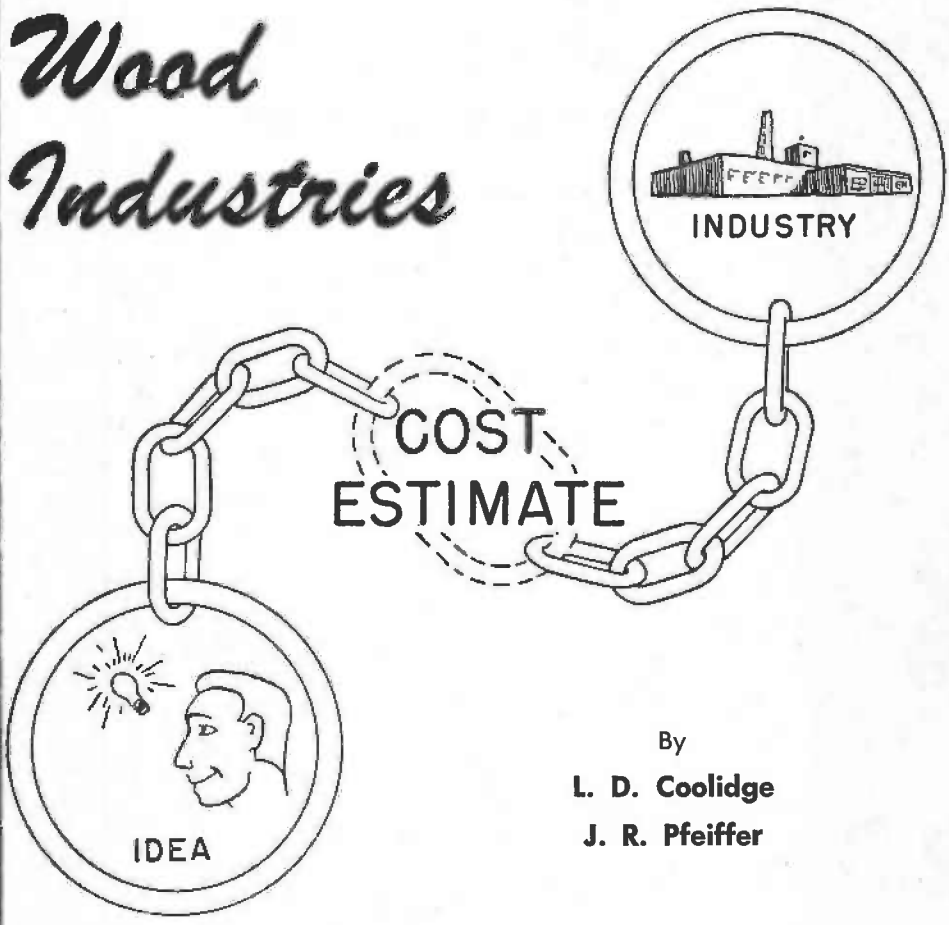
Cost Estimating

for Wood Industries



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Oregon Forest Products Laboratory

About this study . . .

he Story
n Brief

early estimation
can forecast economic possibilities
of new processes or products

THE PRIME OBJECTIVE IN COMPILING THIS GUIDE WAS TO PRO-e means for making early estimates of plant costs, operating sts, and profits from new products or processes in the wood pro-cts industries. Means for making early cost estimates have long en available to manufacturers converting wood chemically, but ese means require adaptation for use in estimating costs of manu-cturing wood products mechanically. Means were outlined by which imating factors, based on previous similar plant construction and erating costs, enable the research or development worker to make rly cost estimates where little cost information is available.

After preliminary research has been done and basic engineering ta computed, additional information must be obtained or estimated fore total physical-plant costs and operating costs can be deter-ned. The over-all accuracy of the total plant estimate is dependent the extent and accuracy of knowledge about these data:

Over-all accuracy dependent on data accuracy

- Types of equipment, sizes, number or quantity of pieces required, and the delivered or installed cost.
- Raw material and utility requirements, and their current costs.
- Direct labor requirements.

From the installed cost of all process equipment, other major ns in the total physical-plant costs may be derived. The various egories into which the physical-plant costs may be divided bear irly constant relationships to the cost of process equipment, follows:

Category	Percentage of total cost of installed process equipment
Site preparation	5.5
Building and building services	20.0
Process piping	6.5
Electrical installations	9.0
Utilities and other service facilities	9.0
Construction overhead	30.0
Contingencies	20.0

The estimated cost of process equipment, plus the costs derive as percentages, add up to an estimate of physical-plant costs th should be accurate to within plus or minus 20 per cent.

To calculate total operating costs from estimates of requirement for raw materials, utilities and labor, the following formula can used:

$$\text{Total operating costs} = \overbrace{(M + U + aL + bI)}^{\text{Production costs}} \times \overbrace{(1 + s + m}^{\text{Selling and management cost}}$$

where: M=Total raw material costs
U=Total utility costs
aL=Labor-dependent costs where L is direct operating labor (suggested factor, $1.8L$)
bI=Investment-dependent cost where I is to physical plant costs (suggested factor, $0.2I$)
s=Selling costs
m=Management costs
$(1 + s + m)$=Suggested factor—1.15

or:

$$\text{Total operating costs} = (M + U + 1.80L + 0.21) \times (1.1$$

To estimate the profit from a projected enterprise, an estima first must be made of the expected annual production and avera selling price so annual sales can be predicted. From these data, r annual profit before income taxes can be computed by subtracti the estimated annual operating costs from the estimated annual sal If profit per invested dollar is required, the net annual profit bef income taxes should be divided by the estimated total inve ment in plant and working capital.

Factors and methods proposed in this guide presuppose that:

- The plant under consideration is to be independent of oth operations for facilities and materials.
- All plant facilities are to be owned, not leased.
- All construction costs are to be included and there will be zero-cost contributions of labor or other items.
- All materials and equipment are to be purchased new and current market prices.

he Idea and the Manual

from incomplete information
can come estimates of
plant costs, operating costs, and profit

THIS MANUAL IS INTENDED TO SERVE AS A GUIDE FOR RESEARCH development workers in the forest products industries who from ne to time must weigh the economic merits of new processes or new oducts currently undergoing development.

The prime objective of the procedures described is to make pos- ble early appraisals of financial feasibility to guide further develop- ent effort.

Many of the procedures outlined here have been transplanted om other industries. Adequate data have not been developed for sting the procedures for specific wood industries. Considerable sub- ntiating evidence to indicate that many of these data are valid for e forest products industries has been obtained, however, from:

- Actual estimates of plant costs;
- Prospectuses of new operations;
- Cost accounting records of plants that have been built.

Objective is early appraisal of financial feasibility

The procedures are advanced in the belief that:

- Experience will support their validity;
- The man who must appraise a new product will find them helpful;
- The labor and cost of first-approximation estimating can, through their use, be minimized.

Correct evaluation of a proposed venture, still in the develo mental stage, will depend on answers to certain critical questions:

- How large an investment in physical plant and in workir capital would be required to get into production?
- How much would it cost to make the product?
- What costs of selling and of distribution would be involvec
- At what selling price would the product yield an adequa return on investment?
- At what scale of operations could the most profitable rel tionship be established between costs and sales revenues?

If answers to these questions are not encouraging—i. e., if reasonable return on the probable required investment is not indicat —important consequences may follow. The project may require r direction to achieve lower costs, or may be abandoned altogether.

The financial attractiveness of a new product or process is n easily determined, particularly early in development work. At su time, guiding estimates may be required most urgently. Typicall only partial information will be at hand:

- A list of major items of process equipment.
- Experimental data relating to materials and utility requir ments. In some instances, results of pilot-plant operati may be available.
- Common-sense judgments of operating labor requiremen derived from review of the manpower needs—to the exte that they are known or may be inferred—for each maj item of equipment.

From these incomplete sources must be extracted estimates probable plant cost and of manufacturing costs for various hypoth tical rates of production. From these in turn, pay-out periods*, brea even points†, and investment yields may be approximated.

Estimation of plant and operating costs necessarily begins with determination of the probable installed cost of major items of pr cess equipment. Cost of process equipment generally will be fro 45 to 60 per cent of the total plant cost in the forest products indu tries. Two courses for preparation of a plant cost estimate are op to the estimator:

1. *A specific item-by-item estimation of all costs* based upon blu prints, materials lists, and detailed estimates of labor requir ments for construction of the proposed plant.
2. An estimation of *major categories of plant cost* based on pr cess-equipment costs and on relationships that commonly e ist between equipment costs and other components of tot plant cost—relationships referred to in the following pag as "estimating factors."

* Early production period required to recover from earnings the investment in the proj
† Production rate at which revenues balance costs.

Similarly, operational costs for a projected plant may be estiated either on a detailed *item-by-item basis;* or in terms of *given equirements for raw materials, utilities and direct operating labor,* nd the relationships generally found to exist in comparable plants etween these basic cost elements and the broader categories of laborependent and investment-determined costs.

Detailed item-by-item estimation is time-consuming, costly, and in some instances presumptuous because of the incompleteness of he engineering data upon which estimates must be based. Estimates fficiently accurate for most development planning purposes can be repared with considerably less expenditure of time and money by se of cost experience from comparable plants because of reasonably able relationships between principal categories of plant costs and of perational costs.

Estimating is preliminary stage

An attempt has been made to show the procedures and techiques involved, using quick estimating factors, in preparing estiates of total plant cost, operating costs and probable return on inestment. In recognition of the fact that costs of specific items of uipment become obsolete over a short period of time, a section ealing with index numbers has been included in an effort to extend e useful life of available cost data and to lessen the need for obining current equipment cost data. Freight rate tables, charts of ze-cost relationships for wood industries equipment, and other necesry cost-estimating tools also have been assembled for use of the cost timator.

Finally, an example has been included to demonstrate cost estiating in determining economic feasibility of a specific wood indusy. Plant cost, operating costs, and returns from a projected hardard plant to use lodgepole pine as raw material have been sumarized.

Throughout the discussion, it has been assumed that the *cost timating to be done is definitely preliminary and at pre-blueprint age.* More precise estimating will be needed later, if a plant is actally to be built, but, by then, data for more definitive estimates may available.

An agency or company desiring to use this guide may have an counting system dissimilar to that shown here. It is believed, howver, that all costs have been accounted for, although specific costs ithin the general categories may be classified differently where a fferent accounting system is used.

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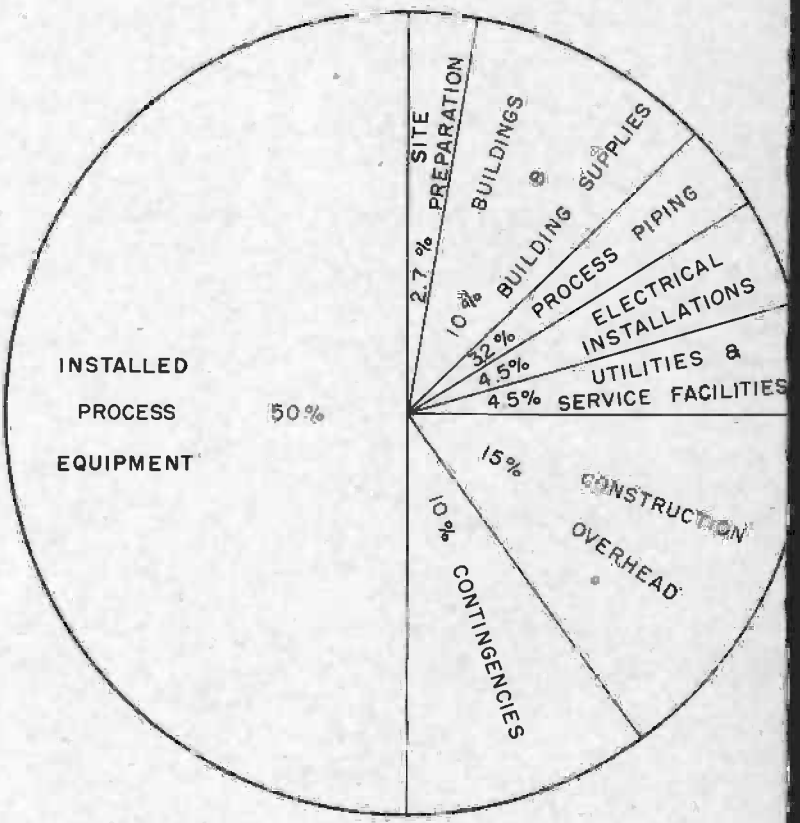
Estimating Methods



to build the physical plan

Capital Investment

jobs and goods
stem from savings invested
in equipment, land, and buildings

THE TOTAL CAPITAL INVESTMENT REQUIRED TO DEVELOP A NEW process or product to the point where a plant has been constructed and is ready for operation generally comprises most or all of the following elements:

A. Process-development costs
B. Promotional and organizational outlays, if the enterprise is new
C. Land costs
D. Physical-plant costs
    Direct costs—
        Process equipment
        Site preparation
        Buildings and building services
        Process piping
        Electrical installations
        Utilities and other service facilities
    Indirect costs—
        Overhead expenses incurred during construction
        Allowance for contingencies
E. Initial working capital

Preliminary estimates commonly cover only costs of the physical plant. All cost categories should be included, however, in later estimates of total capital requirements (Table 1).

Process-development costs (A) and promotional and organizational outlays (B) vary widely with the circumstances of the particular project. Usually no satisfactory basis for early estimate exists, so these elements will not be considered further here.

Costs of acquiring the plant site (C) ordinarily are excluded from estimation until the project has been definitely launched and specific locations are under consideration. Generally, land cost will constitute not more than 1 or 2 per cent of total plant cost for urban sites (63)* and substantially less at suburban, small town, or rural locations. Because of the variability of this cost, however, no estimating factor is included, although this cost should be estimated and included once it is decided where the plant site is likely to be.

Working capital (E) will be required in an amount sufficient to provide for inventory, to carry customers' accounts, and to establish an adequate bank account for current operating expenses. This amount is estimated commonly at from 10 to 20 per cent of fixed capital investment, or about *3 times the value of 1 month's production* (83, 88, 2, 28, 74). The actual amount needed would be determined by procurement, inventory, and credit policies of the enterprise. It must at least suffice.

- To maintain a bank account equal to 1 month's expenditure for wages, raw materials, utilities, and supplies.
- To finance about 1 month's supply of raw materials, 1 or 2 weeks' flow of materials in process, and at least 1 month's finished inventory.
- To carry accounts receivable representing 1 month's sales (19, 83, 2, 28).

Physical-plant costs (D) normally comprise from 65 to 75 per cent of total pre-production investment. Since they are determined largely by the character of the product and the nature of the process they can be estimated usually to within 10 or 15 per cent of the correct amount as soon as engineering data covering product and process are available. Simple quick estimating procedures have been outlined in the following sections.

Physical plant costs hinge on installed process equipment

In preliminary economic evaluation of a project, only one component of plant cost, the installed cost of process equipment, usually is determined from actual price quotations. Other plant costs are appraised by using estimating factors that are expressed as percentages of the calculated cost of process equipment (Tables 4, 5).

TABLE 1. OUTLINE FOR ESTIMATING TOTAL CAPITAL REQUIREMENTS

1. Physical-plant costs	
2. Land costs	
3. Promotional, organizational, and developmental costs	
4. Initial working capital	
Total	

* Numbers in parentheses refer to similarly numbered references in the Bibliography.

The reliability of applying standardized plant-cost estimating factors to widely differing wood products industries depends upon the existence of reasonably stable cost relationships between process equipment and the other elements of plant cost throughout these industries. A substantial and growing literature, referred to in the analysis that follows, attests to that stability. Unquestionably, both inter- and intra-industry differences in plant-cost relationships do exist. Estimating factors suggested in the literature range rather widely in some instances. For most major cost categories, however, a reasonable consensus of informed opinion has been found. On the basis of that consensus and of confirming information derived from engineering estimates, published prospectuses and financial statements, correspondence, conversations, and the accounting records of a number of firms, the authors of this guide are suggesting specific estimating factors to be used in instances where detailed cost information is available for only some plant costs and where estimates are to be used for early economic appraisal only.

Limitations for preliminary estimating

Limiting assumed conditions for use of these preliminary estimating procedures are:

- That the scale of operations be neither unusually small nor very large—in the $50,000 to $5,000,000 range.
- That the plant be independent of other operations, sharing no facilities and obtaining materials and utilities at commercial rates.
- That all plant facilities be owned, not leased.
- That *all* construction costs be included and that there be no zero-cost contributions of labor, land, or capital by the owner or owners.
- That all materials and equipment be purchased *new,* that they be obtained at normal market prices, and that no extraordinary quality features be specified.
- That construction costs not be affected by repeated changes in plant construction plans or by substantial amounts of premium time wages.

The preparation of a physical-plant cost estimate normally proceeds through three stages:

- Assembling basic engineering data concerning the product and process.
- Pricing process equipment (including installation).
- Estimating other physical-plant costs, on the basis of the installed cost of process equipment, using standard estimating factors.

