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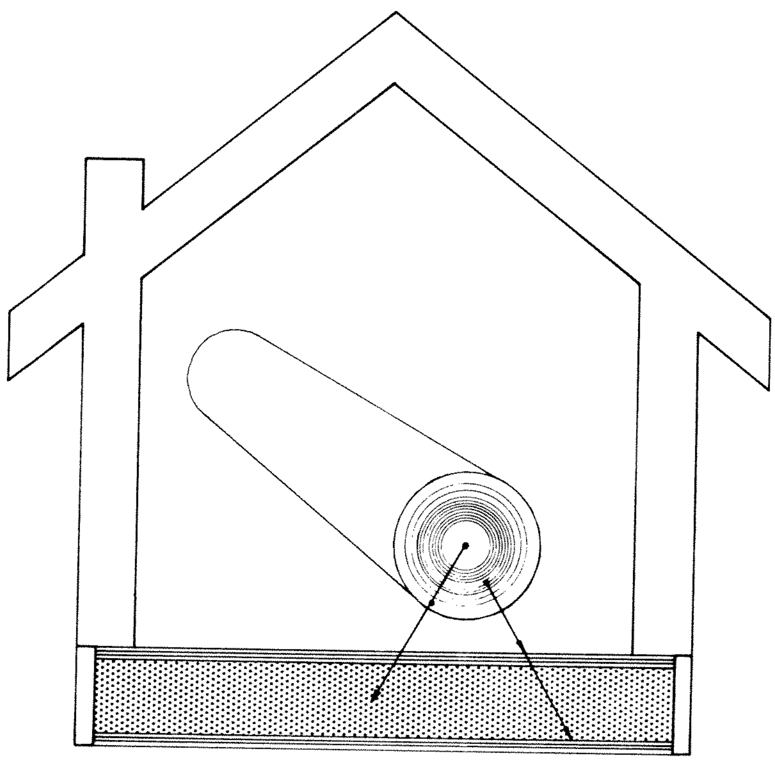
Economic Feasibility of Manufacturing COM-PLY® Floor Joists

Gerald A. Koenigshof



COM-PLY® Report 26

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Economic Feasibility of Manufacturing

COM-PLY® Floor Joists

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Cooperative Research by
U.S. Department of Agriculture, Forest Service
Southeastern Forest Experiment Station
and
U.S. Department of Housing and Urban Development
Division of Energy, Building Technology
and Standards

Preface

This report is one of a series on the possibilities of producing house framing and structural panels with particleboard cores and veneer facings. These COM-PLY or composite materials were designed to be used interchangeably with conventional lumber and plywood in housing. Research on structural framing was initially limited to COM-PLY studs but has now been extended to include larger members such as floor joists and roof truss framing.

In 1973, the home-building industry faced a shortage of lumber and plywood and consequent rising prices. Both industry and government recognized that this was not a temporary problem and that long-range plans for better using the Nation's available forest resources would be necessary.

The Forest Service of the U.S. Department of Agriculture and the U.S. Department of Housing and Urban Development accelerated cooperative research on ways to utilize the whole tree. They concentrated on composite wood products made with flakeboard and veneer as a way of using not only more of the tree stem, but also using less desirable trees and a greater variety of tree species than would be used for conventional wood products. The flakeboard which constitutes a large portion of COM-PLY studs and joists is made from flaked-up wood that comes from forest residues, mill residues, or low-quality timber. Thus, such composites could greatly increase the amount of lumber and plywood available for residential construction, our major use of wood, without eroding the Nation's timber supply.

Research on composite wall and floor framing was performed by the Wood Products Research Unit, Southeastern Forest Experiment Station, Athens, Georgia. The American Plywood Association cooperated in these studies by designing and testing composite panel products that are interchangeable with plywood. Both types of products have been incorporated in demonstration houses.

Included in this series will be reports on structural properties, durability, dimensional stability, strength, and stiffness of composite studs and joists. Other reports will describe the overall project, compare the strength of composite and solid wood lumber, suggest performance standards for composite lumber, and provide construction details on houses incorporating such lumber. Still others will explore the economic feasibility of manufacturing composite lumber and panels and estimate the amount and quality of veneer available from southern pines. These reports, called the COM-PLY series, will be available from the Southeastern Forest Experiment Station and the U.S. Department of Housing and Urban Development.

Contents

ABSTRACT

Investments, production costs, and probable returns for manufacture of COM-PLY floor joists are presented. The report shows that it is possible to obtain a 25 percent or greater after-tax internal rate of return on the investment.

Keywords: Manufacturing costs, lumber cost, economics of lumber manufacture, cost analysis, floor framing costs.

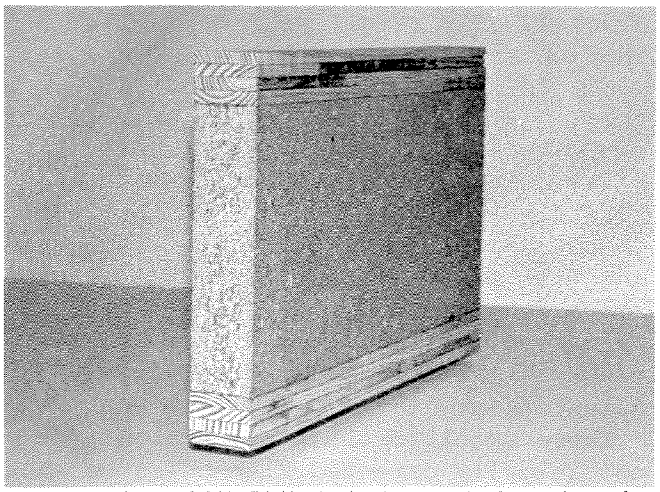

Figure 1.--COM-PLY joist used for framing floors of houses.

Cooperative research by the Forest Service, U.S. Department of Agriculture, and the U.S. Department of Housing and Urban Development has led to development of a new composite lumber product. The new product, called COM-PLY, has potential for significantly increasing our supply of framing for building houses. Made with a structural sandwich construction of 1.5-in-thick flakeboard core placed between 0.25-in-thick layers of solid wood veneers (fig. 1), COM-PLY floor joists are intended to be direct substitutes for sawed lumber now widely used for floor framing (fig. 2).

COM-PLY joists need to be priced competitively with sawed lumber so builders will have incentive to purchase them. Floor joist sizes considered for manufacture in this study are nominal 2 x 8's and 2 x 10's. The only lengths considered are 12 ft for 2 x 8's and 14 ft for 2 x 10's since these sizes are the most commonly used by builders; however, COM-PLY joists can be manufactured in virtually any size that is practical to handle and ship to the job site.

Potential manufacturers want to know how much it will cost to manufacture

Figure 2.--COM-PLY joists being installed in the floor of a house in Marietta, Georgia.

COM-PLY joists. They also want to know if a COM-PLY lumber factory would be a profitable investment--one that would have a greater rate of return on the investment than a sawmill. This report presents estimates on the amount of investment required to build a flakeboard, veneer, and joist-laminating factory; the annual sales and cost of manufacturing COM-PLY joists and the operating cash flow; and the annual net cash flow and internal rate of return.

Any financial feasibility study is only as good as the assumptions upon which it is based. In this study, we assumed that the factory would be located in the South and would use southern pine and hardwoods. Cost assumptions are based on representative industry averages and therefore do not reflect values for any specific company. Much detail has been included in this report to provide guidelines for readers who want to make their own analysis.

Results presented in the report do not guarantee that any firm can profitably manufacture COM-PLY joists--profitability depends on competent managerial skills, market demand, production efficiency, and other business factors. The results strongly indicate that it is economically feasible to manufacture COM-PLY joists. Although a specific firm's price, cost assumptions, and quantity may vary from those assumed in this report, minor variances would not affect the overall conclusions reported. Companies contemplating the manufacture of COM-PLY joists should substitute their own local cost estimates in a similar analysis to check economic feasibility for their particular location.

Financial Feasibility Analysis

Process Used for Manufacture

COM-PLY joists are 1-1/2 x 7-1/4 or 1-1/2 x 9-1/4 in. in cross section and serve as substitutes for 2 x 8 or 2 x 10 sawed joists in framing floors of houses. Unpublished research by Koenigshof and J. E. Duff (Athens, Ga.) showed that by using flakes in the coreboard oriented lengthwise of the COM-PLY joist greatly increased joist strength, stiffness, and fire resistance. Approximately 65 percent of the wood particles in the core should be oriented flakes. The remaining 35 percent of the particles can have a geometry like that used in conventional particleboard underlayments (typically, ring-flaked planer shavings). The flakes are made by flaking veneer peeler cores or other roundwood in a drum-type flaker. The flaker knives are set to cut ribbons of wood 1-1/4 to 3-1/4 in. wide and 0.02 to 0.03 in. thick. The ribbons of wood are broken into flakes of an average width of 0.25 ± 0.125 in. during the flaking process. The result will be a flake that on the average will be 1/4 in. wide, 2-1/4 in. long, and 1/40 in. thick. Ribbons of wood from the flaker can be passed through a hammermill with a large-size screen to break the ribbon into flakes 1/4 in. wide. Wider flakes cannot be used because they tend to curl and will not be uniformly coated with resin during blending. However, length is not critical as long as the length-to-width ratio results in effective orientation.

These specifications are typical for mechanically oriented flakeboard cores. However, research by T. M. Maloney at Washington State University, Pullman, Wash., and by Thomas E. Peters with Morrison-Knudsen, Inc., Boise, Idaho, shows that flakeboards made with ring-flaked particles and Douglas-fir planer shavings have strength and stiffness properties approaching flakeboard with drum-cut flakes when the particles are electrically oriented. Therefore, quite a wide variety of flakes can be used in COM-PLY joists provided that the proper orientation equipment is used to achieve effective particle alignment.

Fine particles that are considered dust or flour and pass through a 30- to 40-mesh screen should be removed as completely as possible from the wood supply. Fine particles retained on a 20- to 40-mesh screen, preferably a 12 to 14 mesh, can make up 15 to 20 percent of the wood in the particleboard. Bark particles can constitute up to 5 percent for fiberous barks such as yellow-poplar. Moisture content of the wood particles before blending should not exceed 6 percent of the ovendry weight of the wood.

To keep the weight of the joist reasonably low, the species of wood can be 50 to 100 percent medium-to-dense softwoods such as southern pine or Douglas-fir; 35 to 50 percent low-to-medium dense hardwoods such as yellow-poplar, sweetgum, or sycamore; and, not more than 15 percent dense hardwoods such as oak, hickory, or beech. Any combination of species can be used provided that the joist will pass the Performance Standards[1] for COM-PLY floor joist. COM-PLY joist made with veneers of oak, sweetgum, yellow-poplar, southern pine, and combinations of these woods have been fabricated and tested for strength and stiffness performance and the results were satisfactory for use. The weighted average dry density of the wood supply used in this study was 28.82 lb/ft^3 and the specific gravity was 0.462.

The flakeboard core can have a specific gravity of 0.6 $\pm$ 5 percent or density of 37.44 $\pm$ 5 percent lb/ft^3. The board can be homogenous or three layered. If homogenous, the resin content will be 6 percent phenolic solids based on the ovendry weight of the wood and the wax content, 0.5 percent solids. If three layered, the resin content will be 6.5 percent phenolic solids in the face layers and 5.5 percent in the inner layer; the wax content, 0.6 percent solids in the face layers and 0.4 percent in the inner layer. For three-layered board, most of the wood fines can be in the face layers, constituting 50 percent of the board thickness. The three-layered board is preferable to the homogenous board.

The internal bond of the board should be more than 100 lb/in^2. Thickness swelling cannot exceed 8 percent after a 24-hour water soak; wax content can be increased to decrease thickness swelling. Phenolic resin must be catalyzed to cure in 10 to 11 minutes when the platen temperature is 400° F for boards 1-1/2 in. thick. Resin in the face layers need not be catalyzed.

The flakeboard core is made on a standard multiplaten hot-press typically used to make commercial particleboard. The processes of manufacturing particleboard are well known and will not be repeated here. However, the press line must accommodate the thick mat required for 1-1/2-in-thick board. The daylight opening of the press must be large enough for the thick board; a prepress to reduce mat thickness is also essential.

To produce oriented flakes in the core, the forming machine should have mechanical- or electrical-flake orientating capability. The flakes should be oriented with their lengthwise dimension parallel to the lengthwise dimension of the flakeboard. The mat can be pressed to a board thickness of 1-1/2 in. by using stops or other means of controlling thickness on the particleboard press. The board surfaces should not be sanded after manufacture.

Veneer, 1-1/4 in. thick, is rotary-cut from southern pine, yellow-poplar, oak, and mixed hardwood peeler blocks and dried to an average of 3 percent moisture content. Other thicknesses of veneer or another species mix can be used by manufacturers if they find them more practical for their particular use. There was no unreasonable amount of spin-out, splitout, or other veneer peeling difficulties experienced in production facilities that supplied 1/4-in-thick southern pine, yellow-poplar, sweetgum, and oak veneer to the Athens laboratory for technical research projects. Dense hardwood such as oak or hickory is assumed to constitute not more than 15 percent of the veneer volume. The choice of 15 percent was arbitrary, and the intent was to keep the weight of the product reasonably low but to still use some of the higher density woods that are in relatively abundant supply.

