AN ABSTRACT OF THE THESIS OF

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Alder (Alnus rubra Bong.), a major hardwood tree in Western Oregon, has potential as a raw material source for producing oriented strand board (OSB), based upon its availability, wood properties, and present under-utilization. While other studies recently examined board performance of alder produced OSB and obtained promising results, this study examined the economic feasibility of producing OSB in Western Oregon with alder as its base material.

The purpose of this study is to determine if a market exists or can be developed, that a sufficient quantity and quality of raw material is potentially available, and that the total costs of production would likely be competitive with other structural panel products, especially plywood. It includes market, technical, and financial analyses, the latter presenting a hypothetical case study of an OSB plant with an annual capacity of 150 MMSF, 3/8 in. basis to produce panels with a density of 40 pcf using alder wood with an average specific gravity (ovendry) of 0.41, and resin and wax contents of 5% and 2%, respectively.

The market analysis involves the collection and analysis of data to identify, describe, and quantify likely markets. The technical analysis considers the effects of various factors such as product description, manufacturing process, and availability of alder to establish whether or not the case example would be technically feasible. The financial analysis includes raw material requirements, prices, production costs, and an evaluation of the case example. Financial summaries are given for a typical one-year plant operation with a return on investment of 15.32%, as well as for a ten-year cash flow analysis with an internal rate of return of 15.10%.

Sensitivity analyses on several components of major production costs shows that wood cost and resin cost are two of the largest single component of the total production cost. The sensitivity analysis on wood cost and panel selling price indicated that the overall feasibility of the case example is much more sensitive to changes in panel selling price than to changes in wood cost.

Based on resource data currently available, an area consisting of Clatsop, Tillamook, and Columbia counties is better suited to supply alder raw material needs compared to other regions of Western Oregon. The study suggests that market can be developed and raw material obtained, while the overall cost would be at an acceptable level. The study also indicates that income would exceed costs, though not sufficiently adequate at 1984 price levels to yield financial returns to justify construction of the case example plant.

The Feasibility of Producing Oriented Strand Board (OSB) from Alder in Western Oregon

by

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Above all, I would like to dedicate this thesis to my wife, Amina for her complete support during the long hours spent with this project instead of her.

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I. INTRODUCTION

An increasing amount of information from research, the predicted decline of softwood timber availability and quality, as well as both short and long term economic and biological considerations -- indicate a need for a new approach to produce structural panels from Oregon forests. The fact that old growth softwood inventories are declining increases the likelihood of introducing a new competitive product. For the Pacific Northwest region, the US Forest Service estimates a harvesting rate of 2.5 times of forest growth in future years (Pennington 1984). Because of this supply and demand imbalance, bid prices at Forest Service auctions rose rapidly from 1979 to 1982. Furthermore, experts predict that greater regionalization of the current panel market will occur due to high transportation cost, and will cause a further erosion in the demand for plywood made in the Pacific Northwest region (Pennington 1984, Guss 1980).

The need for more competitive housing materials was responsible for the successful introduction of structural reconstituted board in Eastern Canada and in Midwestern and Eastern US (Irland 1982, Vajda 1982). Aspen is the most common species used in the production of waferboard and oriented strand board (OSB) in the Midwest and Eastern US. Wherever low value stumpage is available near a population center, the industry has enjoyed a price advantage over softwood plywood (Guss 1980).

Alder Potential in Western Oregon

Alder (<u>Alnus rubra</u> Bong.), a major hardwood tree in Western Oregon which has densities and properties similar to aspen, has potential as a raw material source for producing OSB and waferboard. This potential is based upon availability, wood properties, and under-utilization of alder. According to a Forest Service study (Gedney 1982) there are 2.5 billion cubic feet of alder in Western Oregon, spread over 1.3 million acres of forest land. Alder is mostly found in coastal counties such as: Clatsop, Tillamook, Columbia, Lincoln, Lane, Douglas and Coos county. Figure 1 shows the distribution of alder along the Western Oregon coast.

There are some urgencies to take advantage of this inventory. Alder grows in abundance on both sides of the coast range which are known to be high unemployment areas. A new manufacturing facility built near the source of the wood raw material could put people to work. From its predominance over the years in the home construction industry, Oregon has recently been losing ground to other regions of the country where less expensive reconstituted structural panels are produced. The state's ability to compete could be enhanced by producing OSB from alder. This would be a new industry based on the utilization of a less used wood in Oregon, with the rationale that we can produce a competitive product using a low grade material.

Waferboard and OSB which are manufactured by plants in the Midwest and the East are cutting into traditional markets for plywood, using mostly aspen logs as raw material. If the Northwest plywood makers have to lose markets to a new product, the new plants should preferably be located in the Northwest. Wilson (1983) predicts that if an improved market develops for alder, a cash crop could be realized more quickly by growers because of the possibility of a ten year maturity cycle for alder, rather than the 80 year cycle for Douglas-fir. Most of the alder stands sprouted 30 to 50 years ago when Douglas-fir was cut and not replanted. Many of the alder stands are now mature. Alder trees begin to rot after 40 years of age.