Assembling basic engineering data

Underlying any plant-cost estimate are fundamental engineering data relating to product and process. Experience shows that the estimator can achieve a substantial saving of total estimating time by first systematically establishing and evaluating these data:

- Product data: essential characteristics of the product or products to be produced.
- Process data: nature and sequence of operations to be performed; significant dimensions and quantities of materials to be processed; critical time factors.
- Major items of process and auxiliary equipment required; interconnecting equipment needed for handling materials flow and removing waste; requisite control equipment.
- Probable plant capacity, or alternative capacities, as indicated by . . .
  - . . . nature of the product and process,
  - . . . characteristics and dimensions of materials to be handled,
  - . . . available equipment capacities, particularly for critical equipment items at process "bottlenecks,"
  - . . . factors relating to most economical use of operating labor.
- Volume of production likely to be achieved under normal operating conditions, allowing for production losses and stoppages.*
- Flow of materials at the determined probable production rates —per production hour, per shift or operating day, and per unit of finished product. Allowance must be made for shrinkage, incomplete utilization, spoilage, trim, and rejects.
- Space requirements for equipment and operators, for material handling, and for storage of raw materials, work in process, and finished product.
- Any unusual features of the process that might necessitate installation of special equipment or other facilities—as, for example . . .
  - . . . High-risk machine operations;
  - . . . Explosion or fire hazard;
  - . . . Excessive vibration or noise;
  - . . . Use in production of corrosive materials;
  - . . . Objectionable or dangerous fumes or other waste products;
  - . . . Susceptibility of materials used or of finished product to deterioration from heat, cold, moisture, dryness, or other environmental factors.

* NOTE: A plant running full time throughout the year could operate 8,760 hours. Shutdowns, repairs, and changeovers commonly reduce this figure to about 8,000 hours. With 5-day-week, single-shift operation, 2,080 hours per year are theoretically possible and 1,800 are, on the average, probable of attainment. Generally, down time may be estimated at about 10 per cent of capacity.

Estimating plant capacity

Plant capacity or capacities to be used in estimating must be considered carefully. Virtually all costs are affected by scale of operations, as are judgments concerning profit expectation. Many factors outside the normal concern of the estimator may influence decisions as to plant size. The estimator either must abstract from these problems or must make specific assumptions concerning the effect of each on plant capacity . . .

. . . Extent of the market;
. . . Probable effect of added production upon market price;
. . . Amount of raw material available;
. . . Expected effect upon price of additional demand for raw materials;
. . . Availability of capital;
. . . Personal inclinations of owners.

Before any estimate can proceed, some specific scale of operations must be decided on tentatively. Normally, some indication of an appropriate scale is provided by the experience of others in the industry, by consideration of existing equipment sizes and how best to minimize idle machine capacity, and by rough estimation of operating labor requirements to determine the optimum combination of manpower and machine capacity.

Pricing process equipment

After the basic engineering data have been assembled and evaluated, all items of process equipment should be listed, together with such critical specifications—capacity, temperature, pressure, corrosion resistance, dimensions of materials to be processed—as are likely to exert significant influence on price (Table 2). In addition to major items, the following kinds of auxiliary and related equipment should be included in the checklist:

- ✓ Motors, starters, and related drives and speed-changing equipment.
- ✓ Meters, valves, and other control devices normally supplied as integral parts of the equipment.
- ✓ Safety devices for protection of personnel, for elimination of tramp metal, or minimization of fire and explosion hazard.
- ✓ Conveyors, lift trucks, and other material-handling equipment for loading, unloading, or moving raw materials, materials in process, or finished product.
- ✓ Bins, chests, tanks, silos, hoppers, surge bins and chutes for raw material storage, or for temporary storage or transmittal of materials in process.
- ✓ Drying or humidifying equipment.
- ✓ Packaging equipment.
- ✓ Blowers, cyclones, and other equipment for separation or removal of byproducts or waste.
- ✓ Equipment used for inspection or quality control.
- ✓ Associated special tools and critical replacement parts.

Sources of equipment cost information

Prices must be obtained for each of the listed equipment items. Four sources generally may be relied on:

- Accumulated price data available in the estimator's files
- Published data for standard equipment items showing prices at various capacity levels. (See pages 61 and 53 for a list of such source materials and for charts showing price-capacity relationships for standard items of wood industries equipment.)
- Manufacturer's agents
- Equipment manufacturers

Prices taken from the estimator's files or from published data must be corrected for price changes during intervening time using equipment price indexes. (See page 65.)

TABLE 2. PERTINENT INFORMATION ESSENTIAL FOR DECIDING UPON SPECIFIC EQUIPMENT

Name of equipment	Date
Purpose	
Type	
Capacity or size	
Design pressure and temperature (where applicable)	
Material of construction	
Other construction specifications	
Auxiliary equipment	
1. Horsepower requirements	
2. Drives	
3. Controls	
4. Other	
Name and location of manufacturer	
Shipping weight	
Cost	

Elements of equipment costs

Equipment price quotations are generally complex, commonly including a basic list price, one or more discounts, specification as to allowance or disallowance of freight, variation with capacity, variation with quality, and additional amounts to be added for drives, bases, controls, special tools, needed replacement parts and other items of related equipment. The inexperienced estimator often provides the equipment manufacturer or manufacturer's agent with inadequate information, with the result that repeated contacts prove necessary to obtain the required quotation. The following checklist

is suggested to minimize such time losses, with enumerated elements that must be included for price information to be adequate:

- ✓ Effective price (net allowances and discounts) of the basic item of equipment, for each of the capacities under consideration.
- ✓ Premiums that will be charged for any nonstandard quality features—corrosion-resistant metals, special design or materials for high pressures or temperatures, protection against water or dust, enclosure to minimize fire or explosion hazard, high starting torque for motors.
- ✓ Prices of associated equipment, not included as part of the basic item but supplied by the same manufacturer—
  - motors, drives, speed-changing equipment;
  - loading or unloading equipment;
  - meters, valves and other control equipment;
  - special tools and tool-servicing equipment.
- ✓ Prices of guards, screens, and other safety devices that may be needed with the equipment and are supplied by the same manufacturer.
- ✓ Prices for all items of maintenance equipment and critical replacement parts that will be needed with the process equipment and are supplied by the same manufacturer.
- ✓ For all items, indication as to whether the price is quoted f.o.b. factory or delivered to the customer. If the price is quoted on an f.o.b. basis, weight and the shipping point will be needed to determine freight costs.
- ✓ For all items, indication as to whether the quoted prices cover costs of installation. If not, information concerning probable installation costs should be requested.

Converting equipment costs to delivered or to installed basis

Included in the installed cost of process equipment are the costs of freight, delivery and unloading, and uncrating; the materials and labor for construction of equipment foundations, platforms, supports, ladders and catwalks; and the costs of assembling and mounting. Since equipment prices are quoted variously on an f.o.b. factory basis, delivered cost basis, or installed cost basis, the estimator must compute for some items the costs of freight shipment, or of installation, or both. For preliminary estimating, the following procedures are suggested:

- ▶ To convert f.o.b. prices to a delivered-cost basis (2, 30, 56):
  - Determine weights and shipping points for each item.
  - For shipments from factories located east of the Rocky Mountains to West Coast plant sites rates are shown in Table 3. For shipping points not specifically listed, use the rate applicable to the nearest listed city. For shipments within the Pacific States consult your local freight agent.

TABLE 3. FREIGHT RATES TO THE PACIFIC ZONE

Zone	Major industrial cities included	Effective rates*		
		Less than carload	Carload	
			Min wt 30 M lb	Min wt 40 M lb
		($ per cwt)	($ per cwt)	($ per cwt)
A	All major cities in New England; N. Y., east of Buffalo; Pennsylvania, east of Pittsburgh; Delaware, Maryland, Virginia, and W. Virginia, east of Charleston	10.45	5.03	4.20
B	Buffalo, Erie, Pittsburgh, Cleveland, Columbus	10.12	4.59	3.87
C	All major cities in Michigan, Indiana, and Western Ohio, including Dayton and Toledo	9.91	4.41	3.69
D	All major cities in Illinois and Wisconsin	9.63	4.19	3.52
E-4	St. Louis	8.67	3.70	3.13
E-5	All major cities in Iowa and northern Missouri, except St. Louis	8.93	3.81	3.21
F	Duluth, Minneapolis, Omaha, Kansas City	7.90	3.52	2.98
G	Wichita, Topeka	8.51	3.52	2.98
H	All major cities in Texas, except El Paso	8.96	3.89	3.30
J	Denver	7.43	3.13	2.63
K	All major cities in North and South Carolina, coastal Georgia, and Florida	10.24	4.91	4.11
L	Atlanta, Knoxville	9.92	4.52	3.79
M	Birmingham, Nashville, Louisville	9.70	4.33	3.62
N	El Paso, Albuquerque	9.69	3.89	3.30

* Rates apply to all destinations in the Pacific Zone (Oregon, Washington, California, Idaho, Montana, Nevada, Utah, Arizona, and sections of western Wyoming, Colorado, and New Mexico). Included is 3 per cent Federal tax. Rates are correct as of October 1954.

The following rates were applicable in 1955 for shipments from the cities listed to plant sites in or close to Portland:

From	LCL Rate to Portland*
	Per cwt
Los Angeles	359
Olympia	114
Salt Lake City	382
San Francisco	275
Seattle	128
Spokane	233

* Interpolate for inbetween points.

For purposes of rail freight rate computations most equipment is classified as machinery. Second-class rates are applicable.

- To convert delivered costs to installed costs (2, 28):
  - Installation generally adds from 5 to 30 per cent to the delivered cost of equipment items. Where specific information covering costs of installation is not available the following procedure is sugggested:

    List all items of equipment and total their delivered costs; add 15 per cent to the combined delivered costs of all equipment to include installation (see Table 15).

    While 15 per cent may not be correct for individual items of equipment, it is believed this factor will give a reasonably accurate estimate in the aggregate.

Process equipment costs determine other plant costs

In addition to the investment in process equipment, direct costs of the physical plant will include materials and labor for site preparation, buildings and building services, process piping, electrical installations, and utilities and other service facilities. Indirect costs will include overhead during construction, and an allowance for contingencies.

All suggested estimating factors are on a common basis; namely, on per cent of *installed cost of process equipment.* Estimating factors for physical plant costs should not be confused with other factors, many of which are based on percentages of total plant costs.

Plant site preparation important

Preparation of the plant site will include such items as:

Clearing or demolition

Cleanup

Grading and drainage

Roads and walks

Railroad siding and dock facilities

Fencing

Log-storage-pond construction

Usually, site preparation includes from 2 to 5 per cent of total plant cost (18, 52, 74, 51).

Suggested *estimating factor:* 5.5 per cent of the installed cost of process equipment.

TABLE 4. RECAPITULATION OF PLANT COST ESTIMATING FACTORS

Physical-plant costs	Proportion of installed cost of process equipment	Proportion of direct physical-plant cost	Proportion of direct and indirect cost of physical plant
	Per cent	*Per cent*	*Per cent*
Direct			
Process equipment (installed)*	100.0	66.7	50.0
Site preparation	5.5	3.7	2.8
Buildings and building services	20.0	13.3	10.0
Process piping (installed)	6.5	4.3	3.2
Electrical installation (installed)	9.0	6.0	4.5
Utilities and other service facilities (installed)	9.0	6.0	4.5
Subtotal	150.0	100.0	75.0
Indirect			
Construction overhead	30.0	20.0	15.0
Allowance for contingencies	20.0	13.3	10.0
Total	200.0	133.3	100.0

* Total plant cost equals 2.0 times *installed* cost of process equipment, or 2.3 times the *delivered* cost of process equipment.
Where installed costs are not known, it is suggested that 15 per cent of the combined delivered cost of all process equipment be added for installation charges.

Buildings and building services

Housing and building services for a plant include:

- Process buildings
- Warehouses
- Partitioning, doors, and windows for offices and laboratory
- Building services: lighting
  - plumbing
    - washrooms
    - drinking fountains
    - drains
  - ventilation
  - sprinkler system

Not included are process equipment foundations, supports, platforms, catwalks, ladders, piping, wiring, and drainage systems.

Housing generally requires from 10 to 15 per cent of the total plant cost, depending on over-all plant size, type of construction and materials used, and the extent to which equipment to be installed may require heavier than usual roof trusses and building columns or exceptional headroom. The percentage of total plant cost attributable to building varies inversely with total plant cost, averaging around 15 per cent for plant investments of less than $1,000,000, and from 10 to 12 per cent for larger plants (18, 2, 52, 74, 51). Costs of open-walled buildings are substantially lower, ranging generally from 2½ to 10 per cent of total plant cost. Building cost usually is not increased by more than 5 per cent for extra heavy arch and column construction (53). Some products that have highly seasonal markets may require large warehouse facilities. In that event, the building cost estimate may need revision. The revision, however, should not greatly affect the total building cost factor.

Suggested *estimating factor:* 20 per cent of the installed cost of process equipment.

Process piping for materials handling

Included in one category are the installed costs of piping used to convey raw materials, intermediate products, additives, finished products, steam, water, air, and waste materials generally within the process buildings. Excluded are the costs of steam, water, and other yard distribution piping outside the process buildings, and piping associated with building heating or plumbing systems. Process piping generally amounts to from 3½ to 5 per cent of total plant cost (18, 2, 52, 55).

Suggested *estimating factor:* 6½ per cent of the installed cost of process equipment.

TABLE 5. OUTLINE FOR ESTIMATING PHYSICAL PLANT COSTS

Name and type of operation _____ Location _____

Daily capacity _____ Date of estimation _____

Physical-plant cost categories	Estimating factor	Capacity or size	Quantity needed	Delivered cost	Installed cost
1. Process equipment:	*Per cent**				
A. Items for which only delivered costs are known—					
_____					
_____					
_____					
Combined delivered cost					
Add 15% of combined delivered cost†					
Total installed cost of above items					
B. Equipment for which installation costs are known—					
_____					
_____					
_____					
Total installed process equipment costs	100.0				
2. Site preparation	5.5				
3. Buildings and building services	20.0				
4. Process piping	6.5				
5. Electrical installations	9.0				
6. Utilities, other service facilities	9.0				
7. Construction overhead	30.0				
8. Contingencies	20.0				
Total physical plant costs	200.0				

* Estimating factors are based on total installed process equipment costs.
† Where installation costs are not known, a factor of 15 per cent of the total delivered costs is suggested.

Electrical installations for power distribution

In cost of electrical power distribution are included power and control equipment, materials, and installation labor, including such items as:

Transformers
Yard distribution wiring
Power and instrument wiring within buildings
Control centers, instrument panels, and switchboards

Not included, however, are the following items:

Power-generating equipment
Cost of any changes at substation from which transmission line is run
Transmission line to site
Motor and motor starters
Building lighting

Electrical installations generally amount to from 4 to 6 per cent of the total plant cost, varying with connected horsepower and with the extent to which controls are centralized and automatic (18, 88, 52, 41).

Suggested *estimating factor:* 9 per cent of the installed cost of process equipment.

Utilities and other service facilities

Cost of service facilities includes the items enumerated:

Water: Line from source to site
Storage and treatment facilities
Yard distribution piping

Steam: Steam generating plant, including associated piping, valves, meters and other accessories, the building, and yard distribution piping

Electrical: Cost of any change to substation from which transmission line is run
Transmission line to site
Power generation equipment, if power is to be generated at the site

Fuel: Oil—storage tanks and distribution piping
Gas—line to site and distribution piping
Wood—loading and conveying equipment required to deliver wood to furnace

Air: Compressors
Distribution piping

Refuse: Sewage—yard sewer piping and line away from site
Process residues—burner

Fire protection: Water line to site
Elevated water storage tank, or reservoir
Pumping facilities and standby power source
Fire fighting equipment; extinguishers, hoses, tools

Furniture and equipment: For offices, and in some instances for a plant cafeteria

First-aid equipment

Utility and other service facility costs are highly variable, depending as they do on utility requirements of the process, availability of existing utilities, character and adequacy of water supply, volume of refuse to be disposed of, yard area, the extent to which process facilities are concentrated or scattered, and the extent to which they are operated independently. Total utility and other service-facility costs commonly range between 3 and 12 per cent of total plant cost (18, 52, 74).

Suggested *estimating factor:* 9 per cent of the installed cost of process equipment.