For this study, the veneer was clipped into sheets 2 to 2-1/2 ft wide by 8 ft long, then glued into panels on a standard plywood hot-press or on a particleboard press. For making 2 x 10 joists, the panels are five veneers

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[1] Duff, John E.; Koenigshof, Gerald A.; Wittenberg, Dick C. Performance standards for COM-PLY floor joists. Res. Pap. SE-192. COM-PLY Rep. 14. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station and Washington, DC: U.S. Department of Housing and Urban Development; 1978. 17 p.

thick; for 2 x 8 joists, four veneers thick. The panels are then scarfed or finger-jointed on each end and glued together to form a continuous ribbon of parallel-laminated veneer (PLV) lumber, which is crosscut into panel lengths equal to the length of lumber being made.

The veneers in PLV lumber are glued together with a phenolic adhesive identical to that used for making plywood. Adhesive is applied at a spread rate of 50 lb/M ft^2 of glueline. The glued panels are ripped into pieces 1-1/2 in. wide, called cords. The cords are beveled on two corners during ripping by a V-shaped cutterhead to provide eased-edge lumber. For this study, these cords were then glued to the edge of a flakeboard core in a lumber edge bonding machine with radio-frequency (RF) heating to form a piece of COM-PLY lumber. The cords cut from the PLV lumber are glued to the particleboard cores with phenol-resorcinol adhesive at a spread rate of 90 lb/M ft^2 of glueline. Glue should be spread on both mat surfaces to obtain the maximum quality bond.

General Requirements

This economic analysis assumes that construction of two COM-PLY factories was begun in 1979 at prevailing prices. Two factory sizes are considered: Case I is a factory that produces 169,712,000 board feet (fbm) per year and Case II, 91,282,000 fbm per year. For both cases it is assumed that 45 percent of production is 2 x 8-12 joists and 55 percent is 2 x 10-14 joists. The factories are assumed to operate 250 days per year, three shifts per day at an efficiency of 85 percent. Approximately 108 days would be for 2 x 8 production and 142 days for 2 x 10 production.

Investment

Land. The site selected for this analysis is located in the south-central United States and consists of 50 acres for Case I and 30 acres for Case II. Raw land is assumed to cost $6,000 per acre. The developed site, including amenities such as grading, drainage, settling pond, paving, fencing, rail spur, water supply, fire protection, sanitary facilities, and outside lighting, would cost $987,000 for Case I and $593,000 for Case II:

Item	Cost	
	Case I	Case II
Land @ $6,000/acre	$300,000	$180,000
Skimming and grading	60,000	36,000
Drainage and culverts	30,000	18,000
Settling pond	20,000	12,000
Rockfill (@ $5/$yd^3$)	57,000	35,000
Asphalt paving (@ $.60/$ft^2$)	48,000	29,000
Crushed rock (@ $7/$yd^3$)	21,000	12,600
Fencing (@ $10/ft)	59,000	35,400
RR spur track (@ $30/ft)	24,000	14,000
12-in. water service	36,000	22,000
12-in. underground sprinkler loop, hydrants, and hose stations	200,000	120,000
Domestic water service	2,000	1,000
Sanitary system	40,000	24,000
Effluent treatment	40,000	24,000
Outside lighting	50,000	30,000
Total	$987,000	$593,000

Buildings. The amount of building space required is:

Type of building	Square footage	
	Case I	Case II
Boilerhouse	4,800	2,880
Refining and drying	18,000	10,800
Flakeboard production	36,000	21,600
PLV green end	6,400	3,840
Veneer and PLV production	160,000	96,000
Laminating and finished warehouse	84,000	50,400
Chipper building	4,000	2,400
Electrical and hydraulic rooms	4,000	2,400
In-plant shops, lunchrooms, and offices	8,000	4,800
Total	325,200	195,120

Costs for all buildings (manufacturing plus office space) including slabs, footings, lighting, heating, sprinklers, and wall finishing are $4,260,000 for Case I and $2,649,800 for Case II:

Item	Unit cost/ft^2	Total cost	
		Case I	Case II
Prefab steel buildings (insulated and erected)	$7.00	$2,276,400	$1,365,840
Slabs and footings	3.00	975,600	585,360
Lighting	.80	260,160	156,000
Heating	.70	227,640	136,600
Inside sprinklers	.80	260,160	156,000
Office and labs (partitions and finishing)	--	60,000	50,000
General office (6,000 ft^2 outside of plant)	--	200,000	200,000
Total		$4,260,000	$2,649,800

Machinery and machinery foundations. Table 1 provides a detailed list of machinery, machinery installation, and machinery delivery cost. Machinery cost for Case I is $29,652,100 and for Case II, $19,658,700. The cost of machinery foundations is shown in table 2.

Cash. In this analysis, we assume that the equivalent of 2 months' payroll is sufficient cash to meet the payroll, provide petty cash, and otherwise meet cash needs to operate the business. In a later section, we show that the annual labor cost in 1979 would be $3,192,500 for Case I and $2,197,500 for Case II if the plant were operating at full capacity. Thus, cash required was assumed to be $532,083 for Case I and $366,250 for Case II.

Inventory. Investment is required for raw materials, for materials being processed, and for finished products awaiting shipment. In this study, one-twelfth of the annual cost of raw materials for a factory operating at full capacity was assumed to be sufficient to cover all requirements for inventory investment. It will be shown that the total annual cost of raw materials for Case I is $15,258,714 and $8,396,788 for Case II. Therefore, the investment required for inventory is $1,271,560 for Case I and $699,732 for Case II.

Accounts receivable. A considerable investment is required to cover sales to customers who do not pay immediately upon delivery. These accounts receivable may typically be paid in 10 to 60 days. The average collection period was assumed to be 40 days. Investment to cover accounts receivable was considered to be 40 days of sales. Sales will vary with the unit price received for products and the quantity produced each year.

In 1979 the average price for No. 2 southern pine KD 2 x 8-12's was $282 per thousand board feet (M bm) and for 2 x 10-14's, $352/M bm.[2] However, these prices were above the long-term trend prices because of strong demand for lumber in housing during 1979. The trend prices are $270/M bm for 2 x 8-12's and $317/M bm for 2 x 10-14's. Trend prices are used in economic studies to strike an average for an investment period. The use of current prices that are above the trend at the time of making an analysis would be misleading because they would be artificially high, and a higher return on investment would be shown than is actually achievable; the use of current prices that are below the trend would show a lower return on the investment than is actual, and the investment would be rejected when it would be quite feasible.

Based on trend prices, the sales for this study are:

Joist type	Annual M bm production		Price/M bm		Annual sales
			CASE I		
2 x 8-12	76,370.4	x	$270	=	$20,620,000
2 x 10-14	93,341.6	x	317	=	29,589,300
Total					$50,209,300
			CASE II		
2 x 8-12	41,076.9	x	$270	=	$11,090,750
2 x 10-14	50,205.0	x	317	=	15,915,000
Total					$27,005,750

The accounts receivable working capital for 40 days of sales is $5,502,387 for Case I and $2,959,534 for Case II.

Contingency and Engineering. A consulting engineering firm (Columbia Engineering, Eugene, Oreg.) estimated costs at $2 million for Case I and $1,500,000 for Case II. Investment contingency in the order of 10 percent of the site, building, machinery, and foundation was used by the consultants. The amount is $3,578,000 for Case I and $2,348,000 for Case II. Total engineering and contingency investment is $5,578,000 for Case I and $3,848,000 for Case II.

The investment costs and timing of investments are shown in table 3. The total investment for Case I is $48,612,500 and for Case II, $31,355,500.

[2] Evans, David S., ed. 1979 Random lengths yearbook. Eugene, OR: Random Lengths Publications, Inc.; 1979. 186 p.

Table 1.--Machinery and machinery cost for a COM-PLY joist factory

Machinery or associated item	Cost	
	Case I	Case II
	Dollars	
LOG PROCESSING EQUIPMENT		
Log storage and handling (mobile equipment)		
Log lift machines	251,000	251,000
Block lift machines	175,600	87,800
	426,600	338,800
Log debarking and bucking		
Log decks	360,000	180,000
Hydraulic loaders	108,000	54,000
Log conveyors	38,000	19,000
Crook saws	30,400	15,200
Log conveyors	31,600	15,800
Barker infeed	12,200	6,100
Barkers	242,600	121,300
Log conveyor (barker outfeed)	16,900	0
Log conveyors (to sorting decks)	58,600	29,300
Log sorting deck	75,900	0
Transfer decks	155,000	77,500
Log conveyors	34,000	17,000
Block saws	94,000	47,000
Block conveyor (at saws)	20,000	10,000
Block pockets (residual)	12,000	12,000
Residual block transfer	40,000	0
Block conveyor	12,600	0
Block conveyor with kickers	16,000	8,000
Block pockets	16,000	8,000
	1,373,800	620,200

Continued

Table 1.--Machinery and machinery cost for a COM-PLY joist factory--Continued

Machinery or associated item	Cost Case I	Cost Case II
	Dollars	
Chipping and chip handling		
Residual log conveyor	17,500	0
Residual log transfer	27,600	0
Chipper feed conveyor	23,700	23,700
84-in. whole-log chipper	35,000	35,000
Chip screen	10,500	9,000
Chipper discharge conveyor	9,000	9,000
Chip conveyor to surge bin	31,900	27,000
Chip surge bin	15,000	15,000
HP pneumatic system (chips to storage)	25,000	25,000
Overs and fines conveyor (to hog fuel)	11,000	11,000
Lily pad conveyor and saws	10,000	5,000
Lily pad conveyors (gathering)	34,400	5,000
Lily pad chipper feed conveyor	6,000	6,000
Lily pad chipper outfeed	6,800	6,800
Metal detector	5,600	5,600
Lily pad chipper	15,000	15,000
	284,000	198,100
Waste conveyors and hog		
Waste conveyor under #1 barker	40,400	0
Waste conveyor under #2 barker	25,000	25,000
Waste conveyor under #1 transfer	19,200	0
Waste conveyor under #2 transfer	19,200	19,200
Waste conveyor under #1 sawline	29,800	0
Waste conveyor under #2 sawline	26,000	26,000
Waste gathering cross conveyor	31,900	26,000
Hog feed conveyor	22,800	22,800
Hammer hog (#55)	38,700	38,700
Hog discharge conveyor	14,000	14,000
HP pneumatic system to fuel pile	30,000	25,000
Metal detector	5,600	5,600
	302,600	202,300

Continued

Table 1.--Machinery and machinery cost for a COM-PLY joist factory--Continued

Machinery or associated item	Cost	
	Case I	Case II
	Dollars	
Steaming vats	750,000	400,000
Control and electrical rooms, platforms, walkways, etc.	140,000	90,000
VENEER AND PLV EQUIPMENT		
Green-veneer production		
Log decks, Lathe chargers, Lathes (#277), Trash gate, Veneer tray (short coupled), Clipper infeed table, Veneer chain, Lathe and tray drives, Trash return ->	1,040,000	520,000
Core conveyor and pockets	15,000	12,000
Clippers	66,000	33,000
Clipper controls	78,000	39,000
Automatic veneer stackers	120,000	60,000
Chipper feed conveyor	12,000	12,000
Veneer chipper	30,000	30,000
	1,361,000	706,000
Veneer drying		
Veneer dryers, Dryer feeders, Dryer outfeed, Veneer sorting tables, Moisture detectors ->	1,500,000	750,000

Continued

Table 1.--Machinery and machinery cost for a COM-PLY joist factory--Continued

Machinery or associated item	Cost	
	Case I	Case II
	Dollars	
PLV production		
Layup line and stack conveyors	100,000	75,000
Glue kitchen	25,000	25,000
Prepress, Press loaders, Hot-press[a] (6 ft x 8 ft -- 20 openings), Press unloaders ->	950,000	525,000
	1,075,000	625,000
Panel sawing and handling, chipping waste system, etc.		
Panel saws	110,000	110,000
Panel handling	40,000	40,000
Dry waste hog	15,000	15,000
Hog feed conveyor	8,000	8,000
LP hog pneumatic system	30,000	25,000
Chipper discharge conveyor	15,000	12,000
Chip metering bin	12,000	10,000
Chip screen	6,500	6,000
HP pneumatic system to chip pile	40,000	30,000
Fines and overs to hog fuel	30,000	25,000
Veneer carts	10,000	5,000
Resin bulk storage tanks	20,000	12,000
	336,500	298,000