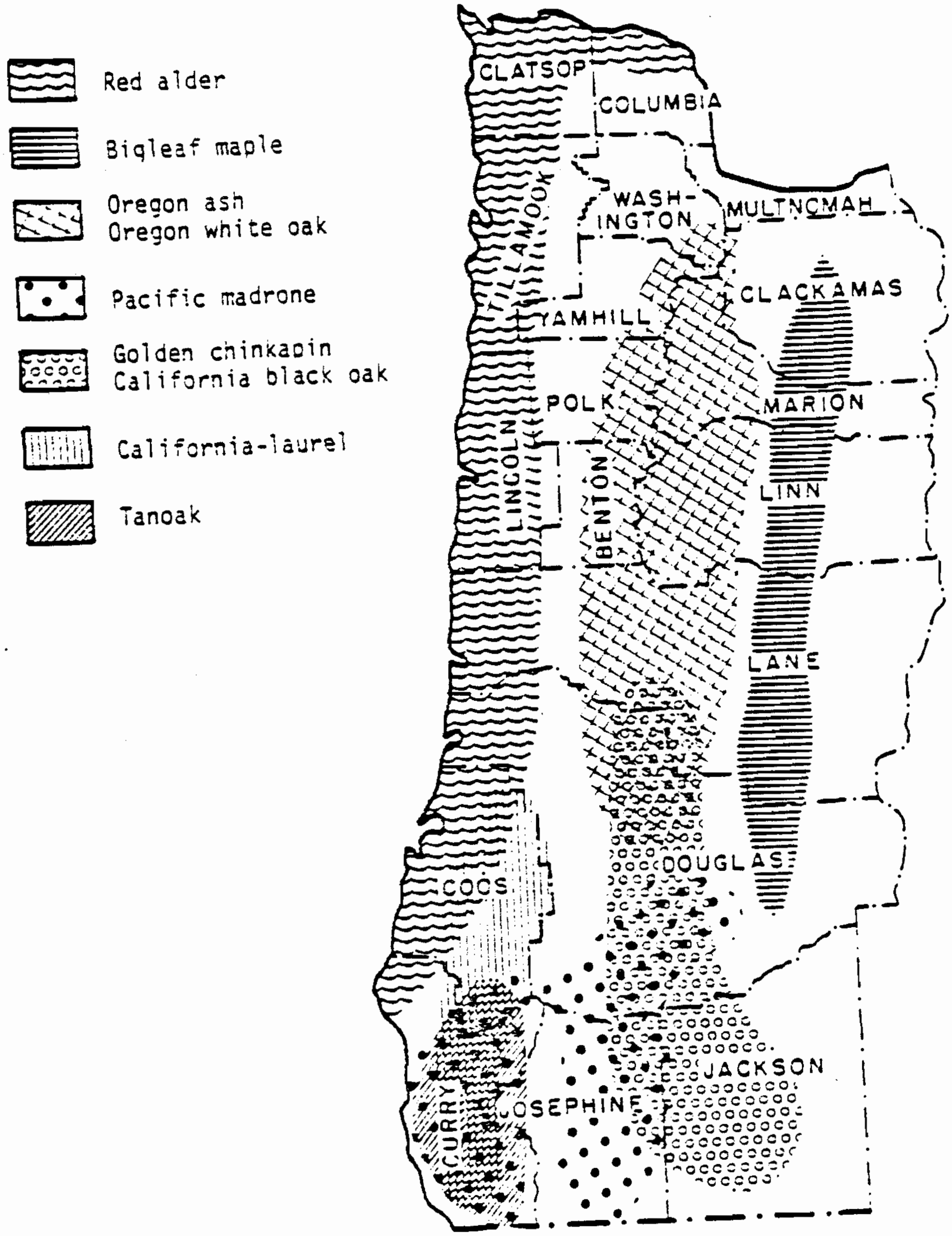

Figure 1. Principal stands of several species of hardwoods timber, in Western Oregon counties.

Source: Overholser 1977.

The hardwood resources of the US in general and those of Western Oregon in particular represent a large and important part of the country's available timber. Much of this hardwood resource is composed of small, low grade or less desirable species that are not suitable for the high quality hardwood market. While some markets for this poorer wood raw material does exist for Western Oregon, they are low in return and limited in the volume that the market can absorb (Resch 1980). A lack of markets for existing low-grade timber from alder inventories provides poor economic incentives for better forest management. On the other hand, OSB is produced at a high utilization rate of up to 85% of the wooden raw material in comparison to that of plywood production at 45 to 55% (Bison 1983). This value for plywood does not include the waste left in the forest in order to supply the species, grade, and diameter requirements for plywood production. The use of alder as the raw material base for OSB contributes to the total utilization concept. It is time to realize that the forest industry is in the business of growing trees and selling them for a number of end uses. We cannot afford much longer to burn 30 to 40% of the wood brought to various mills, nor can we afford to leave 20 to 30% of the wood in the forest (Vajda 1967).

Previous research projects on waferboard and OSB production in the Pacific Northwest showed that low density woods are preferred. Based on findings by Maloney (1978) and Zylkowski (1983), alder was found suitable for OSB production. OSB is a new product entering an old market for structural panels which is presently dominated by plywood. In this study we choose to produce OSB rather than waferboard because of its improved design. This improvement results in higher modulus of elasticity (MOE) and modulus of rupture (MOR) as well as higher internal bond and lower linear expansion along the panel length (Zylkowski 1983). Also its ability to use a wider raw material source in terms of wood density can be attributed to its potential success. In competing with plywood its competitive edge comes mostly from lower material and labor cost, while the other costs are relatively similar (Pennington 1984, Vajda 1980, Salomon 1983).

The feasibility of using alder for OSB production depends upon the board's performance and its competitiveness. Experiments by Zylkowski (1983) showed a promising result. Alder OSB with a 39 pcf density and 3% resin content has board performance properties comparable to OSB made from aspen as well as OSB made from softwoods. Having examined board performance and obtaining promising results, the time has come to examine the economic feasibility of producing OSB in Oregon with alder as its base material -- especially in Western Oregon where alder is in abundance. Furthermore, the use of alder in OSB production can be supplemented by other species because of the ability of OSB to use a variety of wood species and still meet product standards.

Prefeasibility study

Murphy (1956) said that the golden time for success is to get in the right business at the right time. His advice is true and simple, but the accomplishment is not. OSB is a new product entering an old market, the structural panel market presently dominated by plywood. Basically OSB production in Western Oregon has three important benefits. First, it fits Western Oregon, utilizing alder resources that up to now are not fully utilized, as well as the potential to use other hardwood species found in the region. Second, it utilizes available human resources in terms of skills, experiences, and training gained from Oregon's extensive wood products industry. The third benefit is the relative ease with which we are able to obtain community support to encourage new facility. However, there is the matter of financing. The OSB business offers the potential prospect of rapid growth and good return on invested capital.

During preliminary screening of a venture idea, we want to obtain answers to the following criteria:

1. Are there any restrictions, monopolies, shortages, or other causes that will make any production factors unaffordable? The answer is negative.

2. Are the capital requirements excessive? The answer is negative. It requires a relatively large capital investment, but the capital itself is usually available.
3. Are environmental impacts in the production of OSB contrary to government regulations or good public relations? The answer is negative.
4. Are there factors that preclude effective marketing of the product, such as a need for an extensive sales and distribution system that can not be provided by the typical wood industry? The answer is also negative.

After getting satisfactory answers to these basic questions, we want to make some comparative ratings of OSB product ideas by using a subjective evaluation (Clifton et al 1977). We need to evaluate the present market, market growth potential, costs, and risks. Even though the evaluation is subjective, we facilitated the process by using a rating scale of 1 to 10. The complete result for each evaluation criteria is listed in Appendix A, while the final evaluation for each major area of the rating is as follows:

Present Market. Several factors affecting sales were evaluated. With an average rating of 6.8, the size of the presently available market shows that it could absorb sufficient sales volume to support the operation.

Market growth potential. With an average of 7.1, market growth potential indicators show a prospect of rapid growth and adequate return on invested capital in a relatively short time.

Costs. An average rating of 6.8 for production and distribution costs indicates an acceptable profit when the product is priced competitively. We considered associated factors such as cost of raw material, selling price, and efficiency of production process.

Risks. The average rating for risks is 5.9. It is obviously impossible to look into the future with any certainty. Willingness to assume risks is an important factor in OSB manufacturing because of its relatively new technology. However, after considering all factors that affect risk, it appeared that an OSB venture has a good chance to succeed.

The rating for each of the major considerations appears to be promising. In conclusion, it can be pointed out that locating an OSB facility in Western Oregon has five basic factors contributing to a successful venture. They are:

An adequate present market.
A predicted growth market.
Competitive cost of production.
Intermediate risk in demand, price, and cost.

II. OBJECTIVES.

The major objectives of this study are to assure that a market exists or can be developed, that raw material can be obtained, and that the total cost of production will be competitive with other panel products. Basically, income must exceed costs by a margin sufficient to make the project financially attractive.

There are four questions that must be answered affirmatively to meet the objective of this study.

> First, is there sufficient demand for OSB panelboards in the surrounding market area to justify the establishment of OSB plants?
>
> Second, is there a sufficient supply of wood raw material and what region of Western Oregon is best suited, based on wood supply, for the proposed level of annual output?
>
> Third, can the proposed facility produce at a cost level that would be competitive with OSB produced in other regions?
>
> Fourth, will the profit realized from the venture justify the investment?

In short, the study will attempt to show that it is possible and desirable to manufacture OSB using the under-utilized alder resource by trying to answer all four of the above questions affirmatively.