Construction overhead must be included

In addition to the costs of equipment, materials, and labor entering into the physical plant, substantial outlays are necessary for overhead expenses incurred during the period of construction, including:

Engineering
Construction drawings
Planning and supervision of construction work
Contractor's fee
Home office expenses incident to the project
Field office expenses
Pre-operation labor and materials costs for trial runs and training of personnel and inspectors
Insurance: Workmen's compensation
Public liability and damage
Fire
Payroll overhead for permanent employees hired before completion of the plant to help with the construction work—social security payments, other employee benefit costs
Property taxes, licenses, and permits
Equipment and truck rentals
Interest charges on investment in land and plant during the construction and try-out period
Depreciation of buildings and equipment during the construction and try-out period

In aggregate, these costs generally comprise from 10 to 25 per cent of the total cost of physical plant plus overhead, depending largely on the degree of complexity of the engineering involved (18, 54, 52, 55, 74, 87). Engineering and contracting fees commonly range between 3 and 10 per cent of total plant cost. Ten per cent is common for small plants (74). Construction interest charges may be either imputed or actual—imputed if owners' funds are used, actual if construction is financed with borrowed money. In either situation an

interest cost at an annual rate from 3 to 6 per cent of the total investment in land and plant usually will be incurred.

Suggested *estimating factor:* 30 per cent of the installed cost of process equipment.

Allow for contingencies

The estimate of total investment required for a proposed new project should include an allowance for miscellaneous outlays that may prove necessary but that have not been foreseen and estimated specifically, for losses that may arise from uninsurable risks, and from price increases that may occur during the interval between making the estimate and making the final payment for the plant construction. Several factors may intensify the need for such allowance:

Uncertainties concerning the process
Unusual features of the plant site
Exceptional complexity of plant design
General instability of prices and wages

Since most elements of total plant cost have been estimated using factors applied to the installed cost of process equipment, any inaccuracies or uncertainties in respect to equipment costs are of major consequence and are pyramided throughout the estimating process. Rising price trends have been common sources of such error. Two other sources of inaccuracies should be considered for possible increases in the allowance for contingencies:

- Preliminary (precontractual) quotations made on equipment that is to be custom-made. If this category of equipment constitutes a substantial proportion of total equipment cost, the allowance for contingencies should be increased accordingly.
- Estimates of the cost of equipment for which widely differing prices have been quoted for alternative makes of equipment presumably meeting identical specifications. The allowance for contingencies should be increased according to the proportion of total equipment cost falling in this category.

Total cost of physical plant plus construction overhead is generally increased by 10 or 15 per cent to allow for contingencies (18, 54, 53, 87).

Suggested *estimating factor:* 20 per cent of the installed cost of process equipment.

Plant size and plant cost related

When the cost of a specific plant for a given capacity has been determined, it is often desirable to know what effect a larger plant size might have on the economic feasibility of the proposed operation. To help determine this relationship, a significant and handy rule has been devised that has been found useful to other industries, such as the chemical industries, for anyone wishing to estimate the cost of a larger plant when the cost of a small plant is known. A

quick calculation can be made to determine this cost by means of what is known as the "six-tenths factor." A rule of thumb, then, based on this factor, states that "doubling the capacity of a proposed plant will involve a 50 per cent increase in cost, or trebling the capacity will double the investment."

Following is a table showing plant-capacity ratios and the multiplier factor that can be used for estimating the cost of increasing plant size (2, 21, 76).

Calculations involve the following relationships:

Cost of larger plant=Cost of smaller plant $\times$ multiplier

Ratio of capacity, larger/smaller X	Multiplier factor $X^{0.6}$
1.0	1.00
1.5	1.28
2.0	1.52
2.5	1.73
3.0	1.93
4.0	2.30
5.0	2.63
6.0	2.93
7.0	3.22
8.0	3.48
9.0	3.74
10.0	3.98

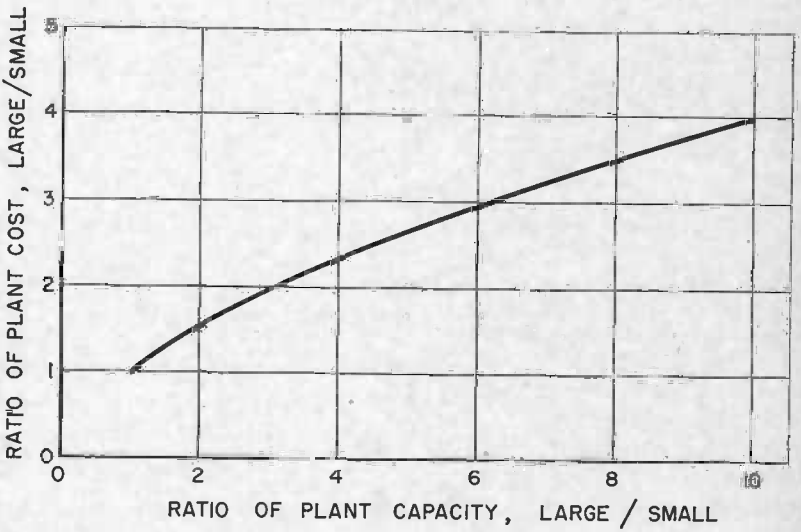


FIGURE 1. *Relationship of plant capacity to plant cost*

Operating Costs

materials, utilities, labor, investment,
selling, management;
all require outlay

FOR PRELIMINARY ESTIMATES, ALL OPERATING COSTS MAY BE considered dependent on:

- *Raw materials and utilities requirements*—as shown by the given engineering data relative to the process
- *Labor requirements*—as indicated by the equipment to be used, the contemplated rate or alternative rates of operation, and the experience of other firms using related processes
- *Total physical plant costs*—either known or predicted

Specifically, the estimate of total operating cost derives from the following basic data:

- Materials, utilities, and labor required per unit of finished product, all production losses being taken into account
- Average number of units to be produced per production day
- Number of production days per year (about 225 for one-shift operation)
- Investment in physical plant

All costs of operation either are computed directly from these data or may be derived from them. Major outlays will be made for materials, utilities, and direct labor for which price quotations can be obtained readily and costs can be computed quickly. Expenditures for labor *overhead* items vary in reasonably stable relationship to direct labor cost and can be approximated satisfactorily using percentage estimating factors. Still other costs are incurred in direct consequence of plant ownership. These are largely independent of the rate of operation of the plant and can best be estimated on the basis of known or predicted plant investment.

Table 6. Outline for Estimating Plant Operating Costs in the Forest Products Industries

Product _____ Date of estimate _____

Total physical plant costs	
Rated capacity of plant per shift	
Expected shifts per day	
Expected production days per year	
Rated capacity of plant per year	
Annual production loss from work stoppages	
Estimated annual production (item 5 minus item 6)	

$$\text{Total operating costs} = \underbrace{(M + U + aL + bI)}_{\text{Production costs}} \times \underbrace{(1 + s + m)}_{\text{Selling and management costs}}$$

where M is raw materials, U is utilities, L is labor cost, s and m are selling and management costs, $a = 1.8$, $b = 0.2$, and $(1 + s + m) = 1.15$

Item	Suggested factor or rate	Amount required	Unit price	Annual cost	Cost per product unit
Production costs					
(M) Raw materials					
1. _____	_____	_____	_____	_____	_____
2. _____	_____	_____	_____	_____	_____
3.					

	2. Fuel (not for steam)					
	3. Steam	70¢ per 1,000 lb				
	4. Water and sewage	$110/100 M cu ft/month				
	5. Other					
	Total utilities					
(*L*)	Direct-operating labor					
	Labor-determined costs					
	1. Direct supervision	10% of direct labor				
	2. Payroll overhead	16% of direct labor				
	Total labor-determined costs					
(*I*)	Investment-determined costs*	20% of physical plant costs, or:				
	1. General overhead	55% of direct labor plus 2% of investment in physical plant				
	2. Maintenance	4% of physical plant costs				
	3. Operating supplies	0.5% of physical plant costs				
	4. Depreciation	10% of process equipment costs and 5% of building costs				
	5. Taxes	2% of physical plant costs				
	6. Insurance	1% of physical plant costs				
	Total investment-determined costs					
	Total all production costs					
(*s* + *m*)	Selling and management costs					
	Selling, distribution, and management	15% of total production costs				
	Total *all* operating costs					

* For rapid estimating, investment-determined costs may be assumed to be 20 per cent of physical plant costs; the more detailed analysis may be made if desired.

The foregoing procedure is summarized by the equation:

$$\text{Total operating cost} = \overbrace{(M + U + aL + bI)}^{\text{Production costs}} \times \overbrace{(1 + s + m)}^{\text{Selling and management costs}}$$

Where: M=materials cost
U=utilities cost
L=direct operating labor cost
a=coefficient combining all labor-dependent costs
b=coefficient combining all investment-dependent costs
I=investment in physical plant
s=selling cost expressed as a percentage of production cost
m=management cost expressed as a percentage of production cost

Two limitations of this procedure should be noted. The total operating cost estimate thus derived includes no allowance for interest costs. Neither does it give any indication of the computational steps to be taken if multiple products are to be produced simultaneously and costs are to be shared for labor or facilities used in common.

On the following pages, procedures are outlined for determining each of the basic cost elements: M, U, L, and I. Percentage estimating factors are advanced tentatively for each of the labor-dependent and investment-dependent cost categories and, in aggregate, for the coefficients a and b and the multiplying factor $(1 + s + m)$, which measures the percentage by which total production cost should be increased to take account of selling and managerial expenses. From the published literature and from a limited amount of direct evidence available, it seems probable that the following values for these overall estimating factors may be appropriate for the wood industries generally:

$$a = 1.8$$
$$b = 0.2$$
$$(1 + s + m) = 1.15$$

Unquestionably, these factors vary with the process and the individual plant. The above generalized values are suggested only for use in preliminary estimating, when more accurate values, specifically applicable to the particular process, may not be available. An outline for estimating operating costs is available in Table 6.

Use current raw material prices

The materials composition of a unit of finished product generally will be shown in the given engineering data. This is a net figure that must be increased to cover production losses of materials through trim, shrinkage, spoilage, broken packages and spillage, or other incomplete utilization or loss.

Prevailing market prices for wood raw materials in various forms are available regularly from such sources as:

Source	Market
Random Lengths	Weekly lumber report
Crows Digest	Biweekly lumber report
Farm Forest Products Market Report	Weekly log prices
National Hardwood Magazine	Monthly hardwood lumber prices
The Paper Industry Magazine	Monthly wood pulp prices
Pacific Pulp & Paper Magazine	Monthly wood pulp prices

Prices for a wide range of standard chemicals used in wood processing are quoted regularly in the *Oil, Paint and Drug Reporter* and in *Chemical and Engineering News*. Other materials prices, including prices for any needed packaging materials, should be obtained by direct quotation.

Prices for raw materials should be net delivered prices, with all regular discounts taken, and inclusive of shipping costs.

Data from the Census of Manufacturers indicate that raw materials costs (including packaging materials and operating supplies) will constitute from 30 to 60 per cent of the dollar value of all finished wood products shipped: about 35 per cent for lumber, 45 per cent for veneer and plywood, 50 per cent for millwork, and 60 per cent for prefabricated structures (16).

Power to convert raw materials

Utility costs include expenses incurred for purchase of electricity, fuel, steam generation, water, and refuse disposal. Costs of some utilities vary considerably in different areas, but estimating factors have been suggested sufficiently reliable for preliminary estimating.

Electricity as power

Industrial power rates are computed variously by different power companies, but generally are determined in part by total kwh (kilowatt-hour) consumption and in part by peak load. For preliminary estimating, sufficiently accurate results may be obtained using an average cost of power per kwh and estimating daily kwh requirements from horsepower ratings of the electrical equipment and expected equipment operating time per day, using a conversion factor of 746 kilowatts per horsepower. It has been suggested that "power requirements should be increased from 10 to 25 per cent to allow for line losses and contingencies" (2, 28). It may be assumed that equipment will have been procured with power factor correction features specified and therefore no adverse power factor will affect rates.

Suggested *estimating factor:* 0.7¢ per kwh, assuming power requirements are in the range of 500,000 kwh per month at 1,200 kw demand.

Fuel as power

Costs for fuel for steam generation are included under steam costs, below. For estimating fuel costs for other purposes, the following are prices that might be used to determine this cost if current fuel costs are not readily available.

Sawdust	$3.15 per unit	
Fuel oil	Prices in tank car lots, *per 42 gal bbl f.o.b. Portland*	Weight *lb per gal*
Light fuel oil (P.S. 300)	$2.68	8.293
Industrial fuel oil (P.S. 400)	$2.30	8.322
Bunker fuel	$2.15	
Gas	$0.85 per M cu ft	

Steam as power

While the cost of steam is difficult to fix for plants of the size commonly used in the wood industry, cost data are available for a few plants in this capacity range. Unless more accurate information becomes available, costs (including fuel) per 1000 pounds of steam can be considered as ranging from 60 to 70 cents as of 1952, the latter figure perhaps being more applicable for plants requiring from 25,000 to 100,000 pounds of steam per hour.

In computing steam consumption, it is suggested that the amount used in production should be increased by 25 per cent to allow for building heating and contingencies (2).

Water requirements and sewage disposal

Process water requirements can be estimated directly from the given engineering data. If the plant has its own water supply, cost of water will be covered by the related estimates of electric power or fuel cost and by the over-all maintenance and depreciation cost estimates for the plant.

Costs of sewage disposal usually are associated with water costs, a composite rate based on volume of water used commonly covering both services.

Prevailing rates for water and sewer service obtained from commercial water companies or municipal water departments vary with location and with the volume used. For industrial users consuming 100,000 cubic feet or 750,000 gallons per month, rates in 1955 ranged from $79.65 to $270.81 for cities in Oregon which had an industrial rate. The latter figure was considerably higher than the average and perhaps should be discounted to some extent. For all of these cities except one the range was from $79.65 to $110.66. It would seem, therefore, that for purposes of quick estimating, the figure of $110 per 100,000 cubic feet would allow the estimator to compute water and sewer costs realistically.

Refuse that can neither be utilized for production of byproducts nor sold to others for such utilization commonly is disposed of through burners, with no attendant costs directly required other than labor and maintenance and depreciation on related equipment. These costs are included in the labor, depreciation, and maintenance categories.

Workers must be paid

Direct operating labor comprises all labor required for machine tending, materials handling, packaging, loading for shipment, waste removal, and foremanship. Not included in this category are nonoperating foremen, supervisory personnel, clerical help, or maintenance workers. The cost of operating labor is considered to include only direct payments to the worker. Indirect payments such as social security contributions by the employer, and payments into retirement funds, are classified separately as payroll overhead.

Preliminary estimates of the cost of direct operating labor are based on available information about the equipment to be used in the process, automatic controls to be installed, expected volume of materials flow, and the probable plant layout, insofar as these items have bearing on labor requirements for materials handling. From these data the estimator proceeds to judgments—conditioned by his own relevant experience or that of his associates—as to probable man-hour requirements per unit of finished product.

Cost of direct operating labor, on a unit basis, can be determined by using, as the average wage rate most likely to be obtained, the most recent report by the U. S. Bureau of Labor Statistics on the average hourly earnings of manufacturing production workers. (These data are published monthly, separately by states, in the Industry Report by the U. S. Bureau of Labor Statistics, *Employment and Earnings.*) Actual wage costs would vary with the specific skills required, the age and experience of workmen employed, and the number of premium hours worked. All these variables are reflected in some degree, however, in the BLS composite figure for average earnings of industrial workers.

The heavy contribution of the wood industries to the all-industry average of industrial workers' earnings in the State of Oregon gives enhanced validity to the use of that average for purposes of estimating wood industries' operating cost.

Supervisors must be paid

Supervisory work is considered to begin at the level of the nonoperating foreman and to extend through the production or department head. Included are personnel engaged in quality control, and any clerical work incident to supervision or to the production process itself. Not included are the supervisory activities of the plant superintendent or other front-office executive personnel.

Direct supervisory costs usually are estimated at 10 per cent of operating labor cost, assuming that process timing and control are

neither highly complex nor integrated to any exceptional degree (32, 3, 5, 6, 59).

Suggested *estimating factor:* 10 per cent of operating labor cost.

Payroll overhead inescapable

Employee benefits requiring cash outlays by the employer in addition to regular payroll, commonly include pensions, disability wages, discontinuance wages, vacation wages, and contributions to social security and group insurance. In aggregate, they commonly amount to from 12 to 20 per cent of the cost of operating labor.

Suggested *estimating factor:* 16 per cent of operating labor cost.

Overhead costs related to plant investment

Under the heading of general plant overhead can be grouped such items as:

- Hospital and first-aid expenses
- Workmen's compensation insurance, or payments to state industrial accident funds
- Sanitation and janitorial expense
- Travel incident to production or plant operations
- Transportation of personnel
- Recurrent expenditures for safety
- Nonoperational technical and analytical services
- Maintenance of roads and yards
- Stockroom operating expenses, exclusive of inventory
- Utilities in nonoperating areas
- Administrative and general office overhead (not including top-management front-office expenses)

These general overhead costs vary in close relationship both to the payroll and to the investment in plant. They are estimated variously at from 40 to 75 per cent of the combined costs of operating and supervisory labor, and plant maintenance.