Continued

Table 1.--Machinery and machinery cost for a COM-PLY joist factory--Continued

Machinery or associated item	Cost	
	Case I	Case II
	Dollars	
FLAKEBOARD EQUIPMENT		
Raw material receiving and handling		
Truck dump and hopper	90,000	90,000
Dump hopper discharge conveyor	20,000	20,000
Radial stacker	60,000	60,000
Chip reclaim hopper and conveyor	35,000	30,000
HP pneumatic system	80,000	60,000
	285,000	260,000
Refining and drying		
HP pneumatic system to refiner metering bin	50,000	35,000
Electromagnet	9,000	7,000
Flaker metering bin	60,000	40,000
Chutes and switch gates	10,000	6,500
Conveyors to refiners	36,000	24,000
Vibrating refiner feeders	24,000	16,000
Ring flakers	330,000	220,000
Roundwood infeed deck	30,000	30,000
Slasher table	50,000	50,000
Apron conveyors to refiners	50,000	35,000
Waste conveyor from slasher	15,000	15,000
Drum flakers	585,000	390,000
LP pneumatic system to dryer feed bins	180,000	120,000
Distributing conveyors to dryer feed bins	20,000	12,600
Flake dryer feed bins	90,000	60,000
Rotary drum dryers ("Heil" 125SD42)	498,500	300,000
Wood-fired dryer furnace	345,000	207,000
Dry fuel silo	80,000	50,000
Fuel refiner	8,000	6,000
Conveyor to fuel refiner	3,000	2,000
Fuel screen	5,000	3,000
Fuel metering bin	30,000	25,000
Conveyor to fuel metering bin	5,000	4,000
HP air system to burners	40,000	30,000
Dryer pneumatic system	306,500	185,000
Walkways, platforms, and support steel	75,000	40,000
	2,935,000	1,913,100

Continued

Table 1.--Machinery and machinery cost for a COM-PLY joist factory--Continued

Machinery or associated item	Cost	
	Case I	Case II
	Dollars	
Material classification and blending		
Fire dump conveyors	30,000	20,000
Classifying screens	84,600	45,000
Overs conveyor to hammermill	12,000	8,000
Hammermill	12,000	8,000
Conveyor to accepts conveyor	15,000	12,000
Fines gathering conveyor	8,000	6,000
HP air system (fines to fuel silo)	30,000	20,000
Flake conveyor to dry storage bin	97,000	80,000
Dry flake storage bin	95,000	90,000
Conveyors to blender metering bins	70,000	50,000
Blender metering bins	200,000	150,000
Electromagnets	18,000	12,000
Weigh belts	36,000	22,000
Weigh scales and instrumentation	35,000	35,000
Blenders	90,000	70,000
Resin and wax mixing system, instrumentation, pumps, and piping	80,000	60,000
Resin and wax bulk storage tanks	40,000	25,000
Conveyors-blenders to forming	40,000	40,000
Distribution conveyors over forming	26,000	26,000
Platforms, walkways, and structural steel	30,000	25,000
	1,048,600	804,000

Continued

Table 1.--Machinery and machinery cost for a COM-PLY joist factory--Continued

Machinery or associated item	Cost	
	Case I	Case II
	Dollars	
Flakeboard production line		
Forming machine and conveyor	500,000	400,000
Press[b]	2,525,000	1,950,000
Loader and unloader	340,000	240,000
Caul system, weight scales, board separator, and electrics	750,000	500,000
Cleanup screw	30,000	20,000
Mat saw pneumatics	20,000	15,000
Reject hopper with outfeed	40,000	25,000
Reject conveyor to bin	60,000	40,000
Reject bin with outfeed	20,000	20,000
Press exhaust hood and fans	15,000	12,000
Press pit cleanup system	6,000	5,000
Bypass stacker, feeder, skin and trim saws (including transfers and trim breakers)	230,000	180,000
Stacker and outfeed rolls	45,000	30,000
Trim conveyors	25,000	15,000
Trim hog	15,000	12,000
Hog trim blower (to fuel)	35,000	30,000
Saw pneumatic system	35,000	25,000
Support steel, walkways, etc.	40,000	25,000
Press stops	15,000	10,000
Aluminum cauls	150,000	80,000
Saw blades	10,000	6,000
Miscellaneous chutes and hoppers	30,000	20,000
	4,936,000	3,660,000

Continued

Table 1.--Machinery and machinery cost for a COM-PLY joist factory--Continued

Machinery or associated item	Cost: Case I	Cost: Case II
	Dollars	
FINGER JOINTING AND LAMINATING		
Finger jointing, gluing machinery, and tooling	488,300	244,200
PLV ripsaw	78,000	78,000
Flakeboard ripsaw	80,000	80,000
Panel feeders	80,000	60,000
Residual flakeboard gluer	92,000	92,000
Joist laminators	1,241,200	827,500
Engineering and research and development	72,000	72,000
Arbors and tooling (PLV)	26,000	26,000
Arbors and tooling (flakeboard)	29,000	29,000
Material handling conveyors	112,000	75,000
Offbearing and stacking	incl. above	incl. above
Waste conveyors	12,000	12,000
Waste hog	6,000	6,000
LP waste pneumatic system	80,000	75,000
HP pneumatic relay system	40,000	25,000
Glue kitchen	10,000	10,000
Resin storage tanks	20,000	15,000
	2,466,500	1,726,700
MISCELLANEOUS EQUIPMENT		
Boiler and fuel handling equipment		
Fuel stacking and reclaiming	100,000	100,000
Fuel conveyor system	150,000	150,000
250 lb/in^2 boiler (70,000 lb; 50,000 lb)	924,000	650,000
Air systems	200,000	130,000
Control	80,000	60,000
Pumps and piping	115,000	75,000
	1,569,000	1,165,000

Continued

Table 1.--Machinery and machinery cost for a COM-PLY joist factory--Continued

Machinery or associated item	Cost: Case I	Cost: Case II
	Dollars	
Auxiliary equipment		
Air compressors	90,000	50,000
Air receivers	20,000	10,000
Air dryers (instruments)	12,000	8,000
Forklifts and loaders	280,000	150,000
Propane tanks	Lease	Lease
Air-conditioning	50,000	30,000
Plumbing fixtures	10,000	8,000
Cooling tower	60,000	40,000
Condensate pumps and tanks	150,000	90,000
Truck scales	16,000	16,000
Knife-grinding and saw-filing equipment	50,000	35,000
Machine shop	30,000	25,000
Lab equipment	30,000	30,000
Maintenance equipment and small tools	100,000	80,000
Spare parts	100,000	60,000
Yard truck and sweeper	34,000	34,000
	1,032,000	666,000
Electrical equipment		
Log processing	136,000	82,000
Block conditioning	25,000	20,000
Veneer, PLV manufacturing	299,000	185,000
Chip and hog fuel receiving and storage	20,000	20,000
Refining and drying	293,000	180,000
Classification and blending	75,000	60,000
Flakeboard production	183,000	110,000
Finger jointing and laminating	99,000	65,000
Boiler and fuel handling	110,000	60,000
	1,240,000	782,000

Continued

Table 1.--Machinery and machinery cost for a COM-PLY joist factory--Continued

Machinery or associated item	Cost: Case I	Cost: Case II
	Dollars	
Piping equipment		
Owner-supplied major valves, pumps, and instrumentation	150,000	100,000
Pollution abatement		
Log debarking and bucking	12,000	8,000
Block conditioning	30,000	20,000
Veneer and PLV production	100,000	50,000
Chip and hog fuel receiving and storage	10,000	10,000
Refining and drying	150,000	100,000
Classification and blending	32,000	24,000
Flakeboard production	43,000	35,000
Finger jointing and laminating	40,000	25,000
Boiler and fuel handling	100,000	75,000
	517,000	347,000
EQUIPMENT INSTALLATION		
Mechanical		
Barking and bucking center	340,000	190,000
Block conditioning (incl. w/equipment)	0	0
Veneer and PLV manufacturing	427,000	230,000
Chip and hog fuel receiving and storage	28,500	28,500
Refining and drying	290,000	175,000
Classification and blending	108,000	100,000
Flakeboard production line	529,000	400,000
Finger jointing and laminating	364,000	220,000
Boiler and fuel handling	157,000	140,000
	2,243,500	1,483,500

Continued

Table 1.--Machinery and machinery cost for a COM-PLY joist factory--Continued

Machinery or associated item	Cost	
	Case I	Case II
	Dollars	
Piping		
Barking and bucking center	78,000	40,000
Block conditioning	50,000	30,000
Veneer and PLV manufacturing	171,000	103,000
Chip and hog fuel receiving and storage	12,000	12,000
Refining and drying	234,000	140,000
Classification and blending	70,000	60,000
Flakeboard production line	183,000	130,000
Finger jointing and laminating	50,000	30,000
Boiler	656,000	500,000
	1,504,000	1,045,000
Electrical		
Barking and bucking center	194,000	116,000
Block conditioning	53,000	35,000
Veneer and PLV manufacturing	427,000	256,000
Chip and hog fuel receiving and storage	34,000	34,000
Refining and drying	293,000	176,000
Classification and blending	100,000	80,000
Flakeboard production line	322,000	225,000
Finger jointing and laminating	172,000	120,000
Boiler and fuel handling	157,000	140,000
	1,752,000	1,182,000
Freight	424,000	296,000
Total	29,652,100	19,658,700

[a]Case I--2 presses; Case II--I press.

[b]Flakeboard press for: Case I, normal 5-1/2 ft x 24-1/2 ft--20 openings; Case II, normal 5-1/2 ft x 16-1/2 ft--16 openings.

Table 2.--Type of machinery foundation and foundation costs for Case I and Case II

Foundation item	Cost	
	Case I	Case II
	Dollars	
Log infeed decks	32,500	17,000
Log conveyors, debarker, and cutoff saws	60,000	30,000
Transfer decks	30,000	15,000
Block pockets and aprons	18,000	9,000
Block conditioning (incl. w/equipment)	0	0
Lathe infeed deck and apron	12,000	6,000
Charger, lathe, core transfer and pockets	45,000	25,000
Veneer chipper and feed conveyor foundation, pit and trench	13,500	11,000
Clipper and tray area	20,000	10,000
PLV press pits	25,000	12,500
Veneer dryers	28,000	14,000
Misc. trenches, pits and foundations, pneumatic systems, screens, etc.	16,000	8,000
Truck dump, hopper, ramp, footings, and pit	36,000	36,000
Radial stacker and outside chip storage slab	67,500	67,500
Ring flaker and dryer feedbins	12,000	12,000
Conveyors from truck dump	4,500	4,500
Ring and roundwood flakers	15,000	10,000
Dryers, with burner and blowers	36,000	18,000
Boiler and fuel storage and handling	50,000	35,000
Roundwood feed conveyors to flakers	17,000	17,000
Dryer fuel preparation and handling	22,500	16,000
Dry flake bins and related conveyors	25,000	25,000
Blender metering bins and related conveyors	7,000	7,000
Resin and wax tanks	20,000	13,000
Press pit and hydraulic tank area	169,000	102,000
Air-compressor foundations, trenches, and miscellaneous foundations	33,800	23,000
Finger jointing, ripsaw, laminators, feeders, stackers, and miscellaneous conveyor foundations	26,000	16,000
Substations, sumps, and yard trenches	24,000	12,000
Misc. blower footings, tower footings, etc.	18,000	9,000
Total	883,300	580,500

Table 3.--Net investment required for the first 3 years for Case I and Case II

Investment	Beginning of first year		End of first year		End of second year		End of Third year		Total	
	Case I	Case II	Case I	Case II	Case I	Case II	Case I	Case II	Case I	Case II
	Thousands of dollars									
Land	300,000	180,000	600,000	360,000	87,000	53,000	0	0	987,000	593,000
Buildings	0	0	2,260,000	1,649,800	2,000,000	1,000,000	0	0	4,260,000	2,649,800
Foundations	0	0	483,300	330,500	400,000	250,000	0	0	883,300	580,500
Machinery	0	0	19,000,000	15,000,000	10,000,000	4,300,000	652,100	358,700	29,652,100	19,658,700
Cash	0	0	159,600	110,000	372,500	256,300	0	0	532,100	366,300
Inventory	0	0	0	0	254,300	140,000	963,300	559,700	1,217,600	699,700
Accounts receivable	0	0	0	0	1,375,600	740,000	4,126,800	2,219,500	5,502,400	2,959,500
Contingency and engineering	557,800	384,800	2,231,200	1,539,200	1,673,400	1,154,400	1,115,600	769,600	5,578,000	3,848,000
Net investment	857,800	564,800	24,734,100	18,989,500	16,162,800	7,893,700	6,857,800	3,907,500	48,612,500	31,355,500

Flow of Materials

The flow of materials through a factory is important to know because this determines the number and size of machines, which in turn determines machinery costs. The quantities of materials purchased can be determined from a materials flow analysis that accounts for waste, which is needed to determine operating costs. The flow of materials is useful in determining the energy required to operate the factory and the fuel recovered from combustible waste. The materials flow analysis provides a balance of materials flowing into and out of the factory as well as in and out of each operation. Such materials balance analysis is essential for determining the cost of wood and the product yields. However, materials balance diagrams are highly complex and there are many possible variations in a balance of flow because there are many combinations of materials that can be used, such as various species, whole tree vs. saw logs, and green vs. dry residues purchased. Waste factors and veneer yields vary considerably in relation to the type of raw wood supply. The flow of materials also varies, depending upon the type of product being made.

A computer program was used to compute the flow of materials through the COM-PLY factories used in this report. The detailed results of the materials flow analysis are too extensive to include in this Paper, so only a summary is presented and only for 100 percent manufacture of 2 x 8-12 joists for Case II. Readers who want the in-depth report on waste factors, product yields, and variations in materials flow that were studied can obtain it from the author.