Study Steps

This study will include a market, a technical and a financial analysis. The market analysis will involve the collection and analysis of data to identify, isolate, describe and quantify the market or markets. The technical analysis will consider the effects of various technical factors. The emphasis for the financial analysis is on estimating costs and on the preparation of financial statements to evaluate the project in terms of profitability by using a case example of an OSB plant using alder wood as its raw material, with an annual capacity of 150 MMSF (3/8 in. basis). The study will also recommend one general location to build an OSB plant as well as its production capacity.

III. TECHNICAL ANALYSIS.

The technical analysis will establish whether or not the venture is technically feasible. We will consider the effect of various technical factors such as product description, manufacturing process, and availability of alder.

Product Description.

In the product description we will describe OSB and allied products. We will also provide some historic background as well as the current and future capacity of reconstituted structural panel plants in the US.

Oriented Strand Board (OSB).

OSB can be classified as a reconstituted structural panel product. A reconstituted panel is a wood product manufactured by reducing solid wood to smaller components, such as a particle, fiber, strand, flake, or wafer and then gluing the small components together into a usable panel product (Pennington 1984). OSB is made from 'strands' which are flakes having a certain length to width ratio of about two to one. The strands have a length of 2 to 3 in. (51 to 76 mm), and a thickness ranging usually between 0.025 to 0.035 in. (0.64 to 0.89 mm). The strands are then oriented along the panel length in the face and back layers and crosswise in the core layer to achieve plywood-like strength, stiffness and dimensional properties. Usually OSB has three layers with a total panel thickness of 3/8, 7/16, 1/2, and 5/8 inches. The usual panel size is 4 by 8 feet. Some plants are making five layer panels for even greater uniformity as well as 4 by 12 and 4 by 16 ft. panels for special applications.

OSB is a composite reconstituted panel which is capturing portions of the market currently held by plywood. OSB was first introduced by Armin Elmendorf in the late fifties, and the US patent was issued in 1965 (Vajda 1980). However, the product did not fully develop until recently, due partly to the low cost of plywood and technical difficulties, especially in proper orientation of the strands (Vajda 1980). A pilot plant was build by Potlatch in Lewiston, Idaho, during the early seventies, followed by a commercial plant. The product was used almost exclusively to produce core panel for com-ply. The second OSB plant was constructed by Georgia-Pacific in Dudley, North Carolina, and was also used primarily for the manufacture of core for composite plywood. In 1981-1982, three new OSB plants were opened, all in the US. In 1983 - 1984 three more plants started operation exclusively for OSB while two other plants owned by Lousiana-Pacific in Houlton, Maine, and Corrigan, Texas, can produce either OSB or waferboard.

Table 1 shows the OSB and waferboard plants for North America that are in operation as of July 1984. For OSB, the total plant capacity is 1240 MMSF, 3/8 in. basis. It also shows that two plants being built by Georgia-Pacific will be going into operation during the second half of 1984 and 1985 with an additional combined annual production of 400 MMSF. Figure 2 shows the location of all reconstituted structural panel plants in the US that either are in production or the planning stages. From this map, we can see that although most plants were initially located in the Midwest and Eastern US, recent and planned capacity is mostly being located in the South and the West. This phenomena tends to point out the further regionalization of the market and also the attempt by manufacturers to produce cheaper panels within market areas.

Table 2 shows the structural reconstituted panel production and capacity trends from 1980 to 1989, while Table 3 shows the Canadian share. Canadian production capacity is given because producers have traditionally exported about half of their production, with the majority of these exports were to the US. According to APA (1984), new Canadian capacity is unlikely to be under consideration before 1987.

Table 1. North American OSB and waferboard plants, operating or planned by company, location and capacity as per August 1984.

	Company	Location	Capacity (MMSF,3/8 in.)	Type	In operation/ planned
1	Elmondorf*	Claremont, NH	100	OSB	IO
2	Georgia-Pacific	Dudley, NC	120	OSB	IO
3	Georgia-Pacific	Woodland, ME	155/165	WB	IO
4	Georgia-Pacific	Emporia, VA	200	OSB	P/2Q84
5	Georgia-Pacific	Grenada, Miss	200	OSB	P/3Q84
6	Lousiana-Pacific	Houlton, ME	125	WB/OSB	IO
7	Lousiana-Pacific	Corrigan, TX	120	WB/OSB	IO
8	Lousiana-Pacific	Chilco, ID	75/80	WB	IO
9	Lousiana-Pacific	Urania, LA	120	WB	P/3Q84
10	Lousiana-Pacific	Oletha, COL	75	WB	P/1Q85
11	Lousiana-Pacific	Kremling, COL	75	WB	P/4Q84
12	Lousiana-Pacific	Riverfalls, AZ	100	WB	P/3Q85
13	Lousiana-Pacific	Northern Cal.	75	WB	P/2Q85
14	Lousiana-Pacific	Two Harbor, MI	75	WB	IO
15	Lousiana-Pacific	Hayward, WIS	260	WB/OSB	IO
16	Potlatch	Bemiji, MINN	150	OSB	IO
17	Potlatch	Cook, MINN	155	OSB	IO
18	Weyerhaeuser	Grayling, MI	220	OSB	IO
19	Alberta Aspen Bd.	Slavelake, ALTA	100	WB	IO
20	Martco	Lee Mojen, LA	120	OSB	IO
21	Weldwood of Canada	Longlac, ONT	127	WB	IO
22	Weldwood of Canada	Slavelake, ALTA	127	WB	IO
23	Great Lakes Forest Product	Thunderbay, ONT	90	WB	IO
24	Northwood Panel	Bemiji, MINN	200	WB	IO
25	Mc Millan Blodel	Hudson Bay, SASK	150	WB	IO
26	Mc Millan Blodel	Thunder Bay, ONT	128	WB	IO
27	Hubert Lumber Coy.	Easton, ME	130	OSB	IO
28	Grant WB	Eaglehard, ONT	350 TPD	WB	IO
29	Forex Leroy Panofor	Val d' Or, QUE	110	WB	IO
30	Pellican Spruce Ltd.	Edson, ALTA	450 TPD	WB	IO
31	Canadian WB	Kelowna, BC	120	WB	P/4Q84
32	Blandin Wood Corp.	Grand Rapids, MI	170	WB	IO
33	Waferboard Corp.	Timmins, ONT	60	WB	IO

Total capacity for 33 plants: 4,372 MMSF

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* in bankruptcy court.

