minn.
9. Rast, E. D., Sonderman, D. L., and G. L. Gammon. 1973. A Guide to Hardwood Log Grading. USDA For. Serv. Gen. Tech. Rep. NE-1. NE For. Exp. Sta., Upper Darby, PA.
10. Summitt, R. and A. Sliker. 1980. CRC Handbook of Materials Science. Vol. IV: Wood. CRC Press, Inc., Boca Raton, Fla. 459 p.
11. Timson, F. G. 1972. Sawlog Weights for Appalachian Hardwoods. USDA For. Serv. Res. Pap. NE-222. 29 p. NE For. Ser. Exp. Station. Upper Darby, PA.
12. Timson, F. G. 1975. Weight/Volume Ratios for Appalachian Hardwoods. USDA For. Serv. Res. Note NE-202. 2 p. NE For. Exp. Sta., Upper Darby, PA.
13. U.S. Department of Treasury. 1971. Asset Depreciation Range (ADR) System. See Appendix.
14. U.S. Forest Service. 1969. Symposium on Logging and Primary Processing Costs. Marietta, Ohio. NE For. Exp. Sta. and NE Area-State and Private Forestry, Upper Darby, PA.
15. Wartluft, J. L. 1974. Yield Table for Hardwood Bark Residue. USDA For. Serv. Res. Note NE-199. 4 p. NE For. Exp. Sta., Upper Darby, PA.
16. Wood Measurement Conference Proceedings. 1967.

Table A-1. Summary—Total Residue Costs ($ Per Oven Dry Ton).

Mill #	Bark	Sawdust	Chips	Coarse Residue
1 (G)	$13.57	$ 6.79	$15.29	$11.71
2 (P)	NA	13.31	NA	15.03
3 (P)	NA	15.99	NA	12.01
4 (G)	12.26	9.72	14.00	NA
5 (P)	NA	19.24	NA	10.91
6 (P)	32.32	14.62	16.23	NA
7 (P)	17.51	7.99	13.15	NA
8 (P)	NA	18.02	NA	13.13
9 (P)	8.30	3.99	6.17	NA
10 (G)	16.46	10.87	15.37	NA
11 (G)	13.29	10.57	12.13	NA
12 (G)	8.05	5.91	8.82	NA
13 (G)	27.87	15.40	20.24	NA
14 (G)	16.41	10.57	11.61	NA
Mean Total Cost All Mills	$16.60 (10)	$11.64 (14)	$13.30 (10)	$12.56 (5)

NA — Not Applicable.

Table A-2. Summary—Total Residue Cost by Mill Type ($ Per Oven Dry Ton).

Mill #	Bark	Sawdust	Chips	Coarse Residue
		Grade Mills		
1	$13.57	$ 6.79	$15.29	$ 6.73
4	12.26	9.72	14.60	NA
10	16.46	10.87	15.37	NA
11	13.29	10.57	12.13	NA
12	8.05	5.91	8.82	NA
13	27.87	15.40	20.24	NA
14	16.41	10.57	11.61	NA
Mean Total Cost Grade	$15.42 (7)	$10.00 (7)	$14.02 (7)	$11.71 (1)
		Pallet Mills		
2	NA	13.31	NA	15.02
3	NA	15.99	NA	12.01
5	NA	19.24	NA	10.91
6	32.32	14.62	16.23	NA
7	17.51	7.99	13.15	NA
8	NA	18.02	NA	13.13
9	8.30	3.99	6.17	NA
Mean Total Pallet Cost	$19.38 (3)	$13.31	$11.85 (3)	$12.81 (4)

NA — Not Applicable.

Table A-3. Summary—Residue Cost Weighted by Mill ($ Per Oven Dry Ton).

Mill #	MBF/Hour	Sawdust (Wght)	Sawdust Cost	Bark Cost	◄(Wght)►	Chips Cost	(Volume (MBF/Hour)) Coarse Residue (Wght)	Coarse Residue Cost
1	2.401	(.079)	$ .55	$ 1.25	(.092)	$ 1.41	(.348)	$ 4.07
2	.933	(.031)	.41	NA	NA	NA	(.144)	2.16
3	.978	(.032)	.51	NA	NA	NA	(.112)	1.71
4	1.904	(.062)	.60	.90	(.073)	1.02	NA	NA
5	1.940	(.064)	1.23	NA	NA	NA	(.281)	3.07
6	1.006	(.033)	.48	1.26	(.039)	.63	NA	NA
7	1.918	(.063)	.50	1.28	(.073)	.96	NA	NA
8	.651	(.021)	.39	NA	NA	NA	(.094)	1.23
9	2.270	(.074)	.29	.72	(.087)	.54	NA	NA
10	2.287	(.075)	.81	1.49	(.088)	1.35	NA	NA
11	3.399	(.112)	1.18	1.74	(.131)	1.59	NA	NA
12	2.620	(.086)	.51	.81	(.101)	.89	NA	NA
13	1.698	(.056)	.86	1.81	(.065)	1.32	NA	NA
14	6.479	(.213)	2.25	4.09	(.249)	2.89	NA	NA
14 Mills	30.484	1.00	$10.55	$15.35	1.00	$12.60	1.00	$12.24