For Case I, the particleboard press had a nominal platen size of 6 ft wide by 25 ft long, of which 72 in. of width by 300 in. of length were usable for untrimmed width of the mat. The press had 20 openings. For Case II, the nominal platen size was 6 ft wide by 17 ft long, of which 72 in. of width and 204 inches of length were usable for untrimmed width of the mat. The press had 16 openings. For both cases, there were 12 pieces of core material for 2 x 8 joists ripped from each flakeboard produced. For both cases, the presses cycled 4.4 times per hour or every 13.64 minutes. At the rate of 4.4 cycles per hour, Case I production would be 7,805 fbm per cycle and 34,342 fbm per hour and Case II would be 4,199 fbm per cycle and 18,476 fbm per hour. For 250 days at an efficiency rate of 85 percent, the annual production for Case I is 175,146,000 fbm and 94,226,500 fbm for Case II, if only 2 x 8's are produced.

The flow of materials occurs in three production lines. One line produces the veneer portion of the joists, one produces the flakeboard cores for the joists, and one laminates the veneer cords to the flakeboard cores. There is some waste generated from each production line that flows to the boiler for fuel, but some manufacturing residue is recycled and used for feedstock for the flakeboard operation. Total waste bark, wood, and flakeboard residues ranged between 607 and 633 lb/M bm of lumber produced. This waste is about 25 percent bark and was used for boiler fuel. Dry-wood volumes are assumed to be 88 percent of their corresponding green-wood volumes.

The flow of veneer is based largely on information obtained from studies by McAlister[3] to determine the grade and yield of veneer from southern pine and various hardwoods. The following tabulation summarizes some of the important ratios taken from McAlister's studies which are used to compute wood flow in the veneer line.

Ratios	Value
Linear feet of green peeler block to cubic feet of green peeler block	1.81
Linear feet of green tree to cubic feet of green tree	2.61

[3]McAlister, Robert H.; Taras, M. A. Yield of southern pine suitable for composite lumber and panels. Res. Pap. SE-180. COM-PLY Rep. 12. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station and Washington, DC: U.S. Department of Housing and Urban Development; 1978. 15 p.

Green cubic feet of peeler block to dry cubic feet of veneer peeled	2.95
Dry cubic feet of tree to dry cubic feet of peeler block	1.21

The volume of veneer required for the end product is a fixed and a known amount. A greater volume of veneer must be peeled or dried to account for waste in various manufacturing operations. To determine the amount of timber in peeler-block form required to operate the factory, the peeled and dried veneer volume is multiplied by 2.95 to get the green-block volume. This is an example of how the ratios were used in making a materials flow analysis.

Table 4 lists the flow of wood through the veneer production line. An important amount shown in table 4 is the quantity of green tree-length timber (71.3 ft^3) required to produce a thousand board feet of COM-PLY joists. The green tree-length timber varies in size from 10 to 22 in. in diameter at breast height (d.b.h.), and the number of trees in each size class is typical for natural pine or mixed hardwood stands (see footnote 3). Trees were assumed to be cut from a 1-ft-high stump and had top diameters of 3 to 4 in. inside the bark. The timber is assumed to be No. 2 saw-log quality, so there is nothing special about the type timber purchases. Note that the dry volume of veneer resulting in cords for joists is about one-fourth of the dry-tree volume. For this example there should be approximately 232 blocks peeled into veneer at the lathe each hour.

Table 5 shows amounts of wood and flakeboard flowing through the flakeboard manufacturing line. The greatest quantity of wood for the flakeboard comes from tree tops and veneer-peeling residues. In this analysis, a small amount of bark was allowed in the product. The whole tree is converted into COM-PLY joists except for some bark and fine residues that are burned in the boiler. In this example, 478 lb of green wood or 315 lb of dry wood are flowing into the boiler for each thousand board feet of joists produced. However, the materials balance analysis shows that additional wood must be purchased from other sources. Table 5 shows that 886 lb of green roundwood or 424 bone-dry lb of mill residues are required in addition to the green tree-length timber (table 4) for a balanced flow.

The total feedstock flowing into the flakeboard line for each thousand board feet of production is 3,626 lb of green wood. Of this, 19 lb are wasted in preparing flakes, which leaves 3,607 lb for the screening operation. Along the flakeboard line, chemicals are added and waste is lost to the boiler or recycled as feedstock. Water with chemicals is added but is later lost in waste materials and as vapor during the flake-drying and board-pressing operations. The apparent increase in the flow of material through the forming operation is due to mat that is recycled through the forming stage.

Table 4.-- Flow of wood through the veneer production line for Case II

Operation	Type wood	Flow/M bm of joist	
		Cubic feet	Pounds
Log processing	Green tree-length timber[a]	71.3	3780.2
Log processing	Dry tree-length timber[a]	62.8	1808.7
Veneer peeling	Green peeler blocks[a]	58.9	3124.2
Veneer drying	Dry veneer	20.0	575.8
Laminate veneer panels	Veneer panels	19.6	564.4[b]
Cut panels into cords	Veneer cords	16.1	464.2

[a]Does not include bark.

[b]The weight of the plywood glue used to laminate veneer is excluded.

Table 5.--Flow of wood and flakeboard through the flakeboard line for Case II

Operation	Type Wood	Flow/M bm of joist	
		Undried weight	Dried weight
		Pounds	
Flake preparation	Tree tops	656	314
	Peeling residues	1,767	845
	Tree bark	185	104
	Veneer residues	57	54
	Flakeboard residues	75	72
	Purchased residues	886	424
	Total feedstock	3,626	1,813
Screening	Wood flakes	3,607	1,805
Drying	Wood flakes	3,391	1,697
Blending	Wood flakes, resin, and wax	1,978	1,764
Forming[a]	Wood flakes, resin, and wax	2,188	1,950
Pressing	Flakeboard	1,948	1,736
Sawing into cores	Flakeboard	1,792	1,728
Cores available for laminating	Flakeboard	1,642	1,583

[a]About 10 percent of the mat is recycled in the forming stage, which accounts for an apparent increase in materials flow in this operation.

Table 6 shows the flow of materials in pounds that occurs in the final laminating stage. For analysis 3 percent of the material was assumed to be rejected because of poor quality and breakage. There are 62.5 pieces of 2 x 8-12 joists for every thousand board feet produced, and, for this example, there is 18.4758 M bm feet of 2 x 8's produced per hour or 1,155 joists to be laminated each hour. Each joist is composed of three pieces (two cords and one core). Therefore, there are 3,465 pieces of material to be handled each hour in a 2 x 8-12 laminating operation.

The flow of materials on a per-thousand-board-foot basis does not vary much from the amounts shown in tables 4 and 5 for lumber sizes 2 x 4 to 2 x 10 for veneer or flakeboard production. However, if saw logs are fed into the system instead of tree-length timber, it will require purchasing a greater amount of flakeable wood (other than saw logs) for feedstock to obtain materials balance. This other purchased wood can be green or dry, or poor or excellent quality with regard to flaking properties. The amount of water to be removed during flake drying and the fuel value of waste is affected by the moisture content of the wood purchased. The quality of purchased wood will affect the amount of wood to be flaked, screened, and burned in the boiler. Therefore, the species, type, moisture content, and quality of wood used to make COM-PLY joists can result

Table 6.--Flow of materials leaving the factory after laminating[a]

Operation and material	Flow/M bm of joist	
	Undried weight	Dried weight
	Pounds	
Laminating cords to cores		
Veneer laminates	474	450
Flakeboard cores	1,592	1,536
Laminating adhesive (veneer to veneer)	28	12
Laminating adhesive (veneer to core)	17	7

[a]3 percent of the final product was assumed to be rejected because of breakage or poor quality. To obtain the flow of materials into the laminating line, divide the quantities shown by 0.97.

in substantial variations in flow of materials from the amounts shown in tables 4 and 5.

Operating Costs

Operating costs are major determinants of annual net earnings or cash proceeds from the investment. In this study, based on operating costs at 1979 prices, the assumption is that the factory operated 5 days per week and 50 weeks per year. Out of each 24-hour day, it is assumed that there are 20.4 hours of useful work. Efficiency is thus 85 percent or 5,100 hours of production at full machine rate per year. The veneer and flakeboard lines should operate at a higher efficiency because essentially only a single item is made on those lines and the setup and startup times are small.

Unit Materials Cost

Wood. For wood requirements, manufacturers of COM-PLY joists can (1) purchase veneer of the grade required for joists and mill residue at lowest cost available for the flakes in the flakeboard, or (2) purchase tree-length timber and peel veneer of the quality needed from that portion of the tree with a diameter of 10 in. d.b.h. or larger. The peeling residues and portions of the tree too small to peel are then converted into flakes for the flakeboard. Tree-length timber has distinct advantages which offset its disadvantages, and is the type used in this study.

One advantage of using tree-length timber is that flakes converted from residues are of higher quality than those made from mill residues typically used in particleboard, and with relatively little waste. It is assumed that wood residues generated from trimming veneer into panel widths and panel trimming are used in the flakeboard core. When computing veneer requirements, veneer lost during manufacture is about 22 percent, but nearly all of it can be converted into wood flakes for the core.

The most important advantage to using full-length trees is that wood particles of optimum size and shape can be made from residues. Particles made by chipping roundwood and then milling the chips into flakes are ideal for COM-PLY joists. Much less resin is required to coat large flakes (up to 2 in. long) than to coat particles made from sawmill residues, which typically contain a large percentage of fine material. Although more energy is required to dry flakes and splinters made from green wood than to dry sawmill residues, this higher cost is more than offset by the reduced amounts of waste, scrap wood, and resin.

A primary advantage of tree-length timber is its cost compared to that for saw logs. Figure 3 shows the cost per cubic foot for southern pine saw logs, tree-length pine, and mixed hardwood saw logs delivered to the mill. These costs were arrived at by dividing the prices published by "Timber Mart-South" by a factor to convert the prices from dollars/M bm to cost per cubic foot. The prices are the average for 13 States in the Southern and Southeastern United States. The conversion factors used were 215.74 for pine saw logs and 242.21 for tree-length pine,[4] and 248.56 for mixed hardwood saw logs.[5] Conversion factors can vary depending on the size and quality of logs or timber purchased. Potential manufacturers of COM-PLY should use prices and conversion factors that are appropriate for their area.

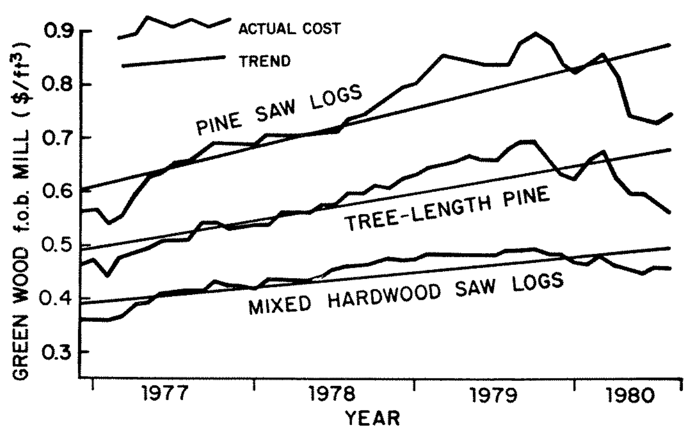

Figure 3.--Cost of wood that can be used to manufacture COM-PLY joists.

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[4] Green cubic feet of log per thousand board feet, Scribner log scale.

[5] Green cubic feet of log per thousand board feet, Doyle log scale.

In 1979, the midyear trend price per cubic foot of green wood was about $0.80 for pine saw logs, $0.62 for tree-length pine, and $0.46 for mixed hardwood logs. The straight-line trend for wood cost is shown in figure 3. For this analysis the mix of wood is 50 percent tree-length pine and 50 percent mixed hard-woods. The average trendline price is $0.54 ft^3.

The other purchased wood was assumed to cost $40 per dry ton, which is about $20 per dry ton more than it would cost for whole-tree chips according to prices published in "Timber Mart-South."

Potential manufacturers of COM-PLY joists must consider all the factors discussed and select a low-cost wood supply of their own for analysis of economic feasibility. However, the quality of the COM-PLY joists with regard to strength, stiffness, durability, and dimensional stability is greatly influenced by the type of wood selected to make the flakes for the core. Therefore, performance as well as cost must be considered when determining the type and cost of wood selected.

Particleboard phenolic resin binder. Resin cost is a major expense. Figure 4 shows industrial average prices for the phenolic resin used in particleboard on a 100 percent solids basis. From 1955 to 1973 the price steadily declined; in 1974, it rose drastically as a result of shortages of petrochemicals. This study assumes the 1979 price of $0.29/lb for phenolic resin. The source of wood for panels influences the amount of resin required in cores.

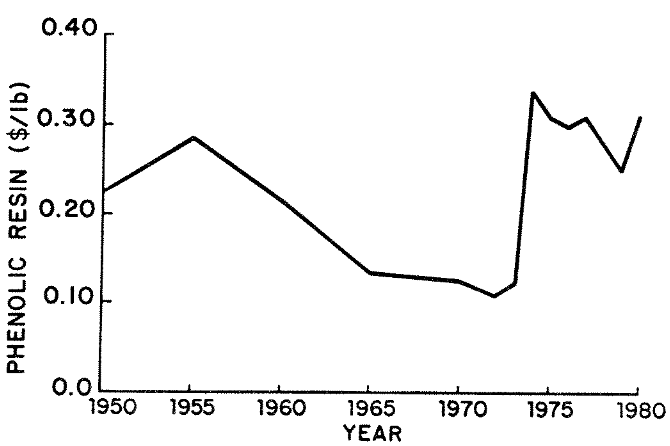

Figure 4.--Price of phenolic resin per dry pound or solids basis.