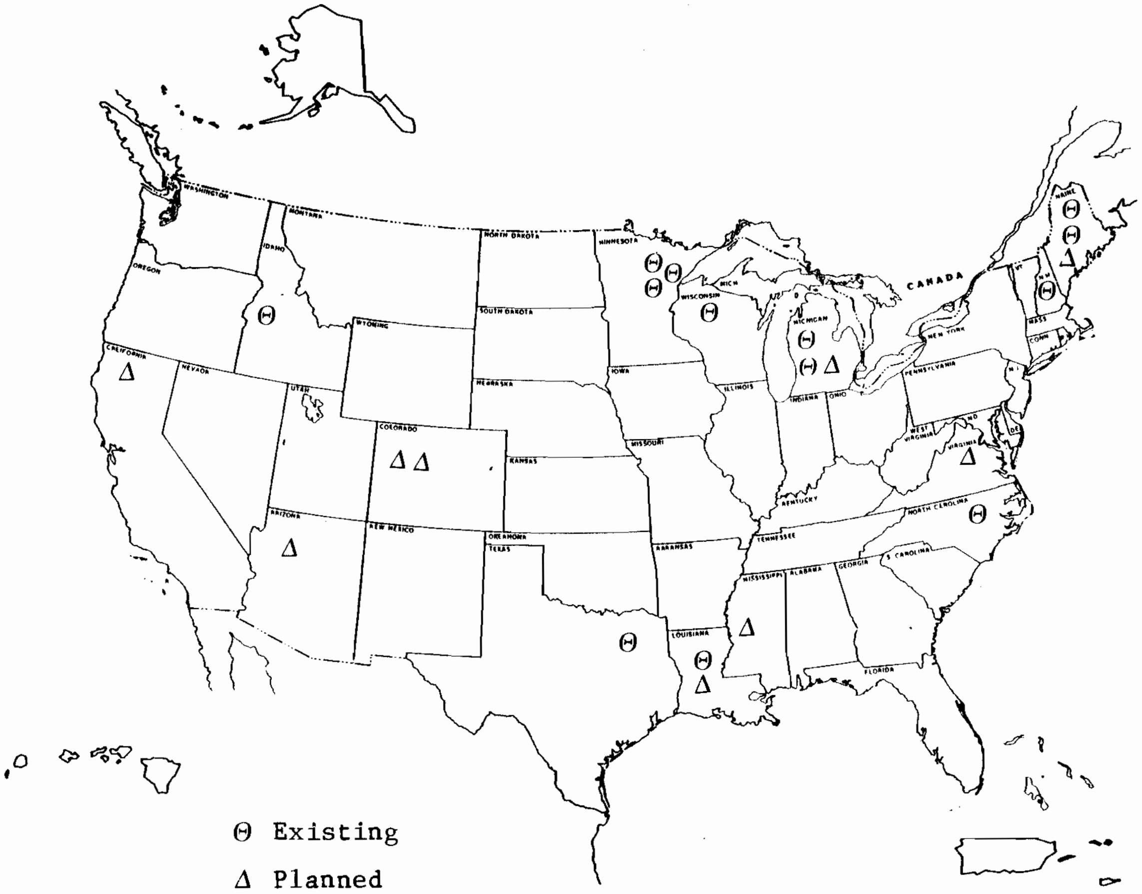


Figure 2. Location of waferboard and OSB plants in USA as per August 1984.

Table 2. USA reconstituted structural panel production and capacity trends, 1980 - 1989 (MMSF, 3/8 in. basis).

	No. of Mills	Capacity	Production	% of Capacity
1980	5	433	196	44
1981	8	993	342	34
1982	10	1,547	597	39
1983	12	1,698	1,280	75
1984	18	2,442	1,850	76
1985	21	2,752	2,100	76
1986	24	3,152	2,600	82
1987	25	3,232	2,850	88
1988	27	3,332	3,000	90
1989	31	3,952	3,500	89

1980 - 1983 Actual
1984 - 1989 APA estimates

Source: APA, 1984

Table 3. Canadian reconstituted structural board production, capacity and export, 1980 - 1984 in MMSF, 3/8 in. basis.

Year	No. of Mill	Capacity	Production	Exports	% of Capacity
1980	8	1,075	616	340	57
1981	8	1,075	783	336	73
1982	9	1,185	606	273	51
1983	11	1,298	961	426	74
1984	13	1,650	1,050	475	64

Source: 1980 - 1983 Statistic Canada (as quoted in APA, 1984).
1984 APA estimates

OSB and Waferboard

Waferboard, a less sophisticated cousin of OSB, was introduced to the marketplace before OSB. Both are structural panels made essentially with the same technology. However, there are some basic differences. Since waferboard was the first of the two new structural panels, it has developed some significant advantages. The major advantages are known market acceptance, proven technology, proven product quality, and a reasonably well established cost of manufacturing (Vajda 1980). On the other hand, there are also several major disadvantages of waferboard, as follows:

1. There are shortcomings in bending and stiffness properties and long term durability.
2. It is limited to certain wood species. Nearly all waferboard plants use aspen.
3. Properties are limited by a production requirement to use powdered resin. Current technology seems to indicate that liquid phenolic resin has better distribution uniformity and retention by the wafer or strand; while powdered resin used in waferboard tends to lose incremental effectiveness at levels above 2%, which could cause potential minute weak spots in the finished products.
4. It is difficult to produce and convey wafer shaped chips.

Of course, it may be possible to eliminate all of these disadvantages. But these changes would tend to negate the major advantages of proven technology, quality, and cost. Market acceptance could be affected as well (Vajda 1980).

The first disadvantage of OSB is the risk associated with technical aspects of introducing a new product. The technical risks are primarily concentrated in three areas, i.e. strand preparation, blending, and orientation equipment. A second major disadvantage is the board's appearance and market acceptance, because OSB can look like inferior particleboard. This could be a major deterrent in attempts to develop the market. This is especially true in the do-it-yourself (DIY) market which has been developed by waferboard.

There are, however, several advantages for OSB. The most obvious and perhaps the most important one is the increased physical properties, such as higher MOE and MOR, as well as reduction in linear expansion along the panel length. This is a distinct advantage in structural applications in direct competition with plywood. Among other merits of OSB, either proven or indicative are the following (Vajda 1978):

1. Ability to better control board strength properties. Possibility exists to 'engineer' a board to meet differing requirements by varying resin content, strand size and orientation, and board density.
2. Ability to use liquid resin, while waferboard is currently limited to powdered resin. The strand mat has a much greater moisture tolerance -- simply because the strands provide a greater chance for moisture to escape. This characteristic permits the use of liquid resins as well as the use of more resin when needed to improve panel properties. Use of the liquid resin can also provide cost savings in terms of handling, storing, and feeding, compared to systems available for powdered resin that are difficult to automate or mechanize.
3. Ability to utilize lower grade wood forms as well as strands, made from chips and/or maxichips. High density wood species can also be used to produce a high grade structural product at board densities of 45 pcf and less.
4. Easier and less troublesome preparation, conveying, binning, and blending of strands compared to wafers. This is especially true for large wafers in excess of 2.5 in. in length and width.
5. Potential marketing advantage. A stronger product that has properties equal or closer to plywood would find broader structural end-uses than waferboard.

The OSB technology is more tolerant to various wood forms, resin types, and species than the conventional waferboard techniques. Even though waferboard has an advantage at present, mainly because of its known appearance, acceptance, and technology -- most observers agree that waferboard will have to be improved in order to capture a larger share of the structural market in competition with plywood (Vajda 1980). OSB provides a relatively tested method of achieving a dramatic improvement in strength and stiffness properties, to yield a product with strength properties similar to plywood (Maloney 1978, Zylkowski 1983). Moreover, the differences between OSB and waferboard technology are quite minimal; much of the technology developed for waferboard is transferable to OSB. OSB has many of the properties of softwood plywood sheathing grade and yet can be made from small-diameter species, sawmill slabs, tree tops, or forest thinnings. OSB is produced at a high wood utilization rate of up to 80% the wood fiber in a tree in comparison to that of plywood use of only 45 to 55%.

Most experts agree that the effort to develop a reconstituted structural wood panel, which could supplement and eventually replace softwood plywood in its structural applications, is likely to find success in the newly emerging OSB technology, rather than with existing waferboard practices. Supported by the above facts, this study evaluates the feasibility of producing OSB from alder in Western Oregon.