NOTE: Sawdust—14 mills, total MBF/hour = 30.484. Weights derived as a % of total; e.g., Mill #1—2.401/30.484 = (.079). This weight was then multiplied by sawdust cost for mill from Table A-1 (6.79). This procedure was followed for each of the 14 mills, the weighted costs were then summed to yield a weighted average.
Bark & Chips—10 mills produced these residues. A similar procedure was followed, the weighting was based on 10 mills.
Total MBF/hour for 10 mills = 25.982.
Coarse residue—5 mills producing, total MBF/hour = 6.903.

Table A-4-1. Summary—Residue Cost Weighted by Mill Volume (MBF/Hour) by Mill Type ($ Per Oven Dry).

Grade Mill #	MBF/Hr	Wght. S-B-C	Bark	Sawdust	Chips	Wt-C.R.	Coarse Residue
1	2.401	(.115)	$ 1.56	$ .78	$ 1.79	1.0	$11.71
4	1.904	(.092)	1.13	.89	1.34	NA	NA
10	2.287	(.11)	1.81	1.20	1.69	NA	NA
11	3.399	(.16)	2.13	1.69	1.94	NA	NA
12	2.620	(.126)	1.01	.75	1.11	NA	NA
13	1.698	(.082)	2.28	1.26	1.66	NA	NA
14	6.479	(.31)	5.05	3.27	3.60	NA	NA
7 Mills	20.788	1.00	$14.97	$9.84	$13.13	1.0	$11.71

NOTE: Sawdust, bark, and chips—7 grade mills producing, base = 20.788 MBF/hour.
Coarse residue—1 grade mill producing, base = 2.401 MBF/hour.

Table A-4-2. Summary—Residue Cost Weighted by Mill Volume (MBF/Hour) & by Mill Type ($ Per Oven Dry).

Pallet Mill #	MBF/Hr	Wght Saw.	Wght B-C	Cost Bark	Cost Saw.	Cost Chips	Wght C.Res.	Cost C.Res.
2	.933	(.096)	NA	NA	$ 1.28	NA	(.207)	$ 3.11
3	.978	(.101)	NA	NA	1.62	NA	(.217)	2.60
5	1.94	(2.00)	NA	NA	3.85	NA	(.431)	4.70
6	1.006	(.103)	.204	6.59	1.50	3.31	NA	NA
7	1.918	(.198)	.369	6.46	1.58	4.85	NA	NA
8	.651	(.067)	NA	NA	1.22	NA	(.147)	1.93
9	2.27	(.234)	.437	3.63	.93	2.70	NA	NA
7 Mills	9.696	1.00	1.00	$16.68	$11.98	$10.86	1.00	$12.34

NOTE: Sawdust, 7 mills producing, base = 9.696 MBF/hour.
Bark & chips, 3 mills producing, base = 5.194 MBF/hour.
Coarse residue, 4 mills producing, base = 3.918 MBF/hour.

Table A-5-1. Residue Cost/Hour ($ Oven Dry Residue).

Mill #	Mill Operations Cost Per Hour	Sawdust	Chips	Bark	Coarse Residue	Total Residue Cost Per Hour	% Total
1	85.8	7.39	15.61	21.50	5.81	50.31	58.6%
4	58.2	12.15	.63	11.72	NA	24.50	42 %
10	135.6	10.36	17.00	18.73	NA	46.09	34 %
11	327.6	16.20	24.71	19.14	NA	60.05	18.3%
12	49.38	5.24	11.49	11.62	NA	28.35	57.4%
13	198	10.81	21.72	19.76	NA	58.29	29.4%
14	355.8	16.93	30.17	40.23	NA	87.33	24.5%
Total Costs Grade	1210.68	79.08	127.33	142.70	5.81	354.92	
% Total Costs	100%	6.53%	10.52%	11.79%	.48%	29.32%	
Total Costs All Mills	2001.48	146.04	170.19	175.40	84.81	576.44	
% Total Costs	100%	7.30%	8.50%	8.76%	4.24%	28.8%	

Mill Cost/Hour = Operations Cost/Minute × 60
Residue Cost/Hour = MBF Lbr/Hour × Ton Residue MBF × Cost Per Ton Green Residue.
All figures in terms of total dollar cost.