Particleboard wax. Liquid-wax emulsions are added to particleboard to reduce thickness swelling when the particleboard is soaked in water for short periods. These emulsions, roughly half wax solids, were priced at $0.082 per liquid pound in 1979.

Laminating adhesive. The veneer components of COM-PLY joists are glued together with standard phenolic plywood glue. The 1979 cost for plywood glue was $0.09 per mixed liquid pound.

Phenol-resorcinol adhesives that cure at room temperature are widely used for laminating large structural timbers. Such adhesives are a mixture of five parts liquid phenol-resorcinol resin and one part para-formaldehyde hardener by weight. In 1979, the cost of these adhesives, when mixed, was about $0.62 per liquid pound. The adhesives contain a large percentage of resorcinol in order to allow curing at room temperature in a few hours, but the adhesive can be cured with high-frequency heating equipment in just a few minutes.

Total materials cost. The total annual cost for materials was estimated by multiplying the quantity of materials flowing for each thousand board feet of production x the annual production x the unit price of the materials. Table 7 lists each material and the weighted average materials flow for 2 x 8's and 2 x 10's that were taken from detailed materials balance analyses. Included are the unit prices for materials and the weighted average annual production for Cases I and II.

Labor Cost

Labor cost varies with the level of skill demanded of workers, fringe benefits paid, and geographic location. In this report, wage rates per hour, including fringe benefits, were: unskilled laborer, $5.75; semiskilled laborer, $6.75; skilled laborer, $7.50. These rates were reported by some forest products manufacturers as typical in the Southeastern United States during 1979.

Table 8 lists the job descriptions, number of workers, number of shifts worked, wage rate paid, hours worked per

Table 7.--Annual cost of materials for a COM-PLY joist factory for Case I and Case II

Material	Materials requirement		Unit price		Total annual cost
			........Dollars........		
CASE I					
Wood (green tree-length)	12,103,520 ft^3	x	0.54	=	6,535,901
Wood (flakeable residue)	36,506 ton (dry)	x	40.0	=	1,460,236
Flakeboard resin	16,479,207 lb (dry)	x	0.29	=	4,778,970
Flakeboard wax	2,860,976 lb (liquid)	x	0.082	=	234,600
Veneer to veneer glue	6,327,189 lb (liquid)	x	0.09	=	569,447
Veneer to core glue	2,708,968 lb (liquid)	x	0.62	=	1,679,560
Total					15,258,714
CASE II					
Wood (green tree-length)	6,510,043 ft^3	x	0.54	=	3,515,423
Wood (flakeable residue)	20,396 ton (dry)	x	40.0	=	815,839
Flakeboard resin	9,020,021 lb (dry)	x	0.29	=	2,615,806
Flakeboard wax	1,565,963 lb (liquid)	x	0.082	=	128,409
Veneer to veneer glue	3,403,156 lb (liquid)	x	0.09	=	306,284
Veneer to core glue	1,637,140 lb (liquid)	x	0.62	=	1,015,027
Total					8,396,788

Table 8.--Estimated labor requirements for COM-PLY joist plant

Operation or job	Case I						Case II					
	Workers	Shifts	Man-days	Time worked per day	Hourly wage rate	Daily labor cost	Workers	Shifts	Man-days	Time worked per day	Hourly wage rate	Daily labor cost
	Number			Hours	Dollars		Number			Hours	Dollars	
Log handling, green and dry veneer												
Green end foreman	1	2	2	16	8.50	136.00	1	2	2	16	8.50	136.00
Log scaler	1	1	1	8	7.50	60.00	1	1	1	8	7.50	60.00
Log-lift driver	1	2	2	16	6.75	108.00	1	2	2	16	6.75	108.00
Yard utility	1	1	1	8	5.75	46.00	1	1	1	8	5.75	46.00
Log deck hydraulic crane	2	2	4	32	6.75	216.00	1	2	2	16	6.75	108.00
Barker operator	2	2	4	32	6.75	216.00	1	2	2	16	6.75	108.00
Deck man	1	2	2	16	6.75	108.00	1	2	2	16	6.75	108.00
Bucking saw	2	2	4	32	6.75	216.00	1	2	2	16	6.75	108.00
Block-lift operator	2	2	4	32	6.75	216.00	1	2	2	16	6.75	108.00
Block-lift operator	1	1	1	8	6.75	54.00	1	1	1	8	6.75	54.00
Lathe deck	2	2	4	32	6.75	216.00	1	2	2	16	6.75	108.00
Lathe operator	2	2	4	32	7.50	240.00	1	2	2	16	7.50	120.00
Green end utility	1	2	2	16	5.75	92.00	1	2	2	16	5.75	92.00
Clipper operator	2	2	4	32	6.75	216.00	1	2	2	16	6.75	108.00
Veneer stacker & green chair	3	2	6	48	5.75	276.00	2	2	4	32	5.75	184.00
Forklift	1	2	2	16	5.75	92.00	1	2	2	16	5.75	92.00
Dryer tender	1	4	4	32	5.75	184.00	1	4	4	32	5.75	184.00
Dryer feeder	2	4	8	64	5.75	368.00	1	4	4	32	5.75	184.00
Dry chair	3	4	12	96	5.75	552.00	2	4	8	64	5.75	368.00
Forklift	1	4	4	32	5.75	184.00	1	4	4	32	5.75	184.00
			75	600		3,796.00			51	408		2,568.00

Continued

Table 8.--Estimated labor requirements for COM-PLY joist plant--Continued

Operation or job	Case I						Case II					
	Workers	Shifts	Man-days	Time worked per day	Hourly wage rate	Daily labor cost	Workers	Shifts	Man-days	Time worked per day	Hourly wage rate	Daily labor cost
	Number			Hours	Dollars		Number			Hours	Dollars	
Veneer layup, ripping, and laminating												
Dry end foreman	1	3	3	24	8.50	204.00	1	3	3	24	8.50	204.00
Stock rustler	1	3	3	24	5.75	138.00	1	3	3	24	5.75	138.00
Veneer layup crew	3	3	9	72	6.75	486.00	2	3	6	48	6.75	324.00
Press operator	1	3	3	24	7.50	180.00	1	3	3	24	7.50	180.00
Press helper	1	3	3	24	6.75	162.00	0	0	0	0	.00	.00
Glue mixer	1	3	3	24	5.75	138.00	1	3	3	24	5.75	138.00
Forklift	1	3	3	24	5.75	138.00	1	3	3	24	5.75	138.00
PLV trim	1	2	2	16	6.75	108.00	1	1	1	8	6.75	54.00
Finger jointer	2	3	6	48	6.75	324.00	1	3	3	24	6.75	162.00
Forklift	1	3	3	24	5.75	138.00	0	0	0	0	.00	.00
Flakeboard end glue	1	2	2	16	6.75	108.00	1	1	1	8	6.75	54.00
Flakeboard rip	1	3	3	24	6.75	162.00	1	2	2	16	6.75	108.00
Forklift	1	3	3	24	5.75	138.00	1	3	3	24	5.75	138.00
Joist laminating line	6	3	18	144	6.75	972.00	4	3	12	96	6.75	648.00
Shipping & warehouse foreman	1	1	1	8	7.50	60.00	0	0	0	0	.00	.00
Shipping clerk	1	1	1	8	6.75	54.00	1	1	1	8	6.75	54.00
Car and truck loading	2	2	4	32	5.75	184.00	2	1	2	16	5.75	92.00
Forklift	2	3	6	48	5.75	276.00	1	3	3	24	5.75	138.00
			76	608		3,970.00			49	392		2,570.00
	Number			Hours	Dollars		Number			Hours	Dollars	
Flakeboard milling and drying, and press line												
Flakeboard foreman	1	1	1	8	8.50	68.00	1	1	1	8	8.50	68.00
Truck dump	1	1	1	8	5.75	46.00	0	0	0	0	.00	.00
Front end loader	1	3	3	24	5.75	138.00	1	3	3	24	5.75	138.00
Slasher	1	3	3	24	6.75	162.00	1	3	3	24	6.75	162.00
Drum flaker	1	3	3	24	6.75	162.00	1	3	3	24	6.75	162.00
Milling and drying operator	1	3	3	24	6.75	162.00	1	3	3	24	6.75	162.00
Forming station	1	3	3	24	6.75	162.00	1	3	3	24	6.75	162.00
Utility	1	3	3	24	5.75	138.00	1	3	3	24	5.75	138.00
Press operator	1	3	3	24	7.50	180.00	1	3	3	24	7.50	180.00
Forklift	1	3	3	24	5.75	138.00	1	3	3	24	5.75	138.00
			26	208		1,356.00			25	200		1,310.00
Miscellaneous												
Quality control technician	1	3	3	24	7.50	180.00	1	3	3	24	7.50	180.00
Boiler	1	4	4	32	5.75	184.00	1	4	4	32	5.75	184.00
Knife grinder & saw filing	1	3	3	24	10.50	252.00	1	2	2	16	10.50	168.00
Cleanup	4	4	16	128	5.75	736.00	3	3	9	72	5.75	414.00
Watchman	1	4	4	32	5.75	184.00	1	2	2	16	5.75	92.00
			30	240		1,536.00			20	160		1,038.00
	Number			Hours	Dollars		Number			Hours	Dollars	
Maintenance												
Foreman	1	4	4	32	11.00	352.00	1	2	2	16	11.00	176.00
Electrician	1	4	4	32	10.50	336.00	1	4	4	32	10.50	336.00
Electrician	2	2	4	32	10.50	336.00	1	1	1	8	10.50	84.00
Millwright	1	4	4	32	10.50	336.00	1	4	4	32	10.50	336.00
Millwright	2	3	6	48	9.50	456.00	1	3	3	24	9.50	228.00
Millwright	1	1	1	8	9.50	76.00	0	0	0	0	.00	.00
Machinist	1	1	1	8	10.50	84.00	1	1	1	8	10.50	84.00
Pipefitter	1	1	1	8	9.50	76.00	0	0	0	0	.00	.00
Parts storeroom	1	1	1	8	7.50	60.00	1	1	1	8	7.50	60.00
			26	208		2,112.00			16	128		1,304.00
Total			233	1,864		12,770.00			161	1,288		8,790.00

day, and daily labor cost for each operation. Total daily labor cost was calculated to be $12,770 for Case I and $8,790 for Case II. These sums multiplied by the 250 days worked per year are the total annual labor costs. At full production capacity, the annual labor costs at the 1979 rate are $3,192,500 for Case I and $2,197,500 for Case II.

Energy Cost

A COM-PLY joist factory requires two types of energy for its operation: electrical, to power motors in machinery, and thermal, to dry green wood and for process steam. Some operations require both types of energy, while others require only one. Actual energy costs depend on the volume of materials being processed, efficiency of the machinery, fuel type, and fuel costs.

Table 9 lists the major energy-using operations for producing composite products and shows the estimated quantities of electrical and thermal energy for a given production unit per M bm of joists produced. For example, drying chips requires 18 to 20 kWh of electrical energy for every green ton of chips processed and 1,980 Btu of thermal energy for every pound of water removed from the chips. The values for energy shown in table 9 are estimates; actual values in a factory could vary widely, depending on machine efficiency.