Suggested *estimating factor:* 55 per cent of operating labor cost, plus, annually, 2 per cent of investment in physical plant.

Maintenance requires additional outlay

The labor, supervisory, and materials expenditures for maintenance of equipment and buildings usually are estimated at from 2 to 10 per cent of the cost of physical plant, depending upon complexity of the equipment and severity of use. Labor constitutes from 50 to 65 per cent of this maintenance outlay. A detailed outline of maintenance labor and materials costs is given in *Factory Management and Maintenance,* 112, (1), January 1954.

Suggested *estimating factor:* 4 per cent of physical-plant cost.

Operating supplies

Miscellaneous supplies will be required for plant operation in addition to the process raw materials and maintenance supplies. Included in this category are such items as janitorial supplies, lamp bulbs, and minor chemical supplies. Annual cost is estimated variously at 10 per cent of operating labor (32), 13 to 20 per cent of plant maintenance cost (3, 5), or 0.5 to 1 per cent of the cost of plant machinery and equipment.

Suggested *estimating factor:* 0.5 per cent of physical-plant cost annually.

Depreciation can be calculated several ways

Depreciation cost is incurred through the decline in value of physical plant from use, weathering, and normal obsolescence resulting from advancing technology. Depreciation normally is deferred cost arising at the time of equipment replacement rather than out-of-pocket expenditure incurred continuously during operation. The year-by-year pattern of the disappearance of value is highly complex, varying among plants and among asset items according to their kind, quality, type of use, rate of operation, and adequacy of maintenance (24).

For cost estimating, usually no attempt is made to predict depreciation accurately, item by item, and for each year of expected useful life. Composite rates, average life expectancies, and standardized prorating are resorted to as a means of reducing the labor of estimating depreciation cost.

Total amount of depreciation is determined by the difference between original cost—including freight charges and costs of installation—and anticipated salvage values at termination of useful life. Predictions of asset life commonly are based on tables prepared by the U.S. Bureau of Internal Revenue (32). (For BIR life expectancies for depreciable items commonly occurring in wood industries plants, see page 63.) Some standardized formula is used for prorating depreciation over the years of expected useful life. Several common formulas are:

- "Straight-line" method—a constant amount each year equal to the value to be depreciated divided by the predicted life.
- "Declining balance" method—a constant percentage of the start-of-the-year unrecovered cost that normally is taken as twice the straight-line rate.
- "Sum-of-the-digits" method—a diminishing percentage of the original cost computed by dividing the number of years of useful life remaining at the start of the tax year by the sum of the series of digits representing for each of the years of useful life, successively, the remaining number of years, and multiplying the resultant fraction by the value at the beginning of the tax year. For example, if an asset has a remaining useful

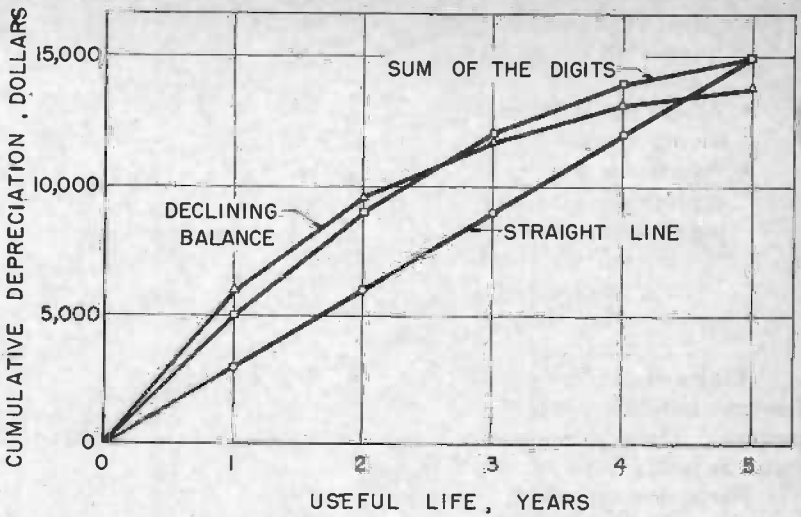


FIGURE 2. *Depreciation over a useful life of 5 years for an item costing $15,000*

life of 5 years, the depreciation allowable for the year would be $5/(5+4+3+2+1)$ multiplied by the value at the beginning of the year. (See Figure 2.)

Any other depreciation method may be used consistently which will not give a total amount of depreciation greater than in the declining balance method after the first two-thirds of the useful life.

Grouping of asset items reduces substantially the work of estimating depreciation cost without significant loss of accuracy. Three methods are used commonly:

- All depreciable assets are grouped together and a single composite rate is applied.

  For quick estimates, useful life of equipment and buildings commonly has been assumed to average 10 years and salvage values have been considered negligible. A composite rate of 10 per cent has been applied to the value of the entire physical plant. This procedure probably has understated the useful life for most plants, overstated depreciation costs, and given a conservative estimate of annual return on investment. For wood industries plants, 15 or 20 years average life and composite rates of from $6\frac{2}{3}$ to 5 per cent probably come closer to actual experience.

  In the foregoing statements, it has been assumed depreciation costs are being determined only for purposes of estimating probable financial return from a project under consideration. Other considerations dic-

tate the most advantageous methods of depreciation accounting for income tax purposes after the plant is operating.

- Assets are grouped according to predicted useful life, items having comparable life expectancies being grouped together.
- Assets are segregated into groups according to use and an appropriate rate applied to each group. The following grouping is used commonly . . .
  - . . . buildings and building services
  - . . . process machinery and equipment
  - . . . office furniture and fixtures
  - . . . transportation equipment

Tables of average useful life compiled by the Bureau of Internal Revenue indicate annual depreciation rates acceptable for income tax purposes. These rates may be assumed to be suitable for cost estimates as well (Table 7).

For quick estimating, it is suggested annual depreciation costs be estimated at 10 per cent of process equipment cost and 5 per cent of the cost of buildings, service facilities, and other auxiliary equipment.

Taxes—those are a certainty!

State, county, and local property taxes and license fees commonly amount to from 1 to 2 per cent of total plant cost annually (3, 5, 6, 59, 62, 63). Not included are income taxes, sales or excise taxes, or franchise taxes, the base for which is measured by income.

Suggested *estimating factor:* 2 per cent of physical plant cost, annually.

Insurance protects normal investment

The insurance program for a plant normally will include coverage for property damage resulting from fire, explosion and wind, damage to persons or property resulting from operation of motor vehicles, and damage to persons or property resulting in other ways from operation of the plant. The combined annual cost of such coverage usually is estimated at 1 per cent of investment in physical plant (3, 5, 6, 12, 59, 62, 63). Not covered are the costs of Workmen's Compensation or State Industrial Accident programs, which have been included above in "General plant overhead."

Suggested *estimating factor:* 1 per cent of physical plant cost, annually.

Selling and management charges

Costs arising from selling and distribution include such items as:

Wages, salaries, and commissions to sales personnel
Sales office expenses
Advertising outlays
Delivery and warehouse costs
Market research and other technical services
Claims and allowances on defective products

TABLE 7. USEFUL LIFE AND INDICATED ANNUAL DEPRECIATION RATES IN THE FOREST PRODUCTS INDUSTRIES

Item depreciated	Useful life	Rate of depreciation
	Years	*Per cent*
Factory buildings with services		
Long-life construction	45	2¼
Average construction	40	2½
Short-life construction	33	3
Warehouses with services		
Long-life construction	67	1½
Average construction	50	2
Short-life construction	29	3½
Process machinery and equipment		
Sawmilling	20–25	5– 4
Logging	10–15	10– 6⅔
Lumber remanufacturing	20–25	5– 4
Office furniture and fixtures	15	6⅔
Transportation equipment	4– 8	25–12½

Selling costs are highly variable, ranging from 0.5 per cent t 10 per cent of gross sales (3, 4, 6). They amount typically to fro 10 to 30 per cent of manufacturing costs (30, 45, 59).

Outlays for management, including salaries of executives, relate office expenses, and legal costs commonly are estimated at from 1 3 per cent (6, 45, 59) of total plant investment annually; or from 1 to 2 per cent (4, 6, 32) of annual sales.

Together with selling and distribution costs, costs of manage- ment may be estimated at 15 per cent of production costs.

Profit or Loss?

key to the venture's success is . . . will it pay?

APPRAISAL OF THE INVESTMENT-WORTHINESS OF A PROPOSED new project usually is based on:

- Predicted annual sales of the product.
- Estimated costs of production and distribution, including costs of management.
- Prevailing standards for acceptance or rejection of proposed capital commitments in terms of desired payout period and minimum acceptable rate of return on investment. To facilitate such appraisal, estimates of profit per dollar of sales and profit per dollar invested should be derived (Table 8).

Anticipated volume and expected average price

Annual sales of the product are predicted in terms of anticipated volume and expected average price. If multiple products would be derived from the process, or if the product would be produced in varying dimensions or at several quality levels, it will be necessary to estimate volume and average price for each product, size, and grade. Furthermore, some assumption may be necessary concerning success of the enterprise in meeting quality standards; i.e., some percentage of the product may have to be assumed to be substandard.

Procedures for estimating costs, both annually and on a unit basis, have been summarized previously. Deduction of total estimated annual costs from total expected annual sales return gives a measure of gross annual profit.

This measure takes into account all normal costs of operation and provides for recovery of investment in depreciating assets over a period of time determined by life expectancies of buildings and equipment as used for purposes of income tax calculations. It makes no provision for depletion—i.e., recovery of capital invested in nat-

ural resources subject to exhaustion—or for abnormal rates of depreciation or obsolescence. It does not provide for recovery of investment (amortization) for nondepreciating or nondepleting assets. Furthermore, it makes no allowance for interest costs on borrowed money, or for income taxes. Refinement of the measure in these respects is rarely possible for the estimator working at early developmental stages. At a later stage the prospective investor can accomplish this refinement in terms of specific circumstances, which he can assume will prevail, in respect to use of borrowed money, with reference to his own individual tax situation, and with due regard to personal expectations concerning payout period.

From the calculations suggested in Table 8, an estimate of annual profit will have been derived. Expressed as a percentage of total expected investment, it gives profit per invested dollar. Expressed as a percentage of estimated annual sales it gives profit per sales dollar (profit margin). Expressed on a unit basis—i.e., annual profit/annual volume of production—it shows the profit margin expected per unit produced.

Break-even price fixing

If no market forecast for the product is feasible, it is impossible to estimate profits. However, break-even *price* may be determined for any assumed volume of operation:

Total operating cost/Number of units to be produced.

TABLE 8. OUTLINE OF METHOD FOR ESTIMATING PROFIT

Product _____ Date of estimate _____

A. Estimated total plant investment		
B. Estimated annual production		(units)
C. Expected average selling price		($ per unit)
D. Estimated annual sales (B × C)		(dollars)
E. Estimated annual operating costs		
Production		
Selling and management		
Total operating costs		
F. Net annual profit before income taxes (*D-E*)		
G. Profit per invested dollar (*F/A*)		
H. Profit per sales dollar (*F/D*)		
I. Profit per unit produced (Profit margin) (*F/B*)		

Or break-even *volume* may be estimated in terms of an assumed average price:

Total operating cost/Assumed average selling price.

If it is possible to estimate sales from available market information, minimum payout period in years may be determined:

Total investment/Total annual sales minus total annual operating cost.

For preliminary appraisal of profit, the following assumptions might well be made:

- That 20 per cent of the funds invested in the enterprise will be borrowed at an average annual interest rate of 5 per cent.
- That 50 per cent of profit after all costs, including interest cost, have been paid will be taken in income taxes.
- That investors commonly will expect to recover their capital in a period shorter than the life expectancy of the depreciating assets—for example, from 3 to 5 years rather than the usual 10- to 20-year depreciation period.

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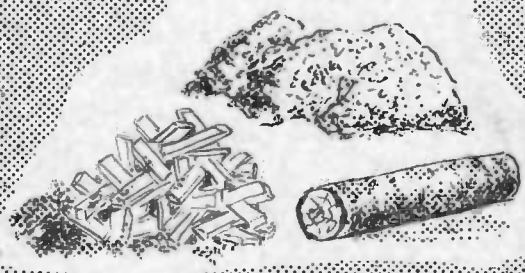
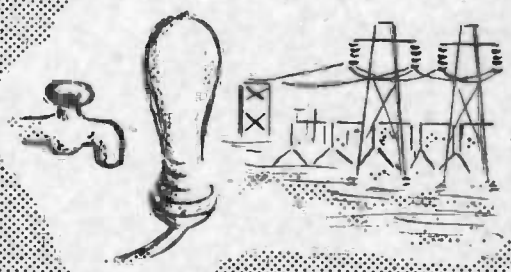
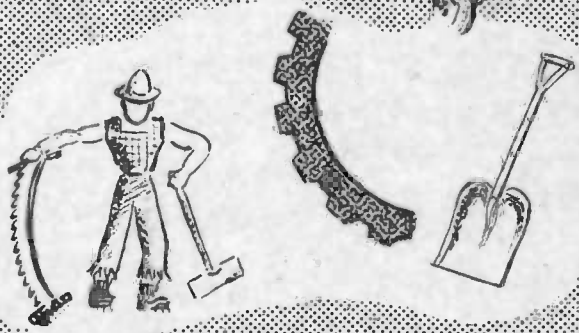


MATERIALS



UTILITIES



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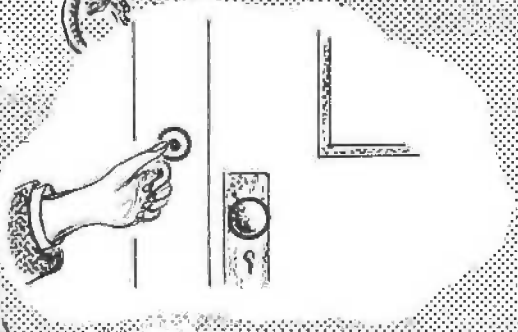
INVESTMENT

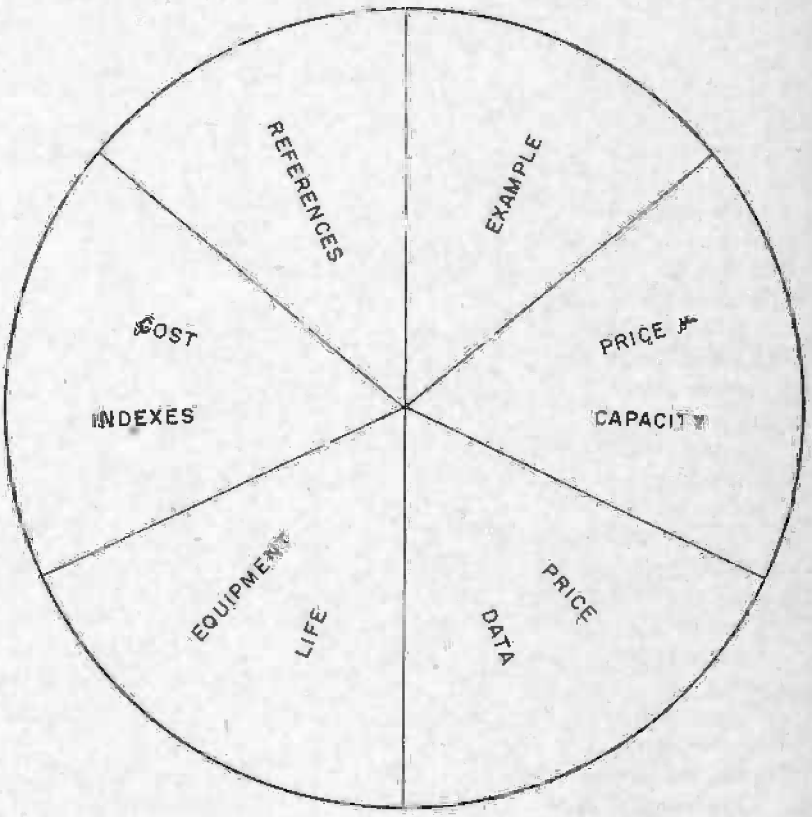


SELLING

MANAGEMENT

II

Estimating Tools



to assist the estimator

An Example: Lodgepole Pine Hardboard

estimated profitability can lead to new industries, new goods

To illustrate the procedures described in the text and to show how a pre-blueprint plant-cost estimate might be made using data that have been developed, a cost estimate is included for a plant to manufacture hardboard from lodgepole pine.

It has been determined that a satisfactory dry-formed hardboard with acceptable properties can be made from lodgepole pine.* It remains, then, to determine economic feasibility for such an operation.

Since readily available water supplies are lacking in most lodgepole pine areas of Oregon, a dry-formed board seemed most practicable. Studies by the Oregon Forest Products Laboratory were confined, therefore, to this process. Because of the few operations in which lodgepole pine currently was being processed, and resulting lack of such materials as slabs, edgings, and trim, it was assumed also that logs would be used as the raw material.