Table A-5-2. Residue Cost/Hour ($ Oven Dry Residue).

Mill #	Mill Operations Cost Per Hour	Sawdust	Chips	Bark	Coarse Residue	Total Residue Cost Per Hour	% Total
2	37.2	13.11	NA	NA	20.52	33.63	90 %
3	111.6	12.56	NA	NA	17.30	29.86	26.6%
5	91.2	12.65	NA	NA	21.96	34.01	37.3%
6	114	4.53	9.09	9.16	NA	22.78	20 %
7	177	8.49	20.96	11.55	NA	41.00	23.2%
8	106.2	10.15	NA	NA	19.92	30.07	28.3%
9	153.6	6.07	12.81	11.99	NA	30.87	20.1%
Total Costs Pallet	790.8	66.96	42.86	32.70	79.70	222.22	
% Total Costs	100%	8.48%	5.42%	4.10%	10.1%	28.10	
Total Costs All Mills	2001.48	146.04	170.19	175.40	84.81	576.44	
% Total Costs	100%	7.30%	8.50%	8.76%	4.24%	28.8%	

Mill Cost/Hour = Operations Cost/Minute × 60
Residue Cost/Hour = MBF Lbr/Hour × Ton Residue MBF × Cost Per Ton Green Residue.
All figures in terms of total dollar cost.

Table B-1. Mean External Transportation Costs ($ Per Oven Dry Ton).

Mill #	Bark	Sawdust	Chips	Coarse Residue
1 (G)	2.31	2.61	2.61	2.61
2 (P)	NA	4.70	NA	4.70
3 (P)	NA	3.62	NA	3.62
4 (G)	3.74	4.52	4.52	NA
5 (P)	NA	8.32	NA	8.32
6 (P)	1.89	2.01	1.96	NA
7 (P)	4.21	4.87	4.58	NA
8 (P)	NA	4.49	NA	4.49
9 (P)	.33	.35	.34	NA
10 (G)	1.79	2.16	2.16	NA
11 (G)	3.80	4.13	4.13	NA
12 (G)	1.45	1.70	1.70	NA
13 (G)	5.26	5.46	5.46	NA
14 (G)	3.58	4.40	4.40	NA
All Mills $(\bar{X})$	2.83 (10)	3.80 (14)	3.19 (10)	4.73 (5)
Grade Mills $(\bar{X})$	3.12 (7)	3.57 (7)	3.57 (7)	2.61 (1)
Pallet Mills $(\bar{X})$	2.14 (3)	4.05 (7)	2.29 (3)	5.26 (4)

NA — Not Applicable.
$(\bar{X})$ — Mean.

Table B-2. Mean Internal Transportation Costs ($ Per Oven Dry Ton).

Mill #	Bark	Sawdust	Chips	Coarse Residue
1	2.09	2.37	2.37	2.37
4	1.54	1.85	1.85	NA
10	1.15	1.39	1.39	NA
11	1.66	1.81	1.81	NA
12	1.06	1.24	1.24	NA
13	4.11	4.27	4.27	NA
14	1.67	2.07	2.08	NA
Total Grade	13.50	15.00	15.01	2.37
$(\bar{X})$ (GR)	1.93	2.14	2.14	2.37
2	NA	2.27	NA	2.27
3	NA	3.18	NA	3.18
5	NA	1.33	NA	1.32
6	4.14	4.42	4.31	NA
7	1.31	1.52	1.43	NA
8	NA	4.62	NA	4.62
9	1.74	1.84	1.77	NA
Total Pallet	7.19	19.18	7.51	11.39
$(\bar{X})$ (P)	2.40	2.74	2.50	2.85
Total (P & G)	20.49	34.18	22.52	13.76
$(\bar{X})$ (P & G)	2.05	2.44	2.25	2.75

NA — Not Applicable.
$(\bar{X})$ — Mean.

Table B-3. Mean Processing and Conveyance Costs ($ Per Oven Dry Ton).