Table 9.--Estimated energy requirements for production of COM-PLY joists

Production operation	Production unit/M bm joists	Electrical energy per unit	Thermal energy per unit
Barking logs	Linear feet of logs	0.004 to 0.012	--
Hogging waste wood and bark	Green tons	20 to 40	--
Conveying chips, logs, etc.	Green tons	5 to 25	--
Steaming peeler blocks	Green tons	--	121,000
Log cutoff and slasher saws	Linear feet of logs	0.003	--
Log-sorting deck equipment	Linear feet of logs	0.004	--
Peeling veneer blocks on rotary lathe	Square feet of veneer	0.007	--
Veneer drying			
Electrical	Square feet of veneer	0.008	--
Thermal	Pounds of water removed	--	1,650
Conveying veneer	Square feet of veneer	0.004	--
Flaking round and waste wood	Green tons of wood	17 to 40	--
Hammermilling flakes	Green tons of chips	15 to 25	--
Drying chips			
Electrical	Green tons	18 to 20	--
Thermal	Pounds of water removed	--	1,980
Screening chips	Dry tons of chips	0.3 to 0.5	--
Blending particles with resin	Dry tons of particles	8 to 9	--
Forming particleboard mat	Dry tons of mat	5 to 6	--
Prepress mat	Square feet of mat	0.005	--
Press mat into particleboard			
Electrical	Dry tons of mat	6 to 7	--
Thermal			
Heat mat	Dry tons of mat	--	120,000 to 160,000
Heat cauls (if used)	Dry tons of mat	--	80,000 to 160,000
Heat losses			
Water evaporation	Dry tons of mat	--	80,000 to 160,000
Radiation	Dry tons of mat	--	6,000 to 12,000
Convection	Dry tons of mat	--	4,000 to 12,000
Press panels for PLV			
Electrical			
Press and prepress panels	Dry tons of panels	6 to 7	--
Thermal			
Heat panels to cure glue	Dry tons of panels	--	100,000 to 140,000
Heat cauls	Dry tons of panels	--	80,000 to 160,000
Heat losses			
Water evaporation	Dry tons of panels	--	22,000 to 44,000
Radiation	Dry tons of panels	--	6,000 to 12,000
Convection	Dry tons of panels	--	4,000 to 12,000
Finish joists	Number of joists	0.003	--
Laminate joists	Number of joists	0.015 to 0.023	466 to 694

Table 10 shows the energy computations for producing 2 x 8-12 joists for Case II. For example, the amount of green-wood flakes to be dried per M bm of joists produced is 1.7 tons, and there will be 1626.44 lb of water removed in the process. The electrical energy required is 19.8 kWh/green ton dried per M bm of joists (from table 9) x 1.7 green tons/M being dried, or 33.57 kWh/M. The thermal energy is 1,980 Btu/lb of water removed per M bm of joists (from table 9) x 1626.44 lb of water removed per M bm or 3,220,354 Btu/M bm. The total electrical and ther- 1
mal power required per M bm of joist production are shown in table 9. However, the total value for electrical energy is shown to be reduced by 70 percent to account for electric motors not being operated at full-rated horsepower on a continuous basis. The electrical power ranged from between 136 to 140 kWh/M bm produced for 2 x 8's and 2 x 10's for Cases I and II. The thermal energy ranged between 48 and 49 therms/M bm of 2 x 8's and 2 x 10's for Cases I and II. Electrical power was assumed to cost $0.03/kWh and thermal energy $0.25 per therm. The total annual cost for energy was found by multiplying the amount of energy used per thousand x the weighted annual production for 2 x 8's and 2 x 10's x the unit cost for energy. However, the materials balance analysis showed that between 926 and 960 lb of green wood (607 to 633 lb, dry basis) would be available for boiler fuel for each M bm of joists produced. This fuel comes from bark, sawdust, and waste too fine to use in the product. Assuming 9,000 Btu of heat for each bone-dry pound of wood and a boiler efficiency of 70 percent, there was considerable thermal energy available from the boiler that would not need to be purchased as fossil fuel.

For Case I the annual cost for electricity was $697,636 and $2,056,846 for fossil fuel without credit for burned waste wood, or $427,740 for fossil fuel if credit is given for burned waste wood. The total annual energy cost for Case I was $1,125,376 which assumes waste wood is burned for part of the fuel. For Case II the annual cost for electricity was $379,016 and $208,750 for fossil fuel after taking credit for burned waste wood for a total annual energy cost of $587,766.

Miscellaneous Production Costs

There are various other costs associated with manufacture that need to be accounted for in operating a factory. These costs are best obtained from accounting records of an actual factory; the amounts shown in table 11 are the values used in this analysis.

Sales promotion expenses were arbitrarily assumed to be $1,506,000 for Case I and $810,000 for Case II and were distributed over the first 3 years of operation in uniformly declining amounts. The 5 percent selling expense listed in table 11 is assumed to include a sufficient amount for promotional expense required after the product is introduced to the market.

Table 12 lists the personnel and salaries for Cases I and II. The total annual administrative costs at 1979 levels are $279,500 for Case I and $228,500 for Case II. Only 50 percent of the salaries were paid during the first year when there was no plant production.

Depreciation Cost

Depreciation must be computed to determine the manufacturing costs, taxable income, and return on investment. The straight-line method of depreciation was used to determine manufacturing cost and the sum-of-the-years digit method for return on investment.

Annual Sales, Operating Cash Flow, and Total Manufacturing Cost

This section shows the cash proceeds or net earnings that accrue as a result of manufacturing operations. Net earnings are computed from sales revenue minus manufacturing costs and taxes. For this analysis, assumptions are zero production the 1st year (because of plant construction), 20 percent the 2nd year, 80 percent the 3rd year, and 100 percent the 4th through the 10th year.

Table 10.--Energy required per M bm to make COM-PLY joists, Case II

Operation	Energy unit		Materials unit		Energy/hour Electrical	Energy/hour Thermal
					kWh	Btu
Barking logs	0.007	x	106.68	=	0.75	--
Hogging fuel	33.000	x	.47	=	15.64	--
Conveying wood	13.000	x	2.29	=	29.73	--
Steaming blocks	121,000.000	x	1.56	=	--	189,012
Log cutoff	.003	x	186.14	=	.56	--
Log sorting	.004	x	186.14	=	.74	--
Peeling veneer	.007	x	959.03	=	6.71	--
Veneer drying	.008	x	959.03	=	7.67	--
Veneer drying	1,650.000	x	598.85	=	--	988,099
Conveying veneer	.004	x	959.03	=	3.84	--
Patching panels	.001	x	.00	=	.00	--
Flaking wood	29.000	x	1.81	=	52.57	--
Hammermilling	22.000	x	.84	=	18.40	--
Drying chips	19.800	x	1.70	=	33.57	--
Drying chips	1,980.000	x	1,626.44	=	--	3,220,354
Screening chips	.500	x	1.80	=	.90	--
Blending	8.800	x	.99	=	8.71	--
Forming mat	5.500	x	1.09	=	6.02	--
Prepress mat	.005	x	102.00	=	.51	--
Pressing mat	6.600	x	.97	=	6.43	--
Heating mat	140,000.000	x	.97	=	--	136,379
Heating cauls	110,000.000	x	.97	=	--	107,155
Water loss	88,000.000	x	.97	=	--	85,724
Radiation loss	9,900.000	x	.97	=	--	9,644
Convection loss	8,800.000	x	.97	=	--	8,572
Finish panels	.005	x	.00	=	.00	--
Finish lumber	.003	x	62.50	=	.19	--
Laminate lumber	.015	x	62.50	=	.94	--
Laminate lumber	466.000	x	62.50	=	--	29,125
Press veneer	6.600	x	.29	=	1.88	--
Heat veneer	100,000.000	x	.29	=	--	28,503
Heat cauls	80,000.000	x	.29	=	--	22,802
Water loss	22,000.000	x	.29	=	--	6,271
Radiation loss	9,900.000	x	.29	=	--	2,822
Convection loss	8,800.000	x	.29	=	--	2,508
					195.75	4,836,970
					x .70[a]	
					137.03	

[a]Electrical energy is 70 percent of total in order to account for motors not running at full-rate horsepower.

Table 11.--Values for computing miscellaneous production costs in operating a COM-PLY factory

Item	Percent of sales	Percent of land, buildings, and facilities cost
Production supplies	2.0	--
Maintenance supplies	1.5	--
Utilities	0.1	--
Grade-certification fees	1.0	--
Other office administrative expenses	0.7	--
Facilities maintenance	--	2.0
Facilities taxes	--	2.0
Facilities insurance	--	1.0
Sales expense	4.0	--
Contingency expense	2.0	--

Table 12.--Personnel and salaries required to operate a COM-PLY joist factory

Personnel	Case I		Case II	
	Number of people	Salary (dollars)	Number of people	Salary (dollars)
General manager	1	35,000	1	35,000
Office manager	1	30,000	0	0
Comptroller	1	27,500	1	27,500
Production manager	1	27,500	1	27,500
Technical director	1	25,000	1	25,000
Maintenance superintendent	1	25,000	1	25,000
Wood buyers	1	22,500	1	22,500
Purchasing agent	1	24,000	1	24,000
Office clerks	6	63,000	4	42,000
Total	14	279,500	11	228,500

The cost for various items are assumed to escalate throughout the investment period. The inflation rates used in this analysis are:

Item	Compound inflation rate
Wood	1.08
Particleboard resin and wax	1.04
Labor	1.065
Power	1.09
Sales and items expressed as a percentage of sales	1.08
All other items	1.06

The Federal income tax assumed was 46 percent and the local tax rate was 4 percent, for a total tax rate of 50 percent.

Some price has to be assumed for the product. In this analysis, the prices of COM-PLY joists are assumed to compete with those of sawed No. 2 grade southern pine joists. These average annual and trend prices f.o.b. mill (fig. 5) were published by Random Lengths over the last 10 years (see footnote 2).

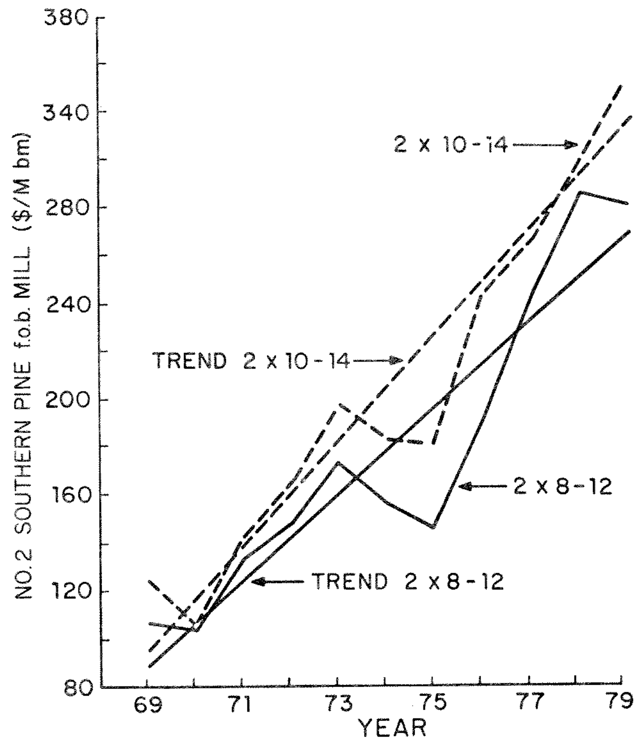

Figure 5.--Selling price f.o.b. mill for No. 2 southern pine 2 x 8 and 2 x 10 lumber.

Table 13 shows how sales were computed for the first 4 years for Case I.

Tables 14 and 15 show the annual cash flow from a COM-PLY joist factory over the 10-year investment period for Case I and Case II. Cash flow from sales was computed by multiplying the f.o.b. mill price x the board footage of joists produced per year as illustrated in table 13. When the factory reaches 100 percent production, it will be operating at an efficiency of 85 percent.

The investments for facilities and machinery were not fully depreciated during the 10-year investment period shown in tables 14 and 15. The terminal salvage value used in this report is equal to the undepreciated facilities, and machinery investment. Because terminal salvage is revenue from a sale and is taxable, it is treated as a sales item during the last year of the investment period.

Computing cash flow for manufacturing costs in tables 14 and 15 is similar to computing the cash flow for sales. Inflation rates were used to escalate costs over the 10-year period. Only 50 percent of the expense for facilities was assumed to occur the first year, but

Table 13.--Sales for first 4 years of the investment period, Case I

Year and item	Annual production rate		Price f.o.b. mill[a]		Plant production		Total sales per year
	M board feet		Dollars per M		Factor		M dollars
1979							
2 x 8-12	76,370	x	270.00	x	0	=	0
2 x 10-14	93,342	x	317.00	x	0	=	0
1980							
2 x 8-12	76,370	x	291.60	x	0.2	=	4,453.0
2 x 10-14	93,342	x	342.36	x	.2	=	6,391.3
							10,845.2
1981							
2 x 8-12	76,370	x	314.93	x	.8	=	19,240.9
2 x 10-14	93,342	x	369.75	x	.8	=	27,610.4
							46,851.3
1982							
2 x 8-12	76,370	x	340.12	x	1.0	=	25,975.3
2 x 10-14	93,342	x	399.33	x	1.0	=	37,274.0
							63,249.3

[a] Amounts shown have been rounded.