Manufacturing process

As a unique product, OSB is relatively simple to manufacture. The log is cut, the resulting strands are sorted and blended with glue, and the mat of the wood strands are consolidated under heat and pressure. The resulting panel is then trimmed to size and surfaced. The OSB manufacturing process is basically similar to the standard particleboard processes with one key difference: special, mechanical, flake orienter heads. The bottom face layer of strands is formed with the individual wood particles in alignment parallel to each other and lengthwise in the direction of the forming conveyor. The core layer is next deposited with the long dimension of strands perpendicular to the previous layer. The top face layer is placed last with the strand length parallel to the bottom face. In this manner, a 3- or 5-layer mat composition is achieved, with the strand orientation of adjacent layers at right angles to each other. Additional layers can be added in a similar manner. After pressing in a hot platen press, the resultant structural board has similar strength and stability characteristics to those of commercial softwood plywood of the same or nearly the same thickness. Thus, OSB can be expected to provide a good alternative to the latter.

Detailed OSB Process Description.

Within the process flow (Figure 3) there are two distinguishable production systems: green strand manufacture and dry strand/panel production. The complete process will be described by dividing them into several major components in a logical sequence, starting with the raw material in the storage yard (Bison 1983).

Log Storage and Preparation

Alder roundwood is brought by truck and stored in the woodyard using conventional log handling and transporting equipment. The different shapes and length of roundwood are sorted and then slashed into two-meter lengths. After debarking, the first important step in preparing the roundwood for production of quality strands is to pass the wood through heating ponds to soften the wood (or to thaw, if necessary) to produce the maximum quality of smooth flakes.

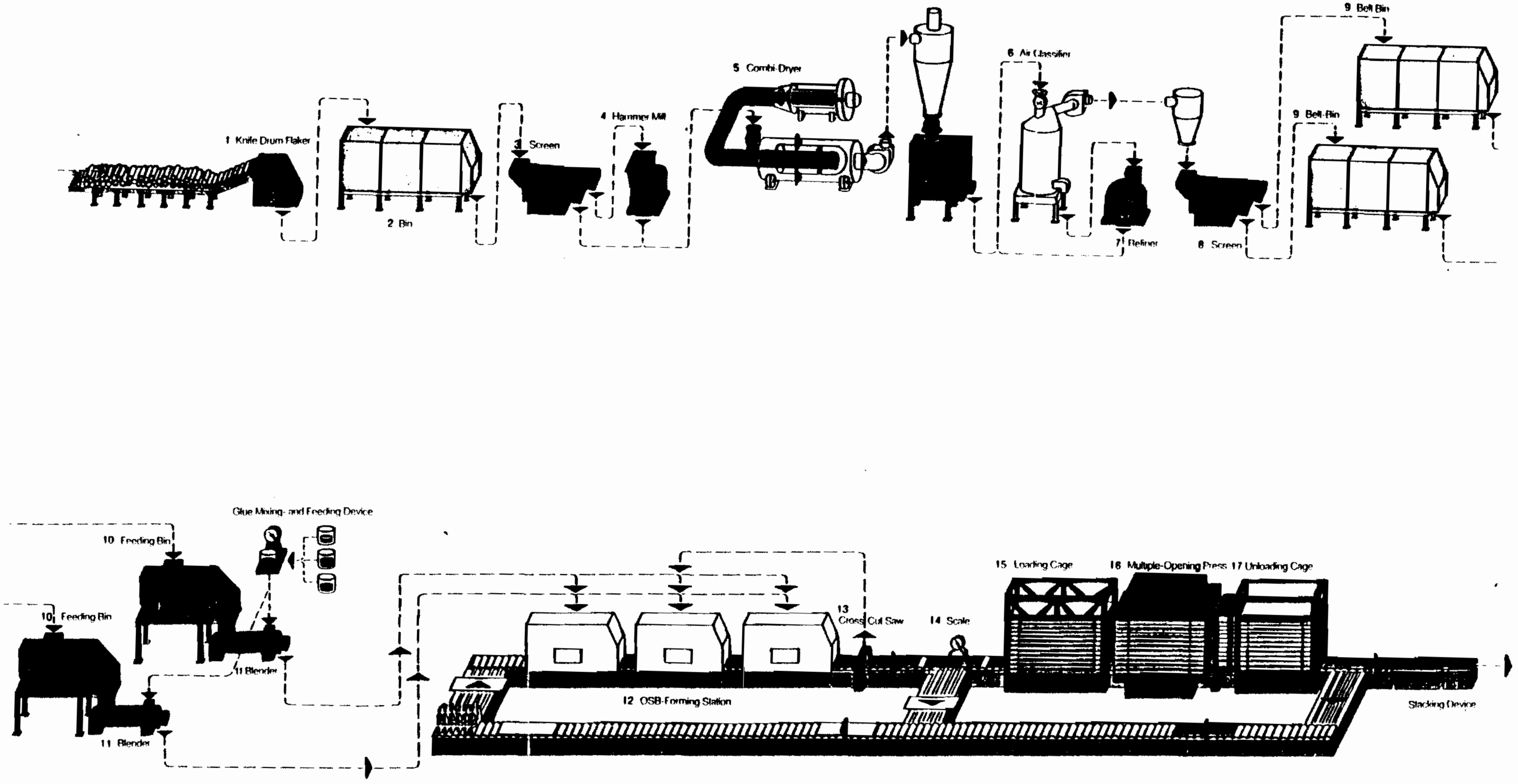


Figure 3. OSB process flow.

Flaking

A conveyer feeds the two-meter blocks into a universal knife drum flaker (1) to obtain the thin long strands. After flaking, the material is stored (2) for even distribution. By screening (3), particles of suitable dimensions are selectively sorted. To obtain the slender strands, the wider flakes are fed through a special hammermill (4) to split them into strands of 0.2 to 0.4 in. (5 to 10 mm) width. All strands are conveyed to the dryer.

Drying

All strands are dried to a predetermined moisture content, usually around 6% (ovendry basis) by using a large, single-pass, drum dryer (5). The drying process stabilize the strand dimensions, strengthen the fibers and prepares the wood for gluing.

Flake Classification

To obtain optimum quality, the material first passes an air sifter (6), the oversized particles are refined (7) and then both return to the production flow. All the material is then screened into three fractions (8) which makes it possible to prepare a suitable composition for any desired panel type. The undersized flakes are either used for fuel or are stored in a separate bin in case the forming station is designed with special air classifying heads for fine closed-surface layers. A certain portion of fines can also be directed to the storage bin for core material which also holds mat trim and rejected mats. The surface and core flake materials are belt-conveyed to respective storage bins. This separate intermediate storage (9) for each fraction provides a wide variety of panel materials for specific panel composition.

Blending

Metering bins (10) controlled by sophisticated electronic equipment assure controlled, uniform feed to the blenders underneath. To achieve an even distribution of resin with a minimum use of resin and minimum physical damage to the flakes, a slow-rotating, large-diameter drum blender is used (11). In resin preparation, the individual components of resin and wax are mixed with water at predetermined proportions by using automated controllers. After mixing, the resin solution is stored and pumped to the blenders in a controlled, constant ratio to the weight of the wood strands.