Plant location and scale of operation must be decided before estimating plant cost. Production data can be calculated once scale of operation and processes to be used have been fixed. To estimate cost of establishing a plant for making hardboard from lodgepole pine, the process, then, should be considered.

For simplification and explanation, the process may be described briefly as follows: Logs are delivered to the plant in 1-cord bundles where they are either stockpiled in the yard or placed directly in the log storage pond. After bundles are broken open, individual logs, with adhering bark, are conveyed to the chipper where logs are reduced to chips. These chips are screened and conveyed to the

* Nixon, G. D., *Suitability of Lodgepole Pine for Dry-formed Hardboard,* Oregon Forest Products Laboratory, April 1953.

TABLE 9. HARDBOARD PRODUCTION, BASED ON EQUAL AREA PRODUCTION OF $\frac{1}{8}$-INCH AND $\frac{1}{4}$-INCH BOARDS WITH PRESS CYCLES OF 7 AND 9 MINUTES, RESPECTIVELY

Board thickness	Press cycles daily	Boards produced					
		Daily*			Yearly†		
Inch		*Number boards*	*M sq ft*	*Tons*‡	*Number Boards*	*M sq ft*	*Tons*‡
$\frac{1}{8}$	90	1,800	57.6	19.8	396,900	12,700	4,376
$\frac{1}{4}$	90	1,800	57.6	39.7	396,900	12,700	8,751
Both	180	3,600	115.2	59.5	793,800	25,400	13,127

* No down time; 24-hour operation.
† Ten per cent down time; 245-operating-day year.
‡ Trimmed, with 6 per cent moisture content; no allowance made for weight increase of tempered boards.

Industry process needs consideration

chip storage bin, or to the cooker. There they are softened prior to being placed in the attrition mill for reduction to fiber. From the attrition mill the fibers are conveyed to the blender where wax and resin are added and the pH adjusted. Afterwards, the fiber is conveyed to the felter where a mat is formed, cut to length, and pre-pressed before being inserted into the press charger. When the charger is filled with pre-pressed boards and the hot press is opened, the boards are inserted into the hot press for a short period of time, after which the pressed boards are taken out of the hot press by means of a receiver unit. The boards are separated from the cauls and, while the cauls are being returned to the pre-press, the boards are conveyed to and through the humidity chamber, where moisture is added. The boards to be tempered are routed from the press to the tempering unit, then go to the humidity chamber. Following humidification, the finished, untrimmed boards are conveyed to and through the skinner saws where the boards are cut to proper dimensions, after which they are packaged or stored ready for shipment.

Carefully select land for plant site

Because of the variable cost of land it would be difficult to include any cost figure for this commodity. It is expected, however, that 10 acres or more should be procured—about 5 acres for buildings and service facilities, and 5 acres for the pond, unloading, and storage areas.

At least the following cost factors should be considered in determining location:

- Availability of raw material, both stumpage and, if possible, mill residue.
- Nearness to railroad.
- Availability and cost of electric power.
- Adequacy of water supply for fire protection and operational requirements.

- Availability of an adequate work force.
- Features of terrain affecting costs of drainage, pond construction, water storage, waste disposal, construction of roads and, if necessary, a railroad siding.
- Local tax rates.

Scale of operations

With a 20-opening press, and press schedules of 7 minutes and 9 minutes for $\frac{1}{8}$-inch and $\frac{1}{4}$-inch boards, respectively, the plant is limited to about 45 tons of finished board per day on a $\frac{1}{8}$-inch basis and 70 tons on a $\frac{1}{4}$-inch basis. Some reduction in press time might be made, and, if so, the output would be increased.

To arrive at an understandable and realistic plant-cost estimate, basic assumptions are necessary. First, only new equipment is to be considered. Second, there will be no sharing of facilities such as electricity and steam between this plant and another woodworking plant. Third, because of variability of the raw material and product, certain assumptions have been made to compute raw material requirements for the plant. Following are these assumptions, together with derived tables showing necessary quantities of raw materials.

Assumptions as to materials and product

- All logs green with negligible bark.
- Moisture content of logs green: 65 per cent.*
- Specific gravity of logs:*
  Dry weight, green volume 0.38
  Dry weight, dry volume 0.43
- Weight of logs, green: 39 pounds per cubic foot.*
- Solid wood content of logs: 95 cubic feet per cord.
- Weight of green chips: 15 pounds per cubic foot.
- Reduction of moisture content in the chipping and screening operation: from 65 down to 60 per cent.
- Average chip length: $\frac{5}{8}$ inch.
- Loss of wood in chipping and screening: 5 per cent.
- Loss of fiber in attrition mill, cyclones, and felter: 1 per cent.
- Average specific gravity of oven-dry finished boards: 1.0
- Average thickness of $\frac{1}{8}$-inch board: 0.125 inch.
- Average thickness of $\frac{1}{4}$-inch board: 0.250 inch.
- Dimensions of finished board: 8 feet by 4 feet.
- Two grades of boards produced per thickness:
  . . . Standard boards:
    First grade—75 per cent of total
    Second grade—25 per cent of total
  . . . Tempered boards:
    First grade—20 per cent of boards to be tempered with oil amounting to 7 per cent by weight in the $\frac{1}{8}$-inch boards, 4 per cent by weight in the $\frac{1}{4}$-inch boards.

* *Strength and Related Properties of Woods Grown in the United States,* Technical Bulletin 479, U. S. Department of Agriculture, September 1935.

- Composition of standard moisture-free board:

Material	Weight per 1,000 g fiber	Percentage of board weight
	Grams	*Per cent*
Fiber	1,000.00	95.76
Resin*	25.00	2.39
Wax†	15.00	1.44
Acid‡	1.96	0.19
Alum§	2.28	0.22
Total	1,044.24	100.00

* Liquid, with 40 per cent solid phenol-formaldehyde.
† A petrolatum wax.
‡ Sulfuric, in 1-Normal solution, 40 ml per 1,000 g dry fiber.
§ Aluminum sulphate, commercial, ground. In 1 N solution, 40 ml per 1,000 g dry fiber. Weight cited is oven-dry, disregarding water of crystallization.

Composition of tempered board:

Same as standard boards, except tempering oil added—about 7 per cent by weight for $\frac{1}{8}$-inch boards, and 4 per cent for $\frac{1}{4}$-inch boards.

- One 20-opening press will be used with the following press cycles:
  ... For $\frac{1}{8}$-inch board: 7 minutes.
  ... For $\frac{1}{4}$-inch board: 9 minutes.
- Eight hours per day operation of chipping plant; 24 hours per day for the rest of the plant. Plant operates 245 days per year.

From the assumptions concerning raw materials and manufacturing variables, there can be derived information about requirements for raw materials and production.

TABLE 10. MATERIALS IN STANDARD $\frac{1}{8}$-INCH HARDBOARD*

Material	Proportion of oven-dry weight	Untrimmed, oven-dry	Untrimmed, humidified†	Trimmed, humidified†
	Per cent	*Pounds*	*Pounds*	*Pounds*
Fiber	95.76	21.82	21.82	19.91
Resin	2.39	0.55	0.55	0.50
Wax	1.44	0.33	0.33	0.30
Acid	0.19	0.04	0.04	0.04
Alum	0.22	0.05	0.05	0.05
Water			1.37	1.25
Total	100.00	22.79	24.16	22.05

* Weights listed are for one 4- by 8-foot board, $\frac{1}{8}$ inch thick; weights for $\frac{1}{4}$-inch board would be double those listed.
† Humidified to 6 per cent moisture content; $1\frac{1}{2}$-inch trim.

Finished boards:

- One-eighth-inch board (at 6 per cent moisture content)—
  - ... Weight per board: 22 pounds.
  - ... Weight per square foot: 0.689 pounds.
  - ... Weight per M square feet: 689 pounds.
  - ... One ton of finished board: 2,900 square feet or 90 + boards.
- One-quarter-inch board (at 6 per cent moisture content)—
  - ... Weight per board: 44 pounds.
  - ... Weight per square foot: 1.378 pounds.
  - ... Weight per M square feet: 1,378 pounds.
  - ... One ton of finished board: 1,450 square feet or 45 + boards.

Production data

Table interpretations:

Table 9: Daily and yearly production of equal surface area of $\frac{1}{8}$-inch and $\frac{1}{4}$-inch boards, with 7- and 9-minute cycles, respectively.

Table 10: Weights of materials in standard boards as they come from the press, then humidified and trimmed.

Table 11: Requirements for tempering oil for boards to be treated.

Table 12: Production of boards at the rate shown in Table 9, with materials listed in Table 10, would require basic raw material as shown.

Table 13: Estimated volume of logs required to produce needed fiber.

TABLE 11. OIL REQUIREMENT FOR TEMPERED BOARDS

Board thickness	Oil content		Oil requirement		
	By weight	Per board	Per press cycle	Daily*	Yearly†
Inch	*Per cent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
$\frac{1}{8}$	7	1.54	30.8	520	114,660
$\frac{1}{4}$	4	1.76	34.8	594	130,980
Total				1,114	245,640

* With equal numbers of $\frac{1}{8}$- and $\frac{1}{4}$-inch boards, and 25 per cent of grade 1 boards tempered.
† With 245 operating days yearly and 10 per cent down time.

TABLE 12. BASIC MATERIAL REQUIREMENTS

Material	Per cycle		Daily*			Yearly†		
	⅜-inch board	¼-inch board	⅜-inch board	¼-inch board	All boards	⅜-inch board	¼-inch board	All boards
	Lb	*Lb*	*Lb*	*Lb*	*Lb*	*Tons*	*Tons*	*Tons*
Fiber	436.4	872.8	39,276	78,552	117,828	4,330	8,660	12,990
Resin	11.0	22.0	990	1,980	2,970	109.1	218.3	327.4
Wax	6.6	13.2	594	1,188	1,782	65.5	130.9	196.4
Acid‡	0.8	1.6	72	144	216	7.9	15.9	23.8
Alum‡	1.0	2.0	90	180	270	9.9	19.8	29.7

* Ninety press cycles each of ⅜-inch and ¼-inch boards; no down time.
† Equal area production of ⅜-inch and ¼-inch boards; 10 per cent down time, 245-operating-day year.
‡ Added to fiber at the rate of 80 ml of 1-Normal solution per 1,000 g fiber.

TABLE 13. LOG REQUIREMENTS

Item	Per board		Per cycle		Per day*			Per year†		
	⅜ inch	¼ inch	⅜ inch	¼ inch	⅜ inch	¼ inch	All boards	⅜ inch	¼ inch	All boards
	Lb	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Tons*	*Tons*	*Tons*
Fiber in board	21.82	43.64	436.4	872.8	39,276	78,552	117,828	4,330	8,660	12,990
Fiber felter loss‡	0.22	0.44	4.4	8.8	396	792	1,188	43	87	130
Chip screen loss§	1.10	2.20	22.0	44.0	1,980	3,960	5,940	219	437	656
Dry wood	23.14	46.28	462.8	925.6	41,652	83,304	124,956	4,592	9,184	13,776
Moisture in logs‖	15.04	30.08	300.8	601.6	2,709	5,418	8,127	2,985	5,970	8,955
Green wood	38.18	76.36	763.6	1,527.2	68,724	137,448	206,172	7,577	15,154	22,731
Green wood, *cords***	0.01	0.02	0.19	0.37	18.5	37.1	50.2	4.090	8.180	12.270

* Equal numbers of ⅜- and ¼-inch boards produced; 24-hour operation, no down time.
† Equal numbers of ⅜- and ¼-inch boards produced; 245-operating-day year, 10 per cent down time.
‡ Fiber loss of 1 per cent in cyclones and felter.
§ Chip loss of 5 per cent in chipping and screening.
‖ Logs at 65 per cent moisture content, dry-weight basis.
** With logs weighing 39 pounds per cubic foot, and estimated volume of 95 cubic feet of solid wood per cord.

With the potential production established, it is possible to proceed toward analysis of costs and returns. The first step is compilation of delivered or installed costs of process equipment, and conversion of delivered costs to installed costs, as in Table 15. Estimating factors that are based on cost of installed process equipment enable an estimate to be made of the physical plant costs, as in Table 14.

An analysis of costs and profit

The production costs may be calculated, based on the planned production and on estimating factors for utilities, and costs determined from labor and physical plant costs, as outlined in Table 16. By adding a percentage to the production costs to allow for costs of selling, distribution, and management the operating costs are estimated, as in Table 19, and recapitulated in Table 17.

The investment in physical plant, plus initial working capital, approximate the total capital requirements, as shown in Table 20.

The planned production and the expected selling price, if known, may be used to calculate the annual return from sales. The sales return, less operating costs, provides an estimate of the net profit before income taxes. A procedure is outlined in Table 18 for estimating profit from the projected hardboard plant.

The hardboard production was classified separately only by thickness in Table 18. Actually, the product would likely be in 2 grades for each thickness—with 20 per cent of the grade 1 boards to be oil-tempered. For simplicity, it was assumed that increased returns from the tempered boards would offset decreased returns from grade 2 boards. One selling price, consequently, was used for all grades, including tempered board, for boards of the same thickness. The selling prices used in estimating were considered reasonably low for f.o.b. mill prices in December 1954.

TABLE 14. PHYSICAL PLANT COSTS

Item	Estimating factor	Installed cost
	*Per cent**	
Installed process equipment		$ 625,586
Site preparation	5.5	34,407
Building and building services	20.0	125,117
Process piping	6.5	40,663
Electrical installations	9.0	56,303
Utilities and other service facilities	9.0	56,303
Construction overhead	30.0	187,676
Contingencies	20.0	125,117
Total physical plant costs		$1,251,172

* Based on cost of installed process equipment.

TABLE 15. PROCESS EQUIPMENT COSTS

Item	Capacity or size	Quantity required	Delivered cost	Installed cost
Unloading Equipment		1	$ 6,000	
A-frame and rigging				
Brow log and deadman				
Piling to support pond bank at log dump				
Small structure to house motor and drum				
Single drum hoist on skids with 30 hp electric motor, with cable				
Three-drum yarder with motor, sled, cable	3 drum	1	6,440	
Conveyor, complete, pond to chipper	H-type mill chain 75'	1		$1,292
Chipper; motor, knives, and other accessories	13" x 11" spout opening	1	17,023	
Conveyor, chipper to chip screen	17 cords/hour; 24" belt	1		2,070
Chip screen	20 cords/hour	1	4,527	3,000
Conveyor, chip screen to storage bin	50' bucket elevator	1		
Conveyor from storage bin to surge bin below cooker	24" belt x 40'	1		1,500
Surge bins	1 unit	2		500
Bucket elevator	25 feet	1		2,070
Cooker	50-75 tons	1	25,950	
Metal detector		1	200	
Attrition mills	25 tons/day	3	65,685	

Blower and cyclone system to convey fiber from refiners to blender	2.5 tons/hour	1	4,372	
Blender	60 tons/day	1	5,000	
Blower and cyclone system to convey fiber to felter	2.5 tons/hour	1	4,372	
Felter, prepress, flying saw and speed changer	4,000 boards/day	1 unit	40,000	
Vacuum-transfer unit for preforms	4,000 boards/day	1 unit	12,250	
Cross-transfer unit		1 unit	5,525	
Speed-up section		1 unit	1,250	
Charger, press	20 openings	1	32,000	
Hot press	20 openings, 4' x 8' platens 5" daylight, 1,000 psi	1	100,524	
Receiver	20 openings	1	32,000	
Outgoing conveyor unit		1	1,250	
Caul and board separating unit		1	7,150	
Cross-transfer unit for cauls		1	1,250	
Return caul conveyor unit complete		1	5,725	
Cauls, type 316-L, clad steel, finished	⅛ by 52 by 100 inches	120		24,179
Humidifier	13.5 by 110 ft	1	67,000	
Tempering unit	1,000 boards/day	1	28,000	
Skimmer saw unit		1	38,000	
Delivered or installed cost			513,893	34,609
Installation cost			77,084	
Total installed cost				$625,586

TABLE 16. PRODUCTION COSTS FOR LODGEPOLE PINE HARDBOARD PLANT

Cost item	Unit price, factor, or rate	Daily requirement	Daily cost	Yearly cost	Unit cost per M sq ft	
					⅛-inch	¼-inch
Raw material						
Wax	$0.03/lb	1,782 lb	$ 53.46	$ 11,788		
Acid	22.35/ton	216 lb	2.41	531		
Alum	37.00/ton	270 lb	5.00	1,102		
Resin	0.29/lb	2,970 lb	861.30	189,917		
Oil	0.125/lb	1,114 lb	139.25	30,705		
Logs	15.00/cord	50.2 cords	753.00	166,037		
			1,814.42	400,080	10.50	21.00
Utilities						
Electricity	$0.007/kwh	24,510 kwh	171.57	42,035		
Steam	0.70/1,000 lb	330,600 lb	231.42	56,698		
Water, sewage	1.10/100,000 cu ft/month	100,000 cu ft	1.10	270		
			404.09	99,003	3.41	4.38
Labor						
Direct-operating	$2.12/hour	308 man hrs	652.96	159,975		
Labor-determined	80% of direct labor		522.37	127,980		
			1,175.33	287,955	9.92	12.75
Investment-determined	20% of physical plant costs		1,021.36	250,234	8.62	11.08
Total			$4,415.20	$1,037,272	$ 32.45	$ 49.21

Table 17. Operating Costs and Annual Production

Product—Hardboard from lodgepole pine	Date of estimate—August 1954
1. Total physical plant costs	$1,251,172.00
2. Rated capacity of plant/day	115,200 sq ft, or 59.5 tons (50%-$\frac{1}{8}$", 50%-$\frac{1}{4}$")
3. Expected production days/year	245
4. Rated capacity of plant/year	28,224,000 sq ft or 14,586 tons
5. Down time (estimated at 10% of rated annual capacity)	Less 2,822,400 sq ft, or 1,459 tons
6. Estimated annual production	25,400,000 sq ft, or 13,127 tons

$$\text{Total annual operating costs} = \overbrace{(M + U + aL + bI)}^{\text{Production costs}} \times \overbrace{(1 + s + m)}^{\text{Selling and management costs}}$$
$$= [(\$400{,}080.00 + \$99{,}003.00 + (1.8 \times \$159{,}975.00) + (0.2 \times \$1{,}251{,}172.00)] \times (1.15)$$
$$= \$1{,}192{,}862.00$$

Table 18. Estimate of Profit from Lodgepole Pine Hardboard Plant

Item	Product: $\frac{1}{8}$-inch boards	Product: $\frac{1}{4}$-inch boards	All boards
A. Estimated total capital requirements*			$1,510,490
B. Estimated annual production	12,700,000 sq ft	12,700,000 sq ft	
C. Expected average selling price	$45/M sq ft†	$70/M sq ft†	
D. Estimated annual sales (B × C)	$571,500	$889,000	$1,460,500
E. Estimated annual operating costs	$37.32/M sq ft	$56.59/M sq ft	$1,192,862
F. Net annual profit before income tax (D — E)			$ 267,638
G. Annual profit per invested dollar (F/A)			$ 0.177
H. Annual profit per sales dollar (F/D)	$0.171	$0.192	
I. Profit per unit produced (F/B)	$7.68/M sq ft	$13.41/M sq ft	

* Excluded are land costs and promotional, organizational, and developmental costs.
† Conservative wholesale price, f.o.b. mill, for standard board in December 1954.