Table 14.--Cash flow from operation of a COM-PLY joist factory during a 10-year investment period, Case I[a]

Item	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
	Thousands of dollars									
A. Sales										
2 x 8	0.0	4,453.9	19,240.9	25,975.3	28,053.3	30,297.5	32,721.3	35,339.1	38,166.2	41,219.5
2 x 10	.0	6,391.3	27,610.4	37,274.0	40,255.9	43,476.4	46,954.5	50,710.9	54,767.7	59,149.1
Terminal salvage	.0	.0	.0	.0	.0	.0	.0	.0	.0	716.8
Total	.0	10,845.2	46,851.3	63,249.3	68,309.2	73,773.9	79,675.8	86,049.9	92,933.9	101,085.4
B. Raw materials										
Logs	.0	1,727.2	7,461.3	10,072.8	10,878.6	11,748.9	12,688.8	13,703.9	14,800.2	15,984.2
Phenolic resin	.0	994.0	4,135.2	5,375.7	5,590.8	5,814.4	6,047.0	6,288.8	6,540.4	6,802.0
Particleboard wax	.0	48.8	203.0	263.9	274.4	285.4	296.8	308.7	321.1	333.9
Laminating adhesive	.0	476.8	2,021.6	2,678.6	2,839.3	3,009.7	3,190.2	3,381.7	3,584.6	3,799.6
Total	.0	3,246.8	13,821.1	18,391.0	19,583.1	20,858.4	22,222.9	23,683.1	25,246.2	26,919.8
C. Production expense										
Direct labor	.0	1,020.0	2,896.8	3,856.4	4,107.0	4,374.0	4,658.3	4,961.1	5,283.6	5,627.0
Power and fuel	.0	245.3	1,069.7	1,457.4	1,588.6	1,731.6	1,887.4	2,057.3	2,242.4	2,444.2
Production supplies	.0	212.9	902.6	1,196.0	1,267.8	1,343.8	1,424.5	1,509.9	1,600.5	1,696.6
Maintenance supplies	.0	106.4	451.3	598.0	633.9	671.9	712.2	755.0	800.3	848.3
Utilities	.0	10.6	45.1	59.8	63.4	67.2	71.2	75.5	80.0	84.8
Total	.0	1,595.3	5,365.6	7,167.6	7,660.7	8,188.5	8,753.6	9,358.8	10,006.8	10,700.9
D. Administrative expenses										
General management	46.3	98.1	103.9	110.2	116.8	123.8	131.2	139.1	147.4	156.3
Office management	38.8	82.2	87.1	92.3	97.8	103.7	109.9	116.5	123.5	130.9
Clerks	54.8	116.1	123.0	130.4	138.2	146.5	155.3	164.6	174.5	185.0
Dues	.0	106.4	451.3	598.0	633.9	671.9	712.2	755.0	800.3	848.3
Other	.0	74.5	315.9	418.6	443.7	470.3	498.6	528.5	560.2	593.8
Total	139.8	477.2	1,081.3	1,349.5	1,430.5	1,516.3	1,607.3	1,703.7	1,805.9	1,914.3
E. Sales promotion	753.0	502.0	251.0	.0	.0	.0	.0	.0	.0	.0
F. Facility expenses										
Maintenance	68.0	144.2	152.8	162.0	171.7	182.0	192.9	204.5	216.8	229.8
Taxes	68.0	144.2	152.8	162.0	171.7	182.0	192.9	204.5	216.8	229.8
Insurance	34.0	72.1	76.4	81.0	85.8	91.0	96.5	102.2	108.4	114.9
Total	170.0	360.4	382.0	404.9	429.2	455.0	482.3	511.2	541.9	574.4
G. Contingency	.0	216.9	937.0	1,265.0	1,366.2	1,475.5	1,593.5	1,721.0	1,858.7	2,007.4
H. Sales expense	.0	542.3	2,342.6	3,162.5	3,415.5	3,688.7	3,983.8	4,302.5	4,646.7	5,018.4
I. Cost of operations (B+C+D+E+F+G+H+L)	1,062.7	14,109.1	30,631.9	37,475.0	38,902.9	40,483.2	42,227.4	44,147.6	46,256.7	48,568.8
J. Taxable income (A-I)	-1,062.7	-3,263.9	16,219.4	25,774.2	29,406.3	33,290.7	37,448.4	41,902.3	46,677.2	52,516.6
K. Income tax (50% x J)	-531.4	-1,631.9	8,109.7	12,887.1	14,703.2	16,645.3	18,724.2	20,951.2	23,338.6	26,258.3
L. Depreciation										
Machinery	.0	6,111.4	5,500.2	4,889.1	4,278.0	3,666.8	3,055.7	2,444.5	1,833.4	1,222.3
Facilities	.0	1,056.8	951.2	845.5	739.8	634.1	528.4	422.7	317.1	211.4
Total	.0	7,168.2	6,451.4	5,734.6	5,017.7	4,300.9	3,584.1	2,867.3	2,150.5	1,433.6
M. After-tax profit (J-K)	-531.4	-1,631.9	8,109.7	12,887.1	14,703.2	16,645.3	18,724.2	20,951.2	23,338.6	26,258.3
N. Net earnings (M+L)	-531.4	5,536.3	14,561.1	18,621.7	19,720.9	20,946.3	22,308.3	23,818.5	25,489.1	27,692.0

[a]Data may not add to totals due to rounding and truncating.

Table 15.--Cash flow from operation of a COM-PLY joist factory during a 10-year investment period, Case II[a]

Item	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
	....	....	....	....	Thousands of dollars	....	....	....	....	....
A. Sales										
2 x 8	0.0	2,395.6	10,349.0	13,971.2	15,088.8	16,296.0	17,599.6	19,007.6	20,528.2	22,170.5
2 x 10	.0	3,437.6	14,850.6	20,048.3	21,652.2	23,384.4	25,255.1	27,275.5	29,457.6	31,814.2
Terminal salvage	.0	.0	.0	.0	.0	.0	.0	.0	.0	475.6
Total	.0	5,833.2	25,199.6	34,019.5	36,741.0	39,680.3	42,854.7	46,283.1	49,985.8	54,460.3
B. Raw materials										
Logs	.0	935.6	4,041.6	5,456.2	5,892.7	6,364.1	6,873.2	7,423.1	8,016.9	8,658.3
Phenolic resin	.0	544.1	2,263.4	2,942.4	3,060.1	3,182.5	3,309.8	3,442.2	3,579.9	3,723.1
Particleboard wax	.0	26.7	111.1	144.4	150.2	156.2	162.5	169.0	175.7	182.8
Laminating adhesive	.0	280.1	1,187.7	1,573.7	1,668.1	1,768.2	1,874.3	1,986.7	2,106.0	2,232.3
Total	.0	1,786.5	7,603.8	10,116.7	10,771.1	11,471.0	12,219.8	13,021.0	13,878.5	14,796.4
C. Production expense										
Direct labor	.0	702.1	1,994.0	2,654.5	2,827.0	3,010.8	3,206.5	3,414.9	3,636.9	3,873.2
Power and fuel	.0	128.1	558.7	761.2	829.7	904.4	985.8	1,074.5	1,171.2	1,276.6
Production supplies	.0	114.5	485.5	643.3	681.9	722.8	766.2	812.1	860.9	912.5
Maintenance supplies	.0	57.3	242.7	321.6	340.9	361.4	383.1	406.1	430.4	456.3
Utilities	.0	5.7	24.3	32.2	34.1	36.1	38.3	40.6	43.0	45.6
Total	.0	1,007.7	3,305.2	4,412.8	4,713.7	5,035.5	5,379.8	5,748.2	6,142.4	6,564.3
D. Administrative expenses										
General management	31.3	66.3	70.2	74.4	78.9	83.6	88.7	94.0	99.6	105.6
Office management	38.8	82.2	87.1	92.3	97.8	103.7	109.9	116.5	123.5	130.9
Clerks	44.3	93.8	99.4	105.4	111.7	118.4	125.5	133.1	141.1	149.5
Dues	.0	57.3	242.7	321.6	340.9	361.4	383.1	406.1	430.4	456.3
Other	.0	40.1	169.9	225.1	238.7	253.0	268.2	284.2	301.3	319.4
Total	114.3	339.5	669.4	818.9	868.1	920.2	975.4	1,033.9	1,095.9	1,161.7
E. Sales promotion	405.0	270.0	135.0	.0	.0	.0	.0	.0	.0	.0
F. Facility expenses										
Maintenance	42.9	90.8	96.3	102.1	108.2	114.7	121.6	128.9	136.6	144.8
Taxes	42.9	90.8	96.3	102.1	108.2	114.7	121.6	128.9	136.6	144.8
Insurance	21.4	45.4	48.1	51.0	54.1	57.3	60.8	64.4	68.3	72.4
Total	107.1	227.1	240.7	255.2	270.5	286.7	303.9	322.2	341.5	362.0
G. Contingency	.0	116.7	504.0	680.4	734.8	793.6	857.1	925.7	999.7	1,079.7
H. Sales expense	.0	291.7	1,260.0	1,701.0	1,837.1	1,984.0	2,142.7	2,314.2	2,499.3	2,699.2
I. Cost of operations (B+C+D+E+F+G+H+L)	626.4	8,795.5	17,998.8	21,790.1	22,524.6	23,344.8	24,256.9	25,267.6	26,384.2	27,614.6
J. Taxable income (A-I)	-626.4	-2,962.3	7,200.8	12,229.4	14,216.4	16,335.5	18,597.8	21,015.5	23,601.5	26,845.7
K. Income tax (50% x J)	-313.2	-1,481.1	3,600.4	6,114.7	7,108.2	8,167.7	9,298.9	10,507.7	11,800.8	13,422.8
L. Depreciation										
Machinery	.0	4,085.0	3,676.5	3,268.0	2,859.5	2,451.0	2,042.5	1,634.0	1,225.5	817.0
Facilities	.0	671.3	604.2	537.0	469.9	402.8	335.6	268.5	201.4	134.3
Total	.0	4,756.3	4,280.7	3,805.1	3,329.4	2,853.8	2,378.2	1,902.5	1,426.9	951.3
M. After-tax profit (J-K)	-313.2	-1,481.1	3,600.4	6,114.7	7,108.2	8,167.7	9,298.9	10,507.7	11,800.8	13,422.8
N. Net earnings (M+L)	-313.2	3,275.2	7,881.1	9,919.8	10,437.6	11,021.5	11,677.1	12,410.3	13,227.7	14,374.1

[a]Data may not add to totals due to rounding and truncating.

the entire expense occurred in subsequent years.

Total operating costs for tax computations were found by totaling the costs for raw materials, production, administration, sales promotion, facilities, contingencies, sales, and depreciation. For example, the operating cost for Case I in the fourth year, when full production is reached, is shown as $37,475,000. Depreciation is included with the operating cost because the Internal Revenue Service allows depreciation to be deducted as an expense for tax computations. Depreciation began in the second year, when most of the investment for machinery and facilities had been made.

The taxable income is the difference between sales and total operating costs, including depreciation. For the fourth year, the taxable income is $25,774,200. Tax on income for the fourth year is $12,887,100 and after-tax profit is $12,887,100.

To obtain the annual net earnings for the fourth year, the depreciation is added back to the after-tax profit. The net earnings for the fourth year are $18,621,700.

Notice that a negative income tax is shown for the first and second years and it would be more correct to show zero income tax for these years. The Federal Government does not make tax refunds to companies that have a loss from operating. However, a large company could charge off these losses against other parts of the business that were operating profitably; therefore, they have been left in this analysis.

Operating costs shown in tables 14 and 15 can be used to compute average 1979 manufacturing cost of joists. This cost is computed by discounting the amount for each item during the fourth year back to the 1979 cost. Total expense for sales promotion was averaged for the 10 years to give an average yearly cost for 1979. Straight-line depreciation for a 10-year period was used for computing depreciation cost for 1979. After making these adjustments, the 1979 values were divided by 169,712,000 fbm of joists produced per year for Case I and 91,882,000 fbm for Case II to obtain the cost/M ft^2. Table 16 shows the 1979 estimated manufacturing cost for COM-PLY joists for Case I and Case II.

Computing the operating costs shown in tables 14 and 15 is difficult, and accurate data are not easily obtained. Potential manufacturers of COM-PLY joists probably have a good source of data in their own company records. By using their own data and making computations similar to those shown in this section, manufacturers can accurately estimate the factory cost for their own company.

Net Cash Flow and Internal Rate of Return

Potential manufacturers of COM-PLY joists want to know what return on their investment they can expect from the cash proceeds of net earnings. The return on investment is found by determining interest rates on the basis of the present-value concept. In simple terms, if we invest $100 today at 6 percent interest, the value 1 year from today is $106. The $106 is called the future sum. The future sum includes the original amount (present value) plus interest accumulated (return on investment). The $100 is analogous to investments or cash outlays to build a factory, while the $106 is analogous to cash proceeds resulting from profitable operation.

Computing the present value of future sums at a given interest rate is referred to as discounting. In this study, the annual cash outlays (such as payout for investments) are considered as negative future sums and annual cash proceeds (such as net earnings from profitable operation) are considered as positive future sums. The object of the analysis is to find the compound interest or discount rate at which the present value of the cash outlays equals the present value of the cash proceeds. This procedure is widely used for evaluating the economic feasibility of investments and is often referred to as a discounted cash-flow analysis. The appropriate compound interest or discount rate is found by trial and error.

Table 16.--Manufacturing cost in dollars per thousand board feet of joists, Case I and Case II

Item	Case I	Case II
	Dollars	
Wood	47.1	47.4
Particleboard resin	28.2	28.7
Particleboard resin catalyst	.0	.0
Particleboard wax	1.4	1.4
Laminating adhesive	13.3	14.5
Labor	18.8	24.1
Power and fuel	6.6	6.4
Other production expense	9.2	9.2
Administrative expense	6.7	7.5
Sales promotion	.9	.9
Facilities expense	2.0	2.3
Contingency expense	5.9	5.9
Sales expense	14.8	14.8
Depreciation	19.0	23.4
Total	173.8	186.6

A low interest rate is selected and the net annual cash flow (outlay and proceeds) or future sums are converted to their present value on the basis of the rate selected. If the cumulated net annual cash flow is positive, then the present value of the cash proceeds is greater than the present value of the cash outlays for the 10 years of the investment period. In that case, a higher interest rate is selected and the procedure is repeated until a rate is found at which the positive present value of cash proceeds equals the negative present value of cash outlays. This interest or discount rate is called the internal rate of return. Internal rate of return was computed for Case I and Case II by the procedure outlined. The after-tax internal rate of return for Case I is 34.5 percent and for Case II, 27.3 percent. These are quite attractive returns on investment. Most banks would expect to see an analysis to show an after-tax return on investment of at least 25 percent before they would lend money for the investment.