Forming

Depending on the required panel composition, the forming station (12) is composed of a number of orienting heads. The orientation of the strands takes place in fully mechanical orienters operating parallel and crosswise to the feed direction of the cauls passing underneath the forming station. The number of orienting units depends on the panel configuration. The metering bin of the core forming head receives the returned material, such as mat trim as well as fines from screening, which are deposited into the core layer. If closed surface layers of fines are desired, two additional forming heads employing an air felting system are placed into the forming line. The continuous mat deposits onto the cauls, and is then cut to the required size by a traveling saw (13). The feed of the corresponding caul and mat is then accelerated to carry them to the scale section (14) for weight control. If the pre-set mat weight tolerance is exceeded, the mat is rejected by a tilting device. Here, the mat is dumped into the trim-and-reject material bin and then conveyed back to the metering bin of the core forming head. The empty cauls then move on to a cross transfer conveyor and then to the caul return conveyor.

Pressing

The caul with the formed mat is carried by the conveyor into the cage of the press loader (15). The mats are edge trimmed before entering the press. This trim material is returned to the core metering bin and is reused. The multi-opening press (16) is of conventional engineering and designed for a specific pressure of 570 psi (40 kg/cm). The number and size of openings in the hydraulic, platen-type hot press depends upon the required capacity. After the infeed device of the press loader has fed the cauls and mats into the press, the press is closed (all platens simultaneously). Boards are cured under high pressure and temperature. Cycle time is based on 5 minutes for 1/2 in. (12.5 mm) thick board.

Unloading and Panel Sizing

Once the press has opened, the pressed panels are moved into the unloading cage (17) and discharged one by one onto an outfeed conveyor. After passing a separation station, the cauls are moved by a cross-transfer conveyor to the caul-return conveyor and returned to the forming line. The pressed panel first passes through double-edge and trim saws, then into a board turner for inspection which also delivers them onto a roller conveyor, feeding a hydraulic stacking elevator for strapping.

Depending on the end-use requirement of the panel, a sanding line and tongue-and-grooving equipment can be placed behind the trim-saw unit. Panel dimensions of up to 8 by 24 ft. (2.5 by 7.5 meters) can be produced and panel thicknesses ranging from 1/4 to 1 in. (6 to 25 mm).

Waste Burning Energy System

All OSB plants use a waste burning energy system. The system is designed to efficiently burn all residue materials generated during manufacturing. The sources of fuel are:

undesirable fine particles, panel edge and end trim, bark from the debarker, dust from sanded panels, any reject furnish at the forming station which cannot be reused, and the formaldehyde-laden exhaust fumes from the press. If all the previously mentioned panel sources are not adequate to generate the necessary heat requirement for the dryer, it can be supplemented by natural gas.

Production Parameters

The performance of an OSB panel is dependent upon a host of production variables. Much research effort has gone into developing the relationship between the many production variables and the ensuing performance of the panel. Table 4 shows the important production parameters and properties of waferboard and OSB. More detailed descriptions of them can be found in Zylkowski (1983).

Table 4. Important production parameters and properties of Waferboard and OSB.

PRODUCTION PARAMETERS

- Particle Parameters
  - Species
    - Wood density
    - Wood strength
  - Particle geometry
    - length
    - thickness
    - width
- Process Parameters
  - Resin content
  - Wax content
  - Press cycle
    - mat moisture content
    - press closing time
    - total press time
    - press temperature
  - Strand orientation
  - Board density

PANEL PROPERTIES

- Physical Properties
  - Density
  - Density gradient (thickness)
- Strength Properties
  - Modulus of rupture (MOR)
  - Modulus of elasticity (MOE)
  - Internal bond (IB)
- Durability in Use
  - Thickness swell (TS)
  - Linear expansion (LE)
  - Strength retention

Source: Zylkowski 1983.

Wood Raw Material

Alder is the most abundant and commercially the most important hardwood in Western Oregon. It is found along the coast from Clatsop County to Curry County in Western Oregon, and rarely more than 40 to 50 miles inland. It occurs at the lower altitudes in pure stands in rather small units and also mixed with Douglas-fir, Western Hemlock, Western Redcedar, and Sitka Spruce. Other hardwoods associated with alder are Bigleaf Maple, Black Cottonwood, Oregon Ash and Pacific Dogwood.

Properties of Alder

The wood is moderately light, even grained, and soft in texture. When alder is compared to an ideal plant type or ideotype in terms of maximum fiber yield, it fits well. Rapid juvenile growth, ease of vegetative propagation, crown shape, nitrogen fixation, microbiological relations, genetic variation, and early flowering are all criteria which show positive results (Gordon 1978). Based on this evidence, as well as reports on regeneration of alder, alder does not appear to be a difficult species to regenerate. Alder reaches sexual maturity at around ten years of age and produces large quantities of seeds annually, with bumper crops about every 4 years (Forest Industries 1972). Tarrant et al (1983) in their list of the characteristics of alder which suggests its potential value in intensively managed forests -- include rapid juvenile growth, a capability to improve soil fertility, a presumed capacity of rapid genetic improvement, and suitability for a wide range of products. Rapid early growth of unmanaged alder is well documented. Seedlings, may grow 3 feet or more in their first year. They may reach 30 ft. by age 5 years and more than 70 ft. by age 20. On well-stocked sites of high quality, mean growth increment may reach 150 CUF per acre per year for 20 to 40 year rotations (Tarrant et al 1983).

Furthermore, the usable yields of managed stands will be much higher. Trees in a 12-year-old alder plantation on the Oregon coast average 5.4 in. in diameter, whereas trees in unmanaged natural stands do not normally reach this size until age 20 (DeBell et. al. 1978). In addition, Stettler (1978) stated that alder may be the tree in the Northwest most ideally suited for rapid genetic gain per unit of time and effort. Alder is a lightweight and fast growing specie ideally suited for composite board material (Maloney 1978). Laboratory made alder flakeboard and OSB showed excellent MOE, MOR, and internal bond which exceeded those for competitive products. Table 5 shows the properties of alder wood, while Table 6 presents the properties of OSB produced from alder.

Table 5. Comparative wood properties of alder and aspen

Properties	Alder	Aspen
Density (pcf)	25.6	21.8
MOR (psi)	9,800	8,400
MOE (10^6 psi)	1.3	1.18
Compression strength ⊥ (psi)	440	370
Tensile strength ⊥ (psi)	420	260

1. Density is based on oven dry weight and green volume
2. ⊥ is perpendicular direction

Source: Wood Handbook 1974.

Alder Availability

In Western Oregon there are about 2.5 billion CUF of alder growing stock spread over 1.3 million acres of alder stands (Gedney 1982). It is found mostly along the coastal counties of Western Oregon. Table 7 shows growth and volume of alder for the Southwest, Westcentral, and Northwest regions of Western Oregon.

Table 6. Properties of alder OSB.

	% Resin and Direction		MOE	MOR	IB	LE^2	TS^3	% MOE retention		% MOR retention	
Density^1			10^6 psi	psi	psi	%	%	VPS	2HB	VPS	2HB
34	3	//	0.605	4056	68	0.111	55	96	84	86	76
		⊥	0.327	2668		0.130		77	82	72	54
	6	//	0.711	4688	104	0.090	34	84	67	89	59
		⊥	0.345	2999		0.125		82	71	62	54
39	3	//	0.811	5390	88	0.088	61	101	79	100	80
		⊥	0.373	3407		0.143		95	68	78	50
	6	//	0.971	6862	138	0.088	39	82	69	89	56
		⊥	0.395	3484		0.123		81	63	69	56
44	3	//	1.131	7616	108	0.069	66	90	69	85	66
		⊥	0.483	4277		0.105		81	72	66	49
	6	//	1.206	8374	152	0.058	41	83	60	81	56
		⊥	0.442	4087		0.105		99	78	72	63

1. Density in lbs. per CUF; MOE, MOR, and IB are density adjusted.
2. LE is measured from 50 to 90% relative humidity (RH).
3. TS is measured from 50% RH to wet condition after 2-hour boil.