Table 19. Total Operating Costs

Cost item	Cost			
	Per day	Per year	Per M sq ft	
			⅛-inch	¼-inch
Production	$4,415	$1,037,272	$32.45	$49.21
Selling, distribution and management (15% of production costs)	662	155,590	4.87	7.38
Total operating cost	$5,077	$1,192,862	$37.32	$56.59

Table 20. Total Capital Requirements

Date of Estimation—August 1954
Plant Capacity—59.5 tons per day

1. Physical plant cost	$1,251,172
*2. Land costs	
*3. Promotional, organizational, and developmental costs	
4. Initial working capital (three times value of one month's total production costs)	$ 259,318
Total	$1,510,490

* Note: No estimate will be made of these items. Total costs of these items, however, are not expected to amount to more than 3 per cent of the total capital requirements.

Price-Capacity Relationships for Wood-Industry Equipment

cost of machinery
can be assessed
according to size, weight, or output

SINCE ANY COST ESTIMATE OF A PLANT NECESSARILY CENTERS about the total investment required for process equipment, it is essential that every effort be made to make this part of the estimate accurate and realistic. There are several methods for getting this information after the equipment requirements are known. Perhaps the most costly method, but at the same time most accurate method, is to obtain direct quotations from each manufacurer each time any equipment is being considered. Most pre-blueprint cost estimates, however, will not merit this expense and a less costly method with some loss in accuracy would suffice.

There are numerous sources of information in which charts are included to show relationship of price to capacity for various types of equipment, as shown in "Reference List for Published Price Data Relative to Standard Items of Industrial Equipment" on page 61. The references listed have been selected because of possible usefulness to the wood industry. Most of this information as well as other equipment cost data, is included in and taken from the literature published by the chemical industry. Data in these selected references, however, are believed applicable to the wood industry for quick estimating purposes wherever the capacities shown in the charts will apply.

To supplement the above data, charts are shown on pages 54 to 60 which include data for equipment used in the wood industry. Wherever meaningful, in order to show the price-capacity ratio, capacity is shown as commonly thought of in the industry with no inference as to quality. Quality is shown, in many instances, by the slope of the line. In a few graphs, for example where equipment from the various manufacturers varied little in size and capacity, or where

there was some variation but no consistent relationship between price and size, some other classification, such as weight, gave a smoother price-capacity curve.

The question is, how to keep the data included in these and other price sources from becoming obsolete within a few months or a year after it is received. It is believed that the useful life expectancy of such data can be increased considerably by the use of an equipment index (see page 65), thereby making possible the use of otherwise obsolete data.

Charts show cost-price relationships

The following information applies to pages 54 to 60, inclusive:

All curves are empirical.

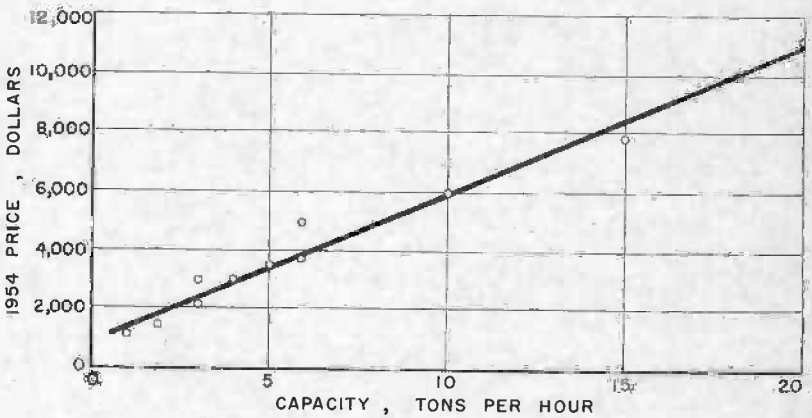
All prices shown are for 1954, with the exception of the information relative to chippers, which is for 1953.

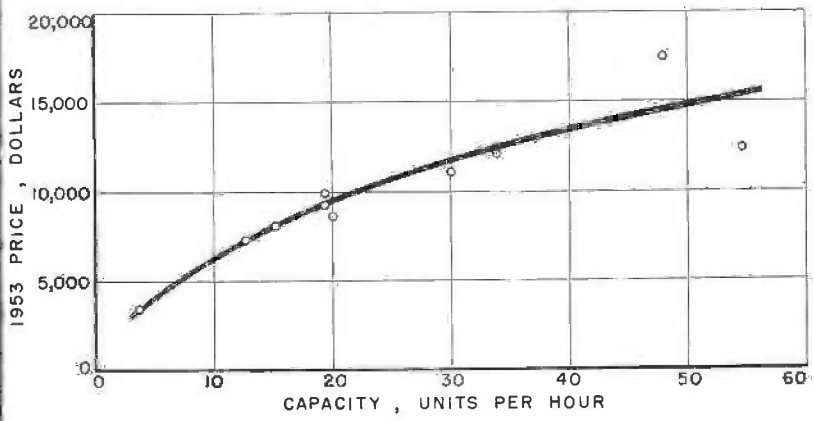
In order to correct to any given date either the prices on pages 54 to 60, those mentioned under "Standard Items of Industrial Equipment," or any other prices that might be available, it is suggested information given under "Equipment Cost Indexes" be used.

For example: For data as of 1948 to be corrected to 1953 for "general purpose machinery and equipment" as shown in the *Bureau of Labor Statistics Price Indexes*, prices for 1948 should be multiplied by 1.24 to correct to 1953.

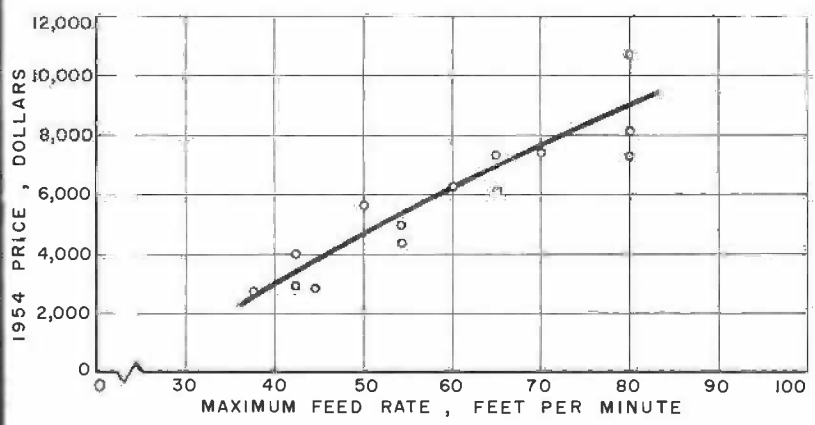
It is suggested as many items as possible be corrected collectively also rather than as individual items, since the chance for error is greater for individual equipment items than for a group of items.