In this era of high inflation, many manufacturing firms find that the price of investment capital is somewhere near 15 percent, which is about the amount they must pay to borrow for a new venture. Tables 17 and 18 show the cash flow for Cases I and II at a discount rate of 15 percent.

Column 1 in tables 17 and 18 shows the year or period of investment. Year 0 represents the beginning of year 1, but numbers 1 through 10 represent yearend times.

Column 2 shows cash outlay except for the value at year 10. This value represents working capital (cash, inventory, accounts receivable) that is recovered at the end of the investment period. The recovered working capital is treated as a positive nontaxable cash flow.

Column 3 is taken from the net earnings (tables 14 and 15). If production operations are unprofitable, the net earnings will be negative; if profitable, the net earnings are positive and represent cash proceeds.

Column 4 is the sum of columns 2 and 3 and represents net annual cash flow.

Column 5 lists the present-value factor for a 15 percent interest rate. At rates of return less than 15 percent, a company might be better off to invest elsewhere. The values in column 4 represent future sums at the end of the year indicated. By multiplying the values in column 4 by the present-value factor in column 5, the amount in column 4 is discounted (moved backward through time) to its present value (shown in column 6). For example, at the end of year 5, the net annual cash flow for Case I was $19,720,900 and the present value of annual return was $9,804,800. In other words, if we had invested $9,804,800 at time zero at a compound interest rate of 15 percent, we would have a future sum of $19,720,900 at the end of 5 years.

Column 7 shows the cumulative present value of annual cash flow in column 6. At a discount rate of 15 percent, the $48,612,500 investment in Case I would be paid back in 5.6 years. The internal rate of return is 34.5 percent. In other words, if we had used present-value factors for a discount rate of 34.5 percent, the investment would have been paid back at the end of the 10th year.

Table 17.--Discounted cash flow, payback period at 15 percent borrowing rate, and internal rate of return for a 10-year investment period, Case I

Year	Outlay (investments) +	Proceeds (net earnings) =	Cash flow ×	Present value at 15% =	Present value annual return	Cumulative present value
	....	....	........Thousands of dollars	....	....	....
0	-857.8	0.0	-857.8	1.0000	-857.8	-857.8
1	-24,734.1	-531.4	-25,265.5	.8696	-21,970.0	-22,827.8
2	-16,162.8	5,536.3	-10,626.5	.7561	-8,035.2	-30,863.0
3	-6,857.8	14,561.1	7,703.3	.6575	5,065.0	-25,797.9
4	.0	18,621.7	18,621.7	.5718	10,647.0	-15,150.9
5	.0	19,720.9	19,720.9	.4972	9,804.8	-5,346.1
6	.0	20,946.3	20,946.3	.4323	9,055.7	3,709.5
7	.0	22,308.3	22,308.3	.3759	8,386.5	12,096.0
8	.0	23,818.5	23,818.5	.3269	7,786.3	19,882.3
9	.0	25,489.1	25,489.1	.2843	7,245.6	27,127.9
10	8,200.4	27,692.0	35,892.3	.2472	8,872.0	35,999.9

Payback period is 5.59036 years at 15 percent borrowing rate; internal rate of return for 10-year investment period is 34.5149 percent; break-even point is 41,334.3 M bm per year.

Table 18.--Discounted cash flow, payback period at 15 percent borrowing rate, and internal rate of return for a 10-year investment period, Case II

Year	Outlay (investments) +	Proceeds (net earnings) =	Cash flow ×	Present value at 15% =	Present value annual return	Cumulative present value
	....	....	........Thousands of dollars	....	....	....
0	-564.8	0.0	-564.8	1.00	-564.8	-564.8
1	-18,989.5	-313.2	-19,302.7	.87	-16,784.9	-17,349.7
2	-7,893.7	3,275.2	-4,618.5	.76	-3,492.2	-20,842.0
3	-3,907.5	7,881.1	3,973.6	.66	2,612.7	-18,229.3
4	.0	9,919.8	9,919.8	.57	5,671.7	-12,557.6
5	.0	10,437.6	10,437.6	.50	5,189.3	-7,368.3
6	.0	11,021.5	11,021.5	.43	4,764.9	-2,603.4
7	.0	11,677.1	11,677.1	.38	4,389.8	1,786.5
8	.0	12,410.3	12,410.3	.33	4,056.9	5,843.4
9	.0	13,227.7	13,227.7	.28	3,760.1	9,603.5
10	4,602.7	14,374.1	18,976.8	.25	4,690.8	14,294.3

Payback period is 6.59305 years at 15 percent borrowing rate; internal rate of return for 10-year investment period is 27.3036 percent; break-even point is 27,614.7 M bm per year.

For Case II, the $31,355,500 investment would be paid back in 6.6 years. The internal rate of return for Case II is 27.3 percent.

An analysis was made of the return the owners would receive on their equity invested in Cases I and II. It was assumed that the owners provided about 25 percent of the total investment, which is a typical percentage lending institutions require. It was assumed that lending institutions would charge 15 percent interest on their part of the investment and that any cash surplus could be invested at a rate of 11 percent. The after-tax return on owners equity was 35.55 percent for Case I and 30.31 percent for Case II which is greater than the internal rate of return for both Cases I and II. Tables 19 and 20 show the detailed computations of return on owners equity for Cases I and II, respectively.

Discussion and Conclusions

This study shows that it is economically feasible to manufacture COM-PLY joists now, with a possible after-tax internal rate of return of more than 25 percent. The manufacturing cost is comparable to that for sawed lumber joists. The number of logs in the sizes required for making conventional lumber joists seems certain to decline, so there will be a ready market for the composite product.

Firms that are already manufacturing particleboard and veneer might realize greater returns by manufacturing COM-PLY joists. The conversion investment would be less than the investment for a new factory shown here, and a positive annual cash flow would occur sooner than if a new plant were built. This approach would make sense for other reasons. So many particleboard plants have been built in recent years that there is too much productive capacity in the United States. As a result, many particleboard plants in the United States are yielding a very low internal rate of return. The earning capacity of such plants could be improved by converting them to COM-PLY joist production.

Consumer demand for particleboard often peaks a year or two after peak demand for lumber, primarily because demand for lumber is greatest during a housing boom. After a housing boom subsides, the need for lumber drops off, as it did late in 1973. Subsequently, construction of shopping centers and manufacture of furniture increase, creating a strong demand for particleboard. Therefore, a manufacturer can weather market fluctuations by producing both COM-PLY joists and particleboard in one factory. A manufacturer can shift production to the product in greatest demand.

Potential manufacturers should carefully compare the manufacturing costs for COM-PLY joists with those for manufacturing sawed lumber. One of the greatest expenses in making conventional sawed lumber is the cost of wood. During periods of peak demand for lumber, the prices for stumpage increase--more so for softwoods than hardwoods. COM-PLY joists can more completely utilize the whole tree and can be made from a mixture of hardwoods and softwoods, thus easing supply pressure during periods of peak demand. If the supply of logs within a reasonable distance from a sawmill is insufficient, the mill can be forced to close. A sawmill faced with a limited timber supply could convert to composite joists and continue to operate on the limited supply of logs for many years. Conversion is possible because fewer and lower quality logs are needed for COM-PLY joists. It must be stressed that even though veneer is used in COM-PLY lumber, it does not require high-priced veneer logs for manufacture. Tree-length timber, which costs about 60 percent of veneer logs, will provide all the veneer required for manufacture and should be used instead of veneer logs. A manufacturer of COM-PLY joists has a distinct raw-materials cost advantage. Wood represents a smaller proportion of the cost of a COM-PLY joist than a sawed joist. For COM-PLY joists, the costs for resin binder, wax, and laminating adhesive is slightly greater than for wood. However, these costs are more stable and changes in them normally do not coincide with changes in wood costs nor do they rise as rapidly.

As time passes, the advantage of COM-PLY joists over conventional sawed joists is likely to increase. Research on further improvements for composite wood products continues. Recent studies made by the Wood Products Research Unit at Athens, Ga., have demonstrated that isocyanate laminating adhesives make a quality glueline between the veneer and the core which can be clamped for as little as 30 minutes at room temperature for curing.[6] The current cost of isocyanate adhesives is slightly higher than the 1979 cost for phenol-resorcinol adhesives used in this economic analysis. However, it appears that in the future the costs will be competitive, and the short curing time without the use of costly heating equipment will reduce manufacturing costs.

Potential manufacturers also have alternate methods available for preparing the veneer. Veneer sheets can be fed into a continuous laminating press so that veneer can be butt-jointed.[7] This method would reduce labor and eliminate the finger-joint operation, would speed up production, and probably decrease the investment. Another method, which also reduces labor costs because it eliminates the finger-joint operation, is to use a long, single-opening hot-press instead of the standard multiplaten plywood press for laminating. The advantage of this method is that the veneer panels can be laid up in long lengths modular to joist lengths.

Potential manufacturers can estimate costs for alternate manufacturing procedures and materials to determine which method is most economical in relation to their equipment.

COM-PLY joists have been used in demonstration houses and builders prefer them to sawed joists because they are straight, do not warp, can be obtained in long lengths, and are more uniform in stiffness properties. The Department of HUD has accepted the COM-PLY joists performance standards. Therefore, the market and investment opportunities appear excellent for this new product.

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[6]Vick, Charles B. An emulsion polymer/isocyanate adhesive for laminating composite lumber. For. Prod. J. In press; 1984.

[7]McAlister, Robert H.; Wittenberg, Dick C. Effect of veneer butt-joint surface on the strength and stiffness of composite beams. Southeastern Forest Experiment Station, Athens, Ga. (Unpublished draft on file.)

Koenigshof, Gerald A.
Economic feasibility of manufacturing COM-PLY® floor joists. Res. Pap. SE-241. COM-PLY Rep. 26. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station and Washington, DC: U.S. Department of Housing and Urban Development; 1983. 37 p.

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COM-PLY Reports

Res. Pap.	Title and Author
SE-166	The COM-PLY Research Project. Koenigshof 1977 (Rep. 1)
SE-155	Performance Standards for Composit Studs Used in Exterior Walls. Blomquist and others 1976 (Rep. 2)
SE-163	Plywood Composite Panels for Floors and Roofs: Summary Report. Carney 1977 (Rep. 3)
SE-167	Laminating COM-PLY Studs in a Factory. Vick 1977 (Rep. 4)
SE-170	Strength and Stiffness of Composite Studs. Wittenberg 1977 (Rep. 5)
SE-171	Adhesives for COM-PLY Studs. Vick 1977 (Rep. 6)
SE-172	Durability and Dimensional Stability of COM-PLY Studs. Duff 1977 (Rep. 7)
SE-175	Structural Performance of Nailed Joints With COM-PLY. Walker 1977 (Rep. 8)
SE-179	Yield of Southern Pine Veneer Suitable for Composite Lumber and Panels. McAlister and Taras 1978 (Rep. 9)
SE-177	Demonstration Houses Built With COM-PLY Products. Koenigshof and others 1977 (Rep. 10)
SE-178	Comparative Racking Strength of Walls Framed With COM-PLY and Sawn Timber Studs. Wittenberg 1978 (Rep. 11)
SE-180	Structural Properties of COM-PLY Studs. McAlister 1978 (Rep. 12)
SE-181	Structural Performance and Standards for COM-PLY Partition Studs. Koenigshof and Wittenberg 1978 (Rep. 13)
SE-192	Performance Standards for COM-PLY Floor Joists. Duff and Wittenberg 1978 (Rep. 14)
SE-197	Economic Feasibility of Manufacturing COM-PLY Studs in the South. Koenigshof 1978 (Rep. 15)
SE-199	Structural Performance of COM-PLY Studs Made With Hardwood Veneers. McAlister 1979 (Rep. 16)
SE-201	Economic Feasibility of Manufacturing COM-PLY Panels in the South. Koenigshof 1979 (Rep. 17)
SE-207	Dimensional Stability and Durability of COM-PLY Studs Exposed to Soaking, High Humidity, and Weathering. Duff 1980 (Rep. 18)
SE-220	Evaluation of Veneer Yields and Grades From Yellow-Poplar, White Oak, and Sweetgum From the Southeast. McAlister 1981 (Rep. 19)
SE-222	End Bearing and Joint Strength of COM-PLY Joists. Wittenberg 1981 (Rep. 20)
SE-224	Linear Expansion Design Theory for COM-PLY® Panels. Talbott and others 1981 (Rep. 21)
SE-225	Resistance of COM-PLY Lumber to Subterranean Termites. Gaby and Carter 1981 (Rep. 22)
Unnumbered (In-House)	Modulus of Elasticity and Tensile Strength Distribution of Veneer of Four Commercially Important Southeastern Hardwoods. McAlister 1982 (Rep. 23)
SE-238	Veneer Yields by Grade From Three Coastal Plain Hardwoods--Blackgum, Sweetgum, and Yellow-Poplar. McAlister and Clark 1983 (Rep. 24)
SE-239	Effect of Veneer Grade on Bending and Compression of COM-PLY Truss Lumber. McAlister 1983 (Rep. 25)

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