Source: Zylkowski 1983.

Table 7. Growth and volume of alder in Western Oregon.

	N'west 1976	W'central 1976	S'west 1975	Western Oregon	Unit
Commercial forestland	554	389	351	1293	1000 acres
Growing stock	1113	753	681	2547	MMCUF
Net annual growth	50.5	22.2	22.8	95.5	MMCUF
Mortality	8.6	8.5	7.2	24.3	MMCUF
Sawtimber	2780	2157	2023	8904	MMBF Scrib.
Net annual growth	174.3	94.3	67	335.6	MMBF Int.
Mortality	23.3	30.5	21.4	75.2	MMBF Int.
	AVERAGE GROWTH AND VOLUME				
Growing stock	2009	1936	1940	1970	CUF/acre
Net annual growth	91	57	65	74	CUF/acre
Sawtimber	5018	5545	5763	6886	BF Scrib/acre
Net annual growth	315	237	190	260	BF Scrib/acre

Source: Gedney 1982.

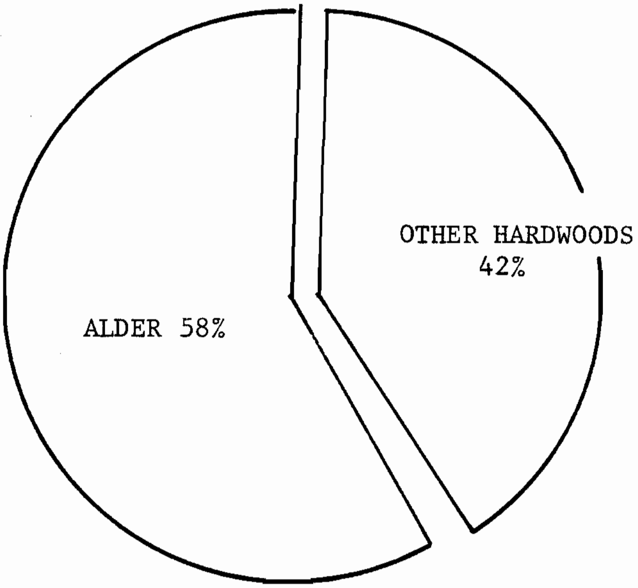


Figure 4a. Dominance of alder in hardwood forest types of Western Oregon.

Source: Gedney, 1982

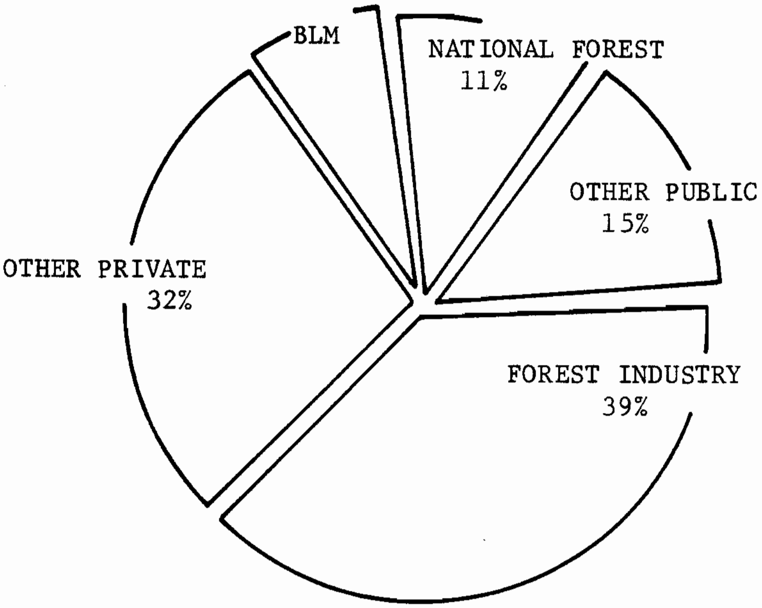


Figure 4b. Alder acreage ownership by type in Western Oregon.

Source: Gedney, 1982

Figure 4a shows that alder makes up about 58% of total volume of all hardwood forest types of Western Oregon or about 70% of the total volume of three principal hardwood stands (Gedney 1982). Most of the alder acreage is owned by forest industries (39%) and other private groups or individuals (32%), as shown on Figure 4b.

Based on alder acreage that occurs mainly along the coastal region, we chose three general regions for a proposed OSB facility with a raw material base of about 75 miles radius in each region (Figure 5). The regions are described as:

> Region 1, in Northwest Oregon, having a raw material base of three counties: Clatsop, Columbia, and Tillamook.
>
> Region 2, in Central Oregon, having a raw material base of Lincoln and Lane county.
>
> Region 3, in Southwest Oregon, having a raw material base in Coos and Douglas county.

Table 8 shows the growth and supply availability based on net annual growth with the current acreage for each proposed study region. Table 8 shows region 1, region 2, and region 3 each having the capability of supplying 26.6, 11.2 and 13.9 billion CUF, respectively each year. The density of alder stands run from 2,407 for region 1 to 3,447 CUF per acre for region 2.

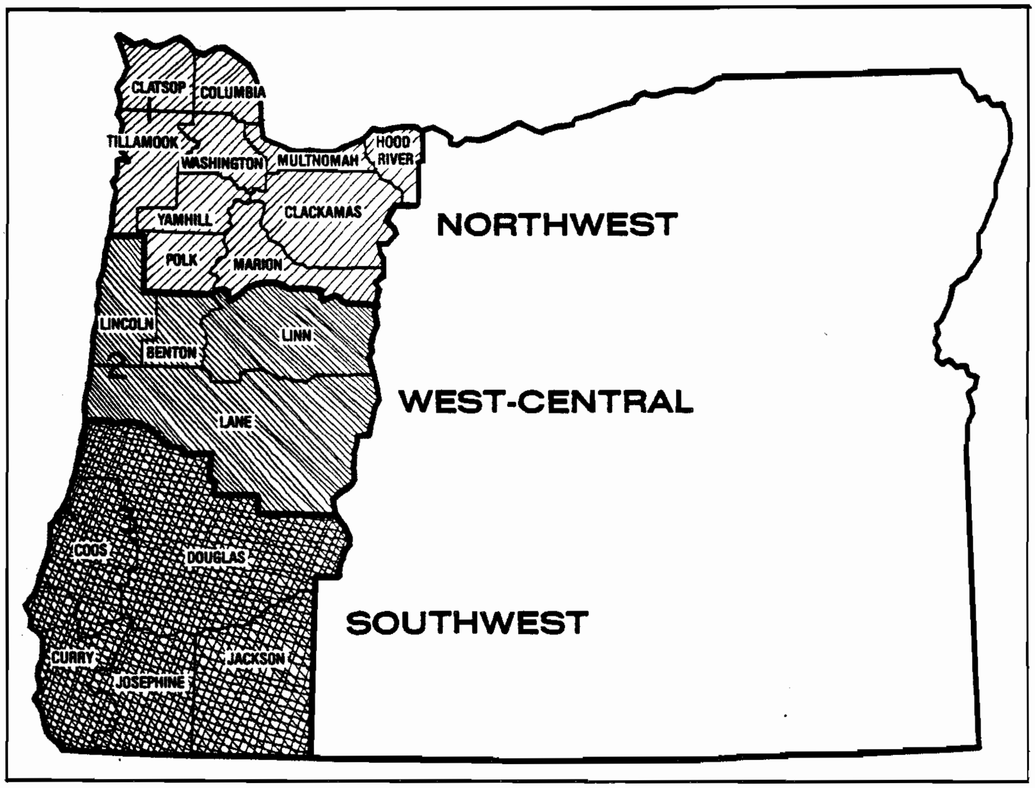


Figure 5. Western Oregon inventory units and three proposed alder supply regions.