Mill #	Sawdust	Chips	Residue
1	.94	8.63	5.70
4	1.60	6.91	0
10	3.20	9.40	0
11	1.03	5.61	0
12	1.39	5.45	0
13	5.56	7.82	0
14	1.66	4.64	0
Total (G)	15.38	48.46	5.70
(X̄) (G)	2.20	6.92	5.70
2	1.58	0	1.09
3	3.00	0	.52
5	2.98	0	1.12
6	3.83	7.27	0
7	1.60	6.51	0
8	2.52	0	1.01
9	1.78	3.80	0
Total (P)	17.29	17.58	3.74
(X̄) (P)	2.47	5.86	.94
Total (G & P)	32.67	66.04	9.44
(X̄) (G & P)	2.33	6.60	1.84

NA — Not Applicable.
(X̄) — Mean.

Table B-4. Mean Debarking and Bark Conveyance Costs ($ Per Oven Dry Ton).

Mill #	Bark
1	8.09
4	6.05
10	10.73
11	6.18
12	4.57
13	14.62
14	6.73
Total (G)	56.97
(X̄) (G)	8.14
2	0
3	0
5	0
6	21.48
7	11.98
8	0
9	4.39
Total (P)	37.85
(X̄) (P)	9.46
Total (G & P)	94.82
(X̄) (G & P)	9.48

NA — Not Applicable.
(X̄) — Mean.

Table B-5. Mean Downtime Costs ($ Per Oven Dry Ton).

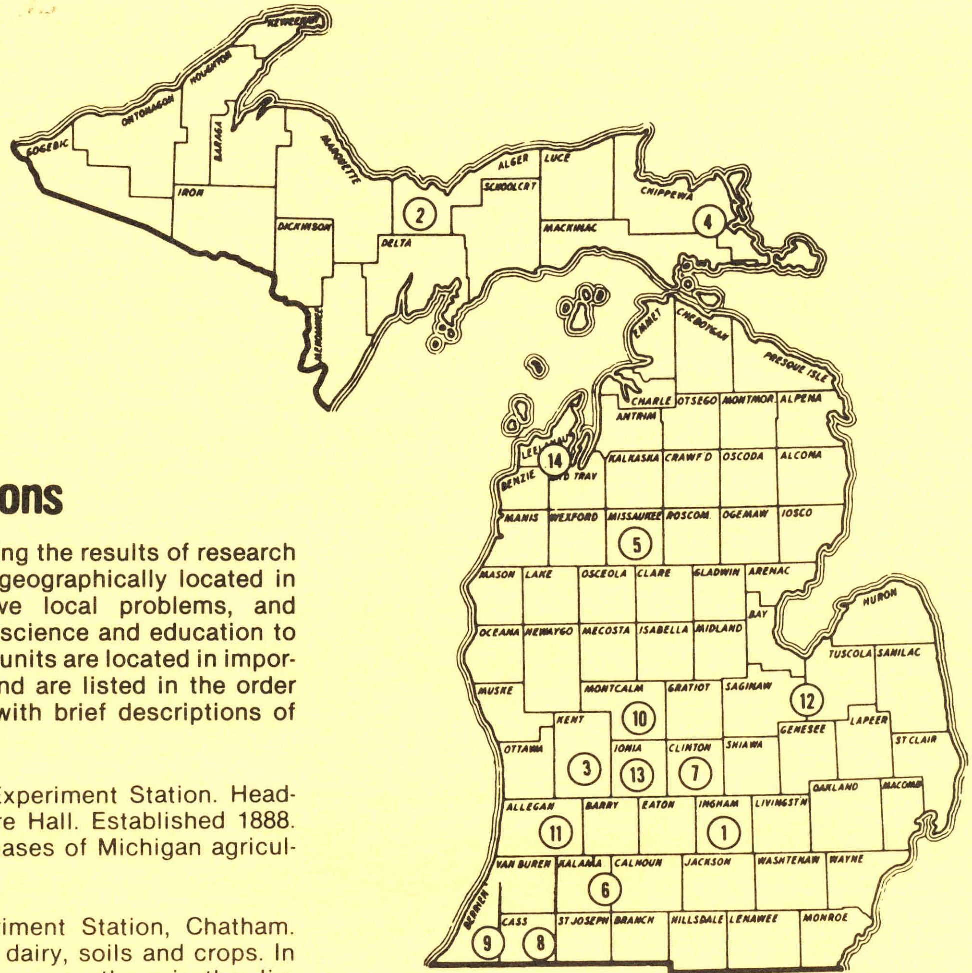
Mill #	Bark	Sawdust	Chips	Coarse Residue
1	.17	0	1.03	1.03
4	.88	.45	.22	NA
10	0	1.01	0	NA
11	.57	2.58	0	NA
12	0	0	0	NA
13	2.27	0	2.74	NA
14	2.81	0	0	NA
Total (G)	6.70	4.04	3.99	1.03
(X̄) (G)	.96	.58	.57	1.03
2	NA	0	NA	0
3	NA	4.43	NA	3.23
5	NA	0	NA	0
6	0	0	.90	NA
7	0	0	0	NA
8	NA	2.14	NA	0
9	0	0	0	NA
Total (P)	0	6.57	.90	3.23
(X̄) (P)	0	.94	.30	.81
Total (G & P)	6.70 (10)	10.97	4.89	4.26
(X̄) (G & P)	.67	.78	.49	.85