Hammer mill rechippers without motors

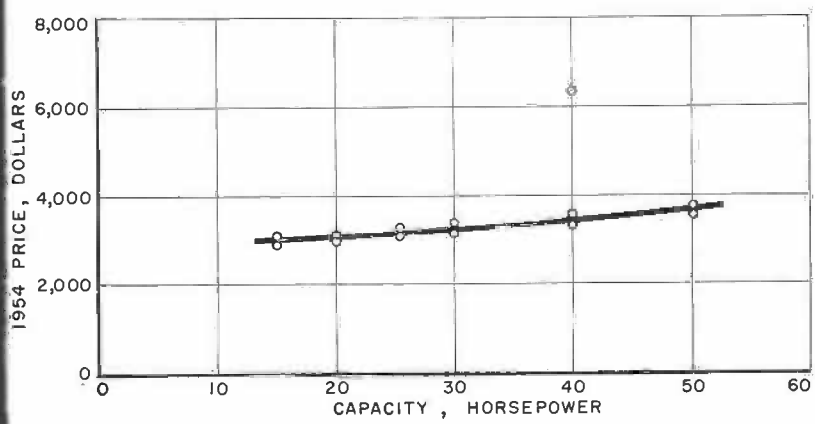




Chippers without knives or power

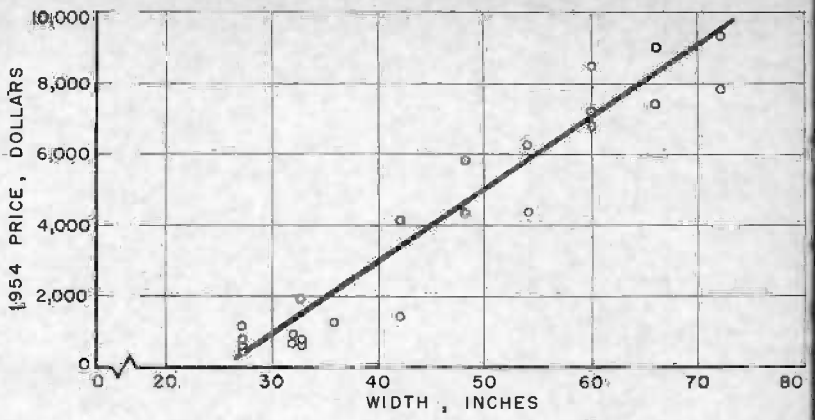


Single surfacers with motors

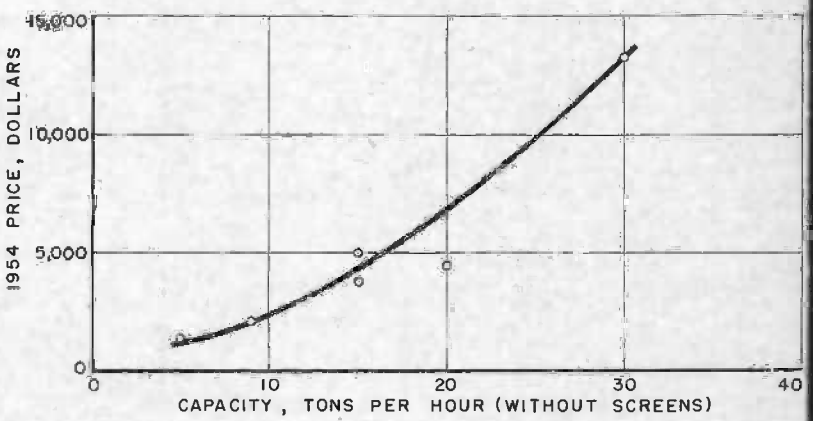


Gang ripsaws with motors and saws

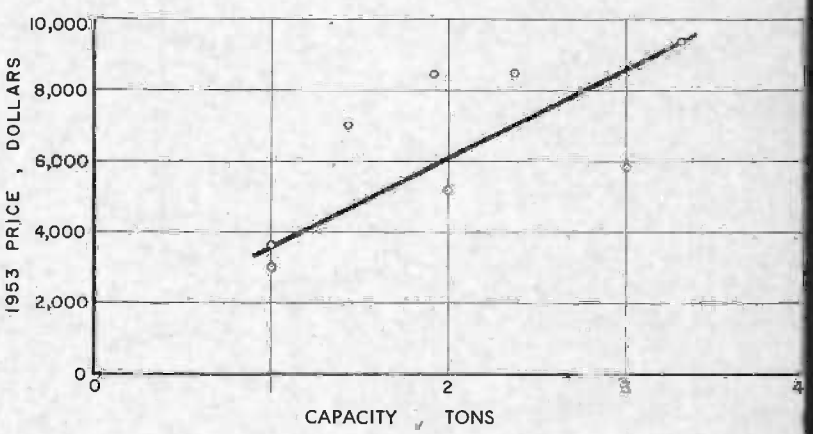
Edgers without motors

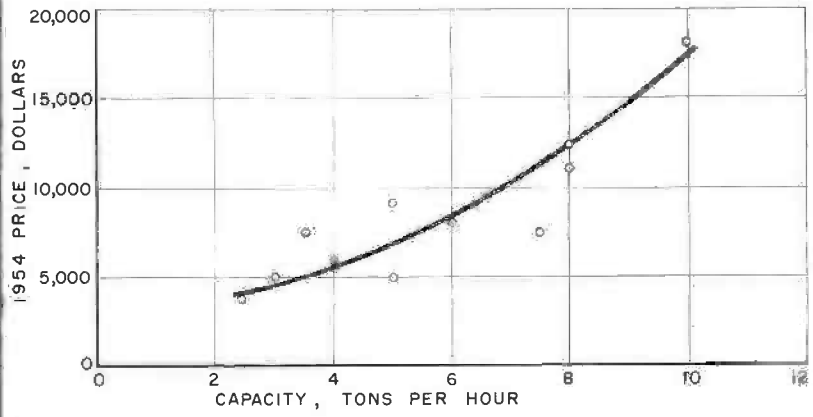


V-type sawmill hogs without motors

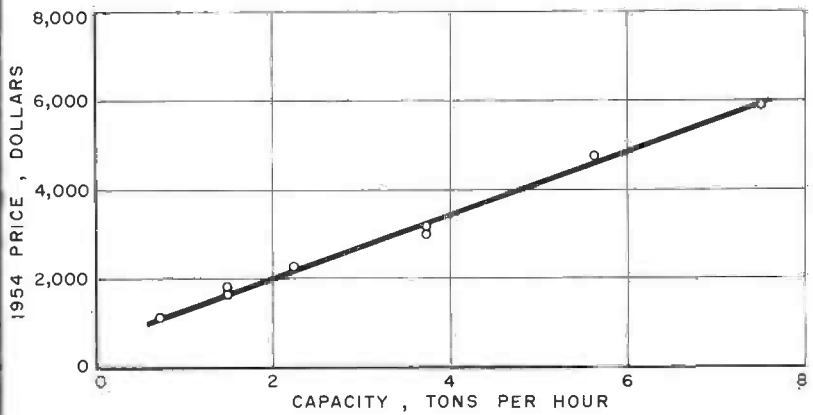


Fork-lift electric trucks

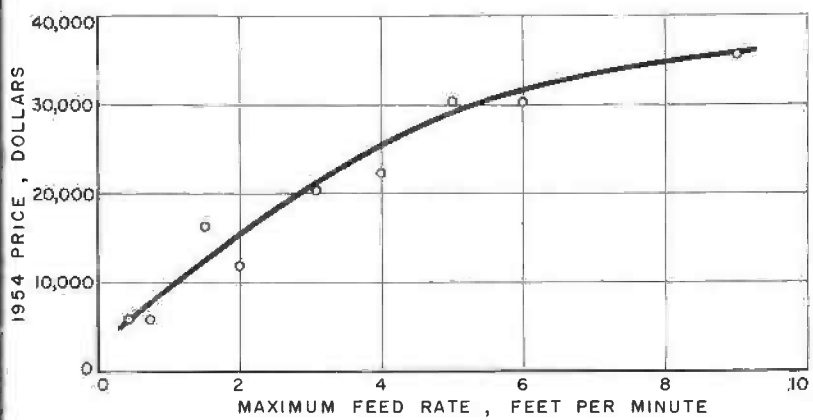




Hammer mills without motors

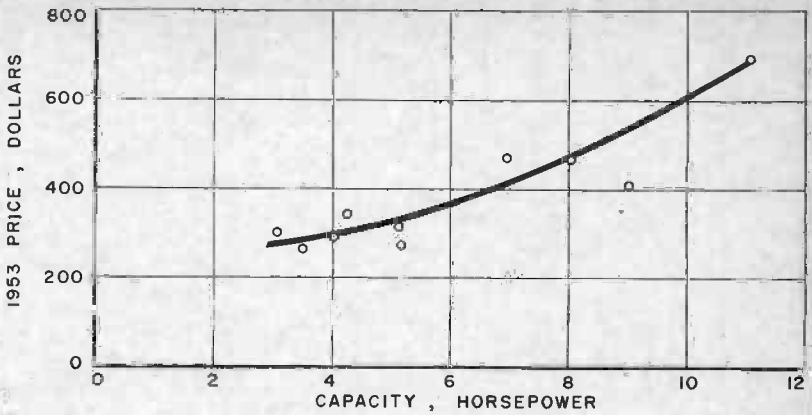


General purpose hogs without motors

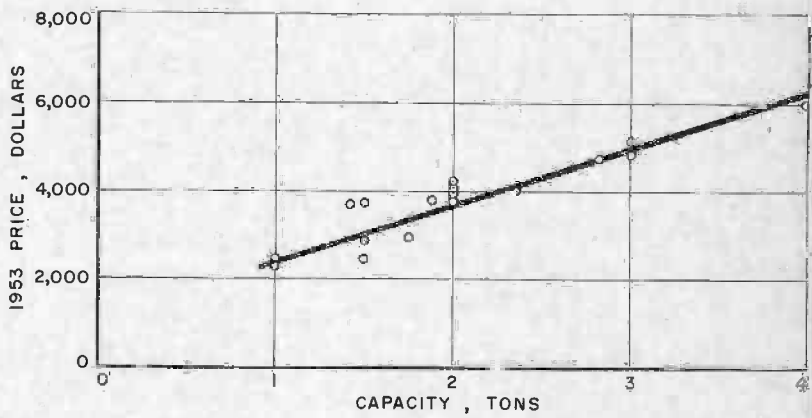


Planers and matchers with motors

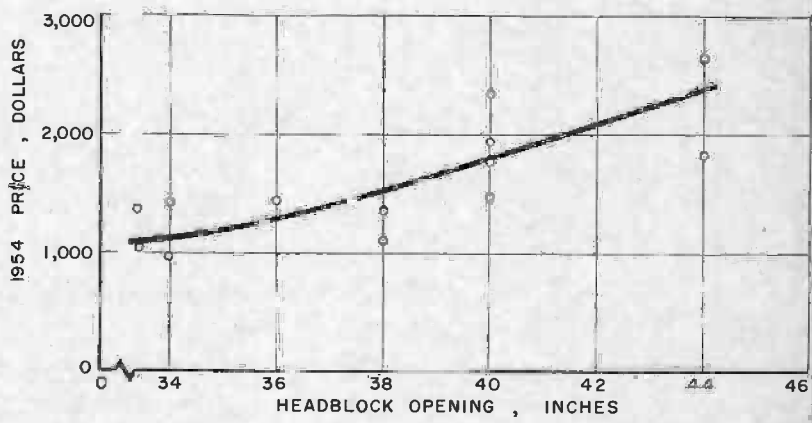
Chain saws

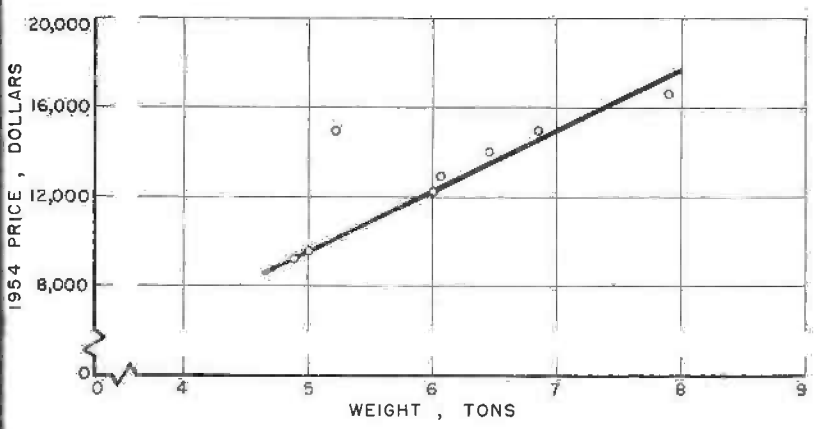


Fork-lift gasoline or diesel trucks

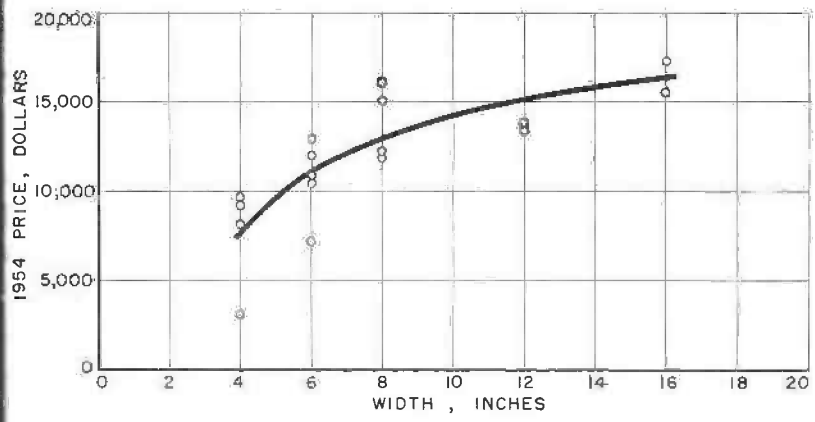


Single circular sawmills without saw or power

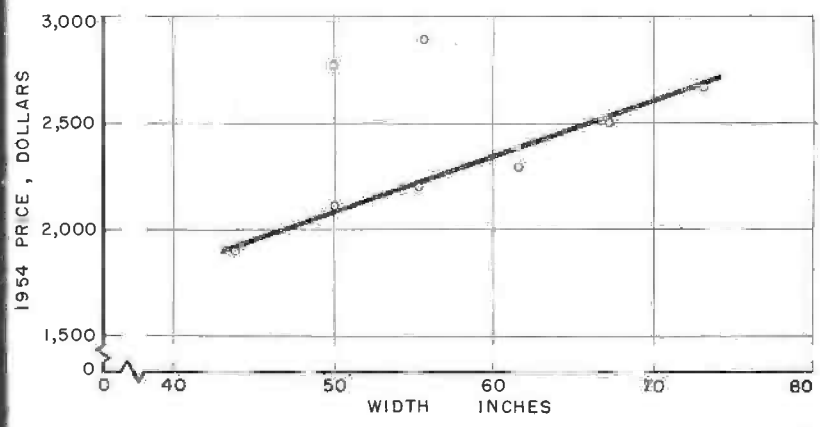




Double surfacers with motors and drives

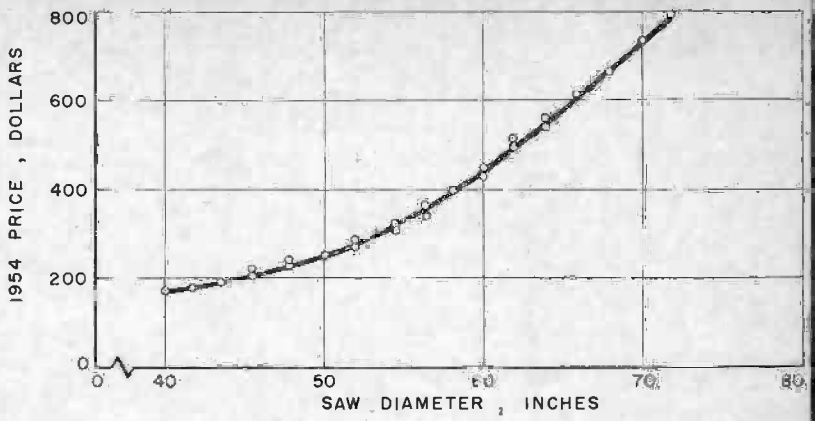


Moulders with motors and four heads

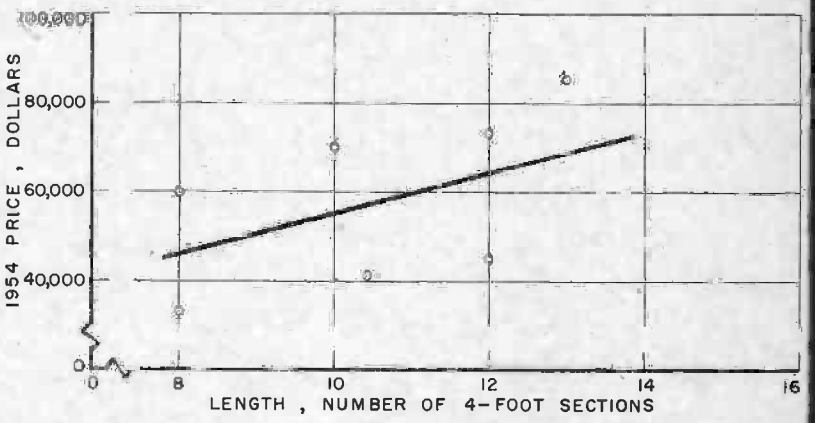


Glue spreaders with motors

Circular saws with bits and teeth



Veneer driers with fans conveyors motors starters



Price References for Wood-Industry Equipment

time and effort are saved
if information is easily found

MUCH INFORMATION ON PRICING OF INDUSTRIAL EQUIPMENT has been accumulated in the chemical industry. References especially pertinent to wood industries have been listed to help the cost estimator. Roman numerals following each equipment item relate to similarly numbered references.

References provide estimating means

References are shown by Roman numerals according to the following list:

I *Chemical Engineering Costs* (88) by O. T. Zimmerman and I. Lavine.
II *Factory Management and Maintenance* (periodical).
III *Chemical Engineering.*
IV *Data and Methods for Cost Estimation* (Part I). (Collection of articles from *Chemical Engineering.*)
V *Chemical Engineering Economics* by Chaplin Tyler.
VI *Chemical Engineering Cost Estimation* (2) by Robert S. Aries and Robert D. Newton.
VII *Data and Methods for Cost Estimation* (Part III).
VIII *Chemical Engineering Cost Quarterly.*
IX *Data and Methods for Cost Estimation* (Part II).

Attrition mills	*I, page 157
Agitators and portable electric mixers	VIII, vol. 1, no. 2, page 44
Agitators, propeller type	VIII, vol. 3, no. 3, page 74
Blowers and fans	I, page 210; IX, page 20
Boilers; steam, small, gas and oil-fired	VIII, vol. 2, no. 1, page 16; IV, page 62
Bucket elevators	VIII, vol. 2, no. 1, page 9

* Roman numerals refer to references listed above.

Life Expectancies for Wood-Industries Equipment

ability to forecast equipment life
necessary for taxes or replacement

IN THE FOLLOWING TABULATIONS ARE PRESENTED BUREAU OF Internal Revenue (47) estimates of average useful life—for depreciable items commonly occurring in wood industries plants.

TABLE 21. AVERAGE USEFUL LIFE OF ITEMS IN WOOD INDUSTRIES PLANTS

Item	*Useful years*	*Item*	*Useful years*
Buildings and Building Equipment			
Factories, not including service equipment	50	Lighting system	
Warehouses, not including service equipment	75	Conduits and fittings	50
Fire equipment		Wiring	20
Fire alarm systems	25	Fixtures	15
Movable equipment	20	Plumbing	20-25
Sprinkler system	50	Machine shop machinery and equipment	17
		Tools, small, misc.	5
Process Machinery and Equipment			
Logging			
Arches	10	Power shovels	15
Camp cars	15	Rails and fittings	25
Camp equipment	10	Skidders	20
Caterpillar tractors	5	Trucks	
Log cars	15	Heavy	5
Log loaders	20	Light	2
Lumber mill		Conveyor chains	10
Bandmills	25	Dry kilns	
Boom, log	15	Blowers	20
Burners	15	Brick and concrete	40
Circular mills		Frame	20
Portable, complete	15	Steam coils and pipe	20
Stationary	25	Edgers	25

Lumber mill (cont'd)

Fire protection equipment	10
Hogs	10
Live rolls	25
Log carriage and feed	20
Lumber buggies	10
Lumber docks, open	12
Niggers and turners	20
Plumbing	25
Saw filing machinery	15
Sprinkler systems	40
Surfacers	20
Trimmers	25

Lumber remanufacturing and woodworking plants

Barkers	
Drum	14
Hand	22
Bending machines	20
Bins, dry materials	
Concrete, chip storage	33
Steel	25
Wood	28
Blowers, chip and refuse systems	14
Boring machines	20
Buggies, lumber	13
Burners, refuse	20
Carriages for resaw	18
Carriers, lumber	17
Chests, wet stock	
Concrete	33
Steel	25
Chippers	17
Cleating machines	10
Clippers, veneer	20
Collectors, dust	25
Conveyors, lumber, slab, and sawdust	20
Cookers	20
Cranes, traveling	
Heavy, electric	25
Light, hand-operated	17
Cylinders, creosoting	20
Digesters, wood stock	
Indirect cooking	25
Rotary	20
Vertical, stationary	28
Dowel making and setting machines	17
Edgers	18
Elevators, bucket, chips	20
Filing machines	17
Flooring machines	20
Grinders, ground-wood pulp	22
Hogs	14
Hoists and cranes	20
Jointers	20
Kilns, dry	20
Lathes	20
Mill machines, shingle	20
Molders	20
Mortisers	20
Nailing machines	20
Planers, woodwork	20
Presses	20
Sanders	18
Screens, flat	18
Shapers	20
Tenoning machines	20
Trimmers, box	18

Auxiliary and Service Equipment

Electrical equipment

Controllers	15
Generators and motors	
Large units, above 3,000 kva	28
1,000-3,000 kva	25
50 to 1,000 kva	
High-speed, direct-connected	20
High-speed, belt-driven	22
Low-speed, direct con	25
Low-speed, belt driven	22
Units below 50 hp,	
Alternating current	17
Direct current	14
Switchboards and wiring	20
Transformers	25

Steam power and generating equipment

Complete plant	20-25

Motor and other vehicles

Automobiles	2-5
Tractors	6
Trucks	
Outside use	
Electric	10
Gas	
Light	4
Medium	6
Heavy	8
Inside use	15

Piping, pumps, and tanks

Pipes	
Cast iron	50-100
Steel	30-40
Wrought iron	50-75
Pumps	
Centrifugal and rotary	20
Gear driven	22
Tanks	
Concrete	50
Steel	40
Wood	20

Equipment Cost Indexes

by knowing rate of
change in equipment prices
we gain accuracy in estimating costs

THERE ARE THREE INDEXES THAT APPEAR MOST USEFUL FOR adjusting equipment cost data for wood industries. They are the U. S. Bureau of Labor Statistics *Wholesale (Primary Market) Price Index,* the Marshall and Stevens, Inc., cost indexes, and the U. S. Bureau of Labor Statistics labor and materials indexes. In the first listed of the three general indexes, the [BLS] *Wholesale Price Index,* commodity group 11, is recommended for general use for the following reasons:

- It is a composite index including a wide range of equipment items.
- It is prepared monthly and is, therefore, current.
- Prices are net of standard discounts and generally represent prices at which transactions have been actually completed f.o.b. factory, rather than formal asking prices.
- Since this index generally falls below the Labor and Materials index and above the Marshall and Stevens, Inc. index, it appears that the BLS wholesale price index might best be used for assessing changes in prices of equipment for wood industries (Figure 3).

No cost index, however, can be relied on for accurate correction of prices of *individual* equipment items. In practice, as many items as possible should be grouped together and prices for the respective years should be totaled before an index number is applied to the total cost to correct to current price.

The manner in which the BLS index may be used is shown by means of a hypothetical illustration.