NA — Not Applicable.
(X̄) — Mean.

Table B-6. Mean Handling and Storage Costs ($ Per Oven Dry Ton).

Mill #	Bark	Sawdust	Chips	Coarse Residue
1	.90	.87	.66	0
4	.06	1.30	.50	NA
10	2.80	3.11	2.43	NA
11	1.08	1.02	.57	NA
12	.97	1.57	.42	NA
13	1.61	.11	0	NA
14	1.60	2.44	.49	NA
Total (G)	9.02	10.42	5.07	0
(X̄) (G)	1.29	1.49	.72	0
2	NA	4.76	NA	6.97
3	NA	1.76	NA	1.47
5	NA	6.60	NA	.23
6	4.51	4.36	1.79	NA
7	0	0	.64	NA
8	NA	4.26	NA	3.02
9	1.85	.02	.26	NA
Total (P)	6.66	21.76	2.69	11.69
(X̄) (P)	2.22	3.11	.90	2.92
Total (G & P)	15.68	32.18	7.76	11.68
(X̄) (G & P)	1.57	2.29	.78	2.34

NA — Not Applicable.
(X̄) — Mean.



Outlying Field Research Stations

These research units bring the results of research to the users. They are geographically located in Michigan to help solve local problems, and develop a closeness of science and education to the producers. These 14 units are located in important producing areas, and are listed in the order they were established with brief descriptions of their roles.

(1) Michigan Agricultural Experiment Station. Headquarters, 101 Agriculture Hall. Established 1888. Research work in all phases of Michigan agriculture and related fields.

(2) Upper Peninsula Experiment Station, Chatham. Established 1907. Beef, dairy, soils and crops. In addition to the station proper, there is the Jim Wells Forest.

(3) Graham Horticultural Experiment Station, Grand Rapids. Established 1919. Varieties, orchard soil management, spray methods.

(4) Dunbar Forest Experiment Station, Sault Ste. Marie. Established 1925. Forest management.

(5) Lake City Experiment Station, Lake City. Established 1928. Breeding, feeding and management of beef cattle and fish pond production studies.

(6) W. K. Kellogg Biological Station Complex, Hickory Corners. Established 1928. Natural and managed systems: agricultural production, forestry and wildlife resources. Research, academic and public service programs.

(7) Muck Experimental Farm, Laingsburg. Plots established 1941. Crop production practices on organic soils.

(8) Fred Russ Forest, Cassopolis. Established 1942. Hardwood forest management.

(9) Sodus Horticultural Experiment Station, Sodus. Established 1954. Production of small fruit and vegetable crops. (land leased)

(10) Montcalm Experimental Farm, Entrican. Established 1966. Research on crops for processing, with special emphasis on potatoes. (land leased)

(11) Trevor Nichols Experimental Farm, Fennville. Established 1967. Studies related to fruit crop production with emphasis on pesticides research.

(12) Saginaw Valley Beet and Bean Research Farm, Saginaw. Established 1971, the farm is owned by the beet and bean industries and leased to MSU. Studies related to production of sugar beets and dry edible beans in rotation programs.

(13) Clarksville Horticultural Experiment Station, Clarksville. Purchased 1974. Plots established 1978. Research on all types of tree fruits, small fruits, vegetable crops and ornamental plants.

(14) Northwest Michigan Horticultural Research Station. Established 1979. Research and education for cherry and other horticultural crops in northwest Michigan.

The Michigan State University Agricultural Experiment Station is an equal opportunity employer and complies with Title VI of the Civil Rights Act of 1964 and Title IX of the Education Amendments of 1972.

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