Assume that the following list of equipment is needed, but prices are known only for the years indicated. It is desired to correct the total price for all equipment to prices in 1954:

Equipment	Known prices	
	1949	1954
	Dollars	*Dollars*
Chain saw		420
Sawmill	4,500	
Circular saw	325	
Edger		3,500
Cutoff saw	525	
Double surfacer	12,500	
Gang rip saw	2,700	
Moulder	11,700	
Double-end tenoner	22,000	
Single surfacer	6,000	
Lift truck	4,250	
Hog	3,500	
Total	68,000	3,920

Using the ratio between the BLS index for commodity group 11 for 1954 (124.6) and for 1949 (106.6) we calculate as follows:

$$68{,}000 \times \frac{124.6}{106.6} = \$79{,}482.00,$$

the corrected cost of equipment listed in the 1949 column.

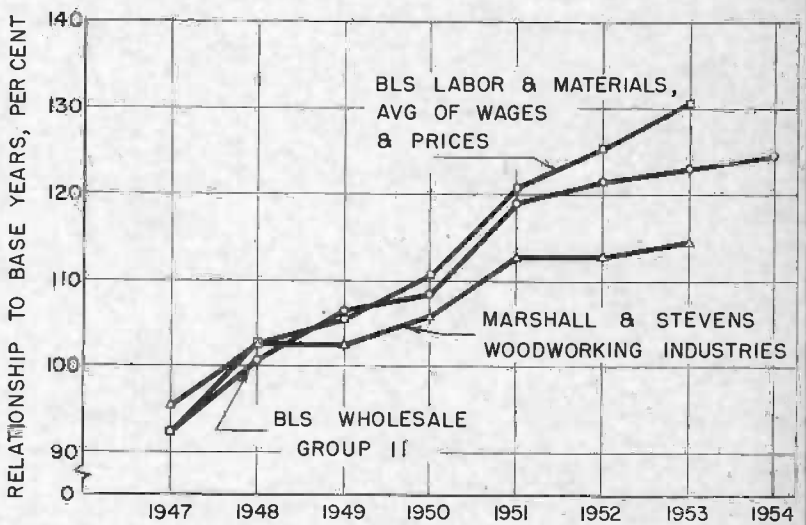


FIGURE 3. *Relationship of 3 cost indexes, with 1947-1949 costs as a basis for comparison*

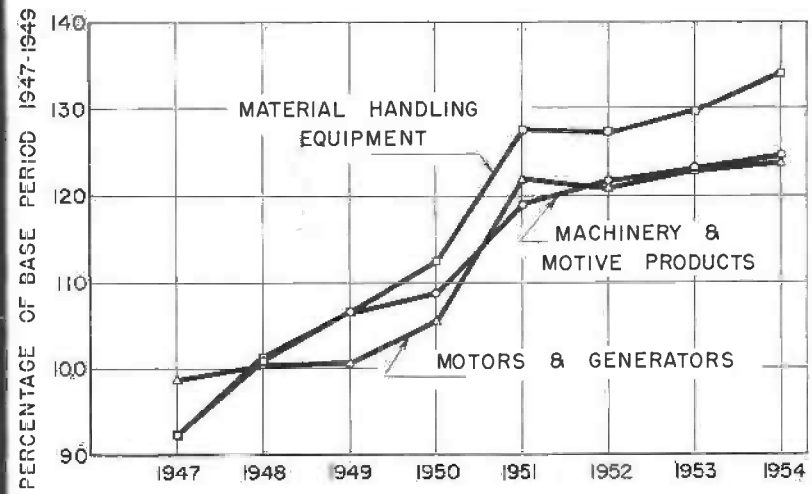


FIGURE 4. *Price movements of 3 classes of machinery in BLS group 11*

This cost ($79,482), plus the total known current cost in 1954 of the other two equipment items ($3,920) indicates a total cost for process equipment in 1954 of $83,402.00.

A summary description of each of the indexes most useful for wood industries follows, with sources for more complete information listed at the end of this section.

BLS wholesale price index

The wholesale price index prepared monthly by the Bureau of Labor Statistics is computed for a wide range of items, based on large-volume sales in the primary market, usually f.o.b. the factory where produced. Separate values are computed for 7 equipment subgroups in the general classification of machinery and motive products (2, 3):

Agricultural machinery and equipment (4)
Construction machinery and equipment
Metal-working machinery and equipment
General-purpose machinery and equipment
Miscellaneous machinery
Electrical machinery and equipment
Motor vehicles

No subgroup has been established specifically for wood industries equipment. Numerous equipment items commonly used in wood industries plants are included, however, within the subgroups comprising general-purpose machinery and equipment (code no. 11-4-0)

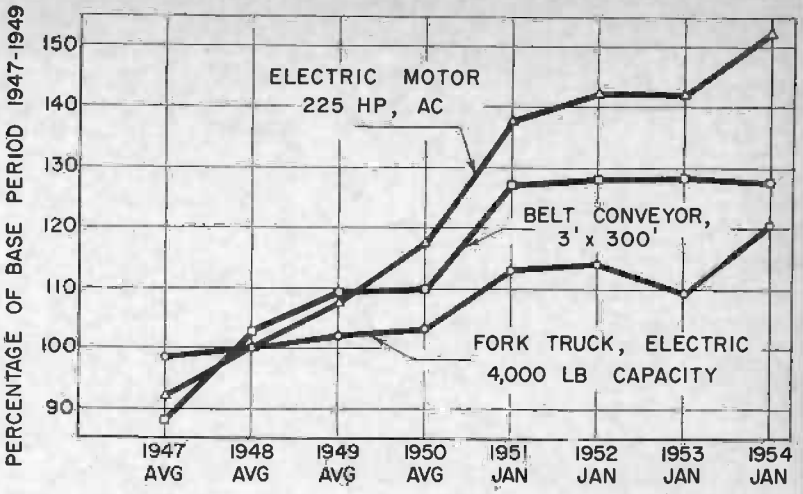


FIGURE 5. *Price movements of 3 specific equipment items in BLS group 11*

and electrical machinery and equipment (code no. 11-7-0). Nine product classes within these subgroups are particularly relevant:

Code No.	*Equipment class*
11-4-1	Pumps and compressors
11-4-3	Furnaces and ovens
11-4-4	Material-handling equipment
11-4-5	Mechanical power-transmission equipment
11-4-6	Mechanical scales
11-4-7	Fans and blowers
11-7-3	Motors and generators
11-7-4	Transformers and regulators
11-7-5	Switchgear and control equipment

Price relatives, but not actual prices, are published monthly for each of these equipment classes (Figures 4, 5).

The equipment prices that enter into the index are generally quoted f.o.b. factory. Electrical equipment prices, with few exceptions, are f.o.b. factory, freight allowed. The quotations represent prices charged by manufacturers variously to other equipment manufacturers, jobbers, dealers, and other users of large amounts. Prices are quoted net of standard discounts, and generally represent prices at which transactions actually have been completed, rather than formal asking prices. In a buyers' market, however, they may be somewhat above the prevailing level of going prices.

All index numbers and relatives computed for the BLS wholesale price index, as revised in 1952, use 1947-49 as a base period.

Marshall and Stevens equipment costs index

An index of equipment costs is issued quarterly and annually by Marshall and Stevens, Inc., in services sold by the company to clients for use primarily in appraisal work. The index also is published in summary form in the annual construction costs issue of the *Engineering News-Record*.

Separate indexes are prepared for 47 industries. Each index traces composite change in the costs of an entire plant, including installed cost of equipment and items such as services, furniture and fixtures, and hand tools combined in proportion to their average occurrence in that industry. Excluded are the costs of land, buildings, and transportation equipment other than intraplant transportation.

Most useful for estimating equipment cost changes in the wood industries are the composite index for process industries and the specific index for the woodworking industry.

Labor and materials index

In addition to the wholesale price index, the U.S. Bureau of Labor Statistics prepares an index based on costs of labor and materials. One convenient source for this latter index is the *Chemical Engineering Cost Quarterly.*

The index is based on the premise that:

> "The cost of process equipment is due in part to labor costs and in part to material costs. As these two change, the cost of equipment changes correspondingly. Therefore, if it is known how labor and material costs have changed since the cost data were compiled, and the percentage of the equipment cost due to labor and materials, it is possible to prepare cost indexes which enable one to bring costs up to date (68).

Furthermore:

> "In the absence of more exact information, it is probably sufficiently accurate, in the case of process equipment, to assume that materials and labor each account for about 50 per cent of the cost where ordinary materials of construction are employed and about 67 per cent and 33 per cent, respectively, for equipment of special materials of construction. Actually, the labor and material indexes do not differ greatly, and an appreciable difference in the assumed proportion of cost due to labor and materials would not introduce a great error" (1).

Tri-index comparison

A comparison of the three types of equipment cost indexes is shown in Table 22 for the period from 1947 through 1953. To facilitate comparison, the Marshall and Stevens, Inc., indexes have been converted from a 1926 base to the 1947-49 base used for BLS indexes. Conversion factors used were: For the Process Industries index, divide the data based on 1926 by 1.577; for the Woodworking Industries index, divide the data based on 1926 by 1.568.

Close correspondence will be noted among the three BLS wholesale price index series shown. The combined labor-and-materials index runs consistently higher than the wholesale price index, in consequence of the relatively greater advances made in hourly wage rates in the durable-goods industries. Evidence is lacking, however,

TABLE 22. EQUIPMENT COST INDEXES
(1947-49 = 100)

Year	BLS wholesale price*			Marshall and Stevens, Inc.		Labor and materials		
	Group 11	Group 11-4-0	Group 11-7-0	Process industries average	Wood-working industries	Wages†	Prices‡	Wages + price†
1947	92.5	92.6	96.1	94.6	95.4	92.9	91.3	92.1
1948	100.9	100.9	100.7	102.6	102.3	101.3	103.9	102.6
1949	106.6	106.5	103.2	102.6	102.3	105.7	104.8	105.2
1950	108.6	110.3	106.4	105.7	105.5	110.5	110.3	110.4
1951	119.0	123.5	121.9	112.9	112.6	120.1	121.0	120.6
1952	121.5	122.6	120.3	113.2	112.9	127.2	123.0	125.1
1953	123.0	125.3	123.6	114.4	114.1	134.5	126.9	130.7
1954	124.6	128.2	126.2			138.1		

* Group 11, machinery and motive products; group 11-4-0, general-purpose machinery and equipment; group 11-7-0, electrical machinery and equipment.
† BLS index of average hourly wages in the durables industries.
‡ BLS index of metals and metals products prices.

TABLE 23. PRICE MOVEMENTS OF NINE CLASSES OF MACHINERY WITHIN BLS GROUP 11 PARTICULARLY RELEVANT TO THE WOOD INDUSTRIES, AS SHOWN BY BLS WHOLESALE (primary market) PRICE INDEXES, 1947 to 1954 (1947-1949=100)

Year	Group 11 machinery and motive products	11-4-1 pumps and compressors	11-4-3 furnaces and ovens	11-4-4 material handling equipment	11-4-5 mech power transmission equipment	11-4-6 industrial scales	11-4-7 fans and blowers	11-7-3 motors and generators	11-7-4 transformers	11-7-5 switchgear and control equipment
1947	92.5	92.1	92.4	92.3	90.5	96.9	88.7	98.9	97.2	95.2
1948	100.9	100.4	99.8	101.1	101.9	101.4	97.9	100.5	100.3	100.3
1949	106.6	107.5	107.7	106.6	107.5	101.8	113.5	100.6	102.5	104.6
1950	108.6	109.3	113.1	112.3	110.7	104.4	121.4	105.4	104.0	112.7
1951	119.0	123.3	128.7	127.3	125.9	117.0	141.7	121.8	116.8	131.6
1952	121.5	123.2	129.2	127.1	124.6	119.0	137.1	120.9	117.1	127.4
1953	123.0	129.0	130.5	129.8	128.7	129.0	138.3	122.8	124.2	130.2
1954	124.6	131.8	135.8	134.0	133.1	134.9	143.7	123.3	128.1	135.1

to prove that wood-industries equipment price changes are reflected more accurately by this index than by the wholesale price index for commodity group 11. Use of the latter is recommended until such evidence is forthcoming.

Marshall and Stevens, Inc. indexes have been consistently below BLS equipment price indexes, by substantial amounts, since 1950. This difference is related in part to the fact that Marshall and Stevens, Inc. indexes reflect not only changes in process-equipment costs, but in costs of service facilities as well. Furthermore, these are delivered and installed costs. These indexes, therefore, may be used most appropriately in correcting *installed* costs of process and auxiliary equipment, including services, for changes in price levels. Quoted prices at the factory may be adjusted more accurately using the BLS wholesale price indexes.

The Marshall and Stevens, Inc. equipment cost index for woodworking industries, it should be noted, follows closely the composite index for nine process industries. This circumstance gives support to the view that equipment prices for the wood industries adhere to the general pattern of equipment price movements and that satisfactory results, therefore, may be expected from the use of general equipment indexes in correcting cost data for these specific industries.

None of the index numbers discussed may be relied upon for accurate correction of the prices of individual equipment items. In Table 23, price movements of nine specific classes of machinery and equipment are compared, 1947 through 1953, using BLS wholesale price indexes. Parallelism—often close—will be noted; but significant—occasionally wide—disparities also will be observed. When comparisons of price changes for individual items within equipment classes are made, the tendency to differ becomes even more pronounced, as shown in Table 24 and Figure 5.

References for three cost indexes

For detailed description of the BLS wholesale price indexes, consult the following publications of the U.S. Department of Labor:

"A description of the revised wholesale price index," *Monthly Labor Review,* February 1952.

Key to groups, subgroups, and product classes of wholesale price index, January 1952.

Wholesale price index: specifications and code numbers for individual commodities, 1947-1951. Issued February 1952. Also specification changes issued subsequently at irregular intervals.

For BLS wholesale price indexes, price relatives and actual prices, for years prior to 1952, see the following publications of the U.S. Department of Labor:

Wholesale price index: indexes for groups, subgroups, and product classes of commodities, 1947-1951. Issued February 1952.

Wholesale price index: prices and price relatives for individual commodities in the revised index, 1947-50. Issued February 1952.

Wholesale price index: prices and price relatives for individual commodities in the revised index, January-November 1951. Issued February 1952.

TABLE 24. PRICE MOVEMENTS FOR NINE SPECIFIC EQUIPMENT ITEMS USED IN THE WOOD INDUSTRIES, 1947-1954, AS SHOWN BY BLS WHOLESALE PRICE RELATIVES

(1947-49 = 100)

	10-72-11	11-41-41	11-44-21	11-44-51	11-45-01	11-47-01	11-73-35	11-74-11	11-75-62
1947 Avg.	93.4	91.0	88.0	98.2	93.0	87.2	92.6	98.0	95.4
1948 Avg.	104.3	101.5	102.8	99.9	100.7	98.0	100.0	100.2	99.9
1949 Avg.	102.3	107.6	109.2	101.9	106.3	114.8	107.4	101.8	104.6
1950 Avg.	104.0	111.4	109.7	103.1	111.6	124.3	117.4	104.6	114.5
1951 Jan.	125.3	127.1	126.7	112.6	128.9	144.6	136.8	120.1	132.3
1952 Jan.	125.4	126.8	127.2	113.9	128.9	141.5	141.6	120.1	132.1
1953 Jan.	117.6	126.8	127.5	109.2	124.5	137.6	141.6	121.3	131.4
1954 Jan.	113.2	136.5	127.0	120.1	133.9	143.8	152.0	130.5	137.4

* Identification of equipment items:

10-72-11 Bulk storage tank, 4,960-5,000 gal, above-ground, horizontal, ¼-inch heads and shell, standard fittings, painted, manufacturer to user, f.o.b. factory.
11-41-41 Stationary air compressor, electric horizontal, double-acting, 100 hp, manufacturer to user, f.o.b. factory.
11-44-21 Belt conveyor, 36 inches wide, 300 feet long, manufacturer to user, f.o.b. factory.
11-44-51 Fork truck, 4,000-lb capacity, electric, manufacturer to user, f.o.b. plant.
11-45-01 Speed reducer, class I, worm or spiral level gear, manufacturer to user, f.o.b. factory, freight allowed.
11-47-01 Centrifugal blower, SWSI, arrangement 3, 36-inch wheel diam, manufacturer to user, f.o.b. factory.
11-73-35 Alternating current synchronous motor, 225 hp, manufacturer to original equipment manufacturer, f.o.b. factory, freight allowed.
11-74-11 Distribution transformer, 15 KVA, manufacturer to user, f.o.b. factory, freight allowed.
11-75-62 Motor control, AC, 25-30 hp, 220 V, manufacturer to original equipment manufacturer or distributor, f.o.b. factory, freight allowed.

For BLS current wholesale price indexes, price relatives and actual prices, as issued monthly since January 1952, see the following monthly publications of the U.S. Department of Labor:

Survey of Current Business. Wholesale price indexes are reported, in convenient form, for all commodity groups and major subgroups, but not for classes within subgroups or for individual commodities.

Wholesale (Primary Market) price index, news release. Wholesale price indexes are reported for all commodity groups, subgroups, and product classes, but not in general for individual commodities.

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additional information will be valuable to some estimators

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