Table 8. Growth and volume of Alder in each proposed region in Western Oregon.

	Region 1	Region 2	Region 3
Alder acreage (1000 acres)	292	197	214
Growing stock (MMCUF)	703	685	567
Average net annual growth (CUF/acre)	91	57	65
Supply based on average net annual growth and current acreage (MMCUF)	26.6	11.2	13.9
Percentage of growing stock of Alder per region (%)	25	30	21
Density (CUF/acre)	2,407	3,447	2,649

Source: Basset (1979), Jacobs (1978)
Mei (1979), Metcalf (1965), and Gedney (1982).

Figure 6 depicts the annual amount of alder for each region as well as the wood requirement for OSB plants at 75 to 250 MMSF annual capacities (3/8 in. basis), that is derived from Table 25. Based on the resource data currently available, we can see that region 1 is better suited to supply the alder regardless of the number or size of plants. Considering only a 150 MMSF plant, region 1 may easily supply three plants, region 2 and 3 have enough raw material to supply one plant of the same size. These estimates were made after considering the removal rate of the existing hardwood industries currently using alder, but not the possibility of alder stands which are inaccessible for logging, due to environmental protections. The estimates also did not consider the preference toward Douglas-fir from owner of mixed stands. The above estimates indicate that with sufficient resources, plant needs could be supplied from current growth of existing alder stands.

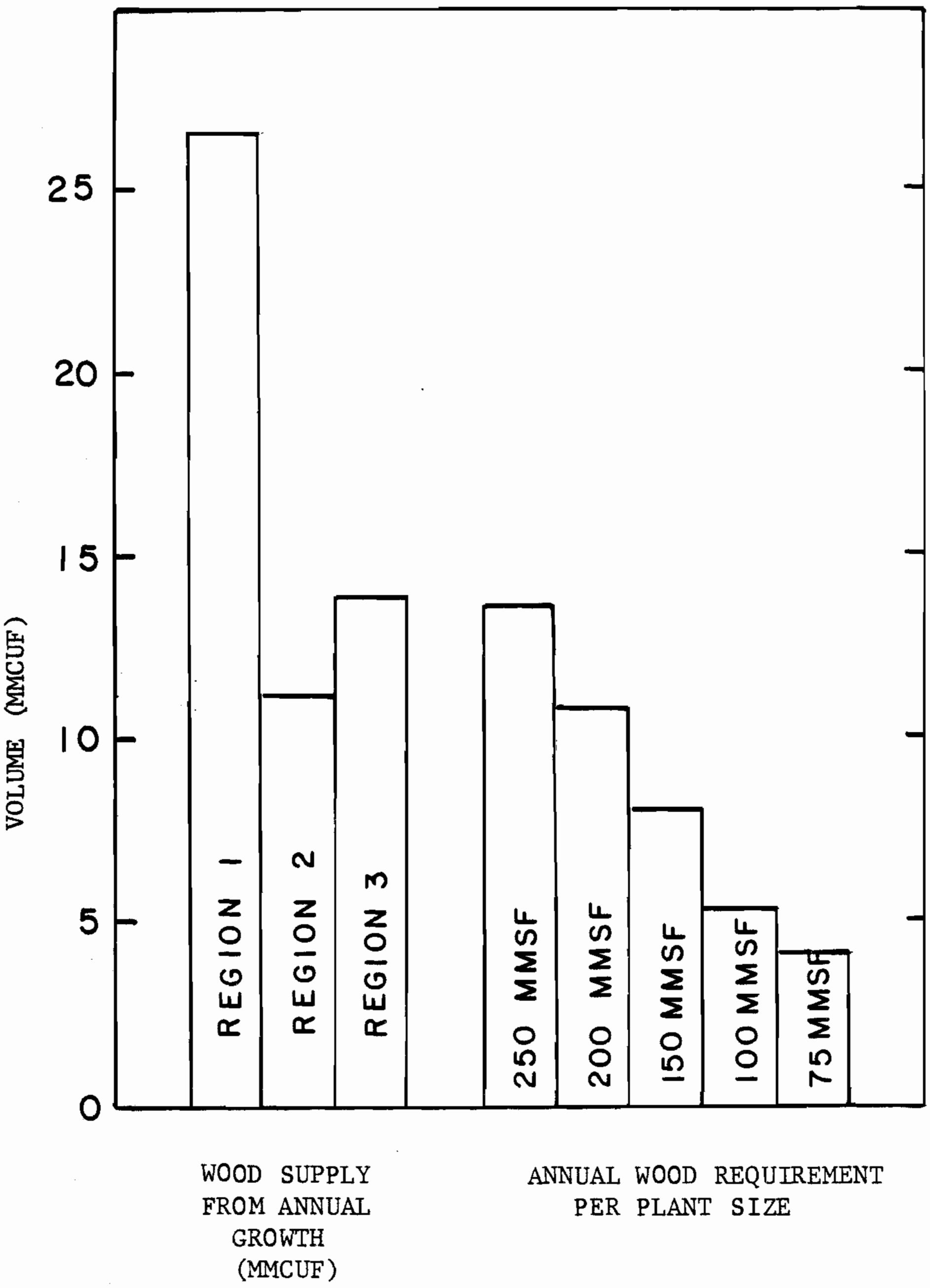


Figure 6. Comparison of annual growth of alder for each proposed region and wood volume needs for various sizes of OSB plants in Western Oregon.

It is important to note that if we also considered the amount of mortality as well as an assurance that stands will be better managed in the future, then the wood supply outlook for each region could be much greater. An improved wood supply should be able to support potential growth in other uses of alder, especially for pulp and lumber. However, to be sure about the wood raw material base, an expanded detailed study of the alder supply for each region should be made. Table 9 shows that utilization of hardwoods (including alder) in Western Oregon is very low. Figure 7, based on 1976 statistics (Forest Service 1977), shows that the mortality rate for hardwood is almost double the removal rate, while the removal rate itself amounted only to one tenth of the annual growth rate of hardwoods in the Western Oregon region. According to Resch (1980), it is safe to assume that 90% of the total hardwood log consumption by primary industries in Western Oregon consisted of alder.

Table 9. Total hardwood log consumption by primary industries of Western Oregon, 1976 figures.[1]

Mills	Number	Consumption (MMBF Scribner net)
Lumber	18	45.6
Veneer	1	3.0
Pulp/board	1	16.5
Log export	-	-
Survey total		65.1

[1] Assume 90 percent alder.
Source: Resch (1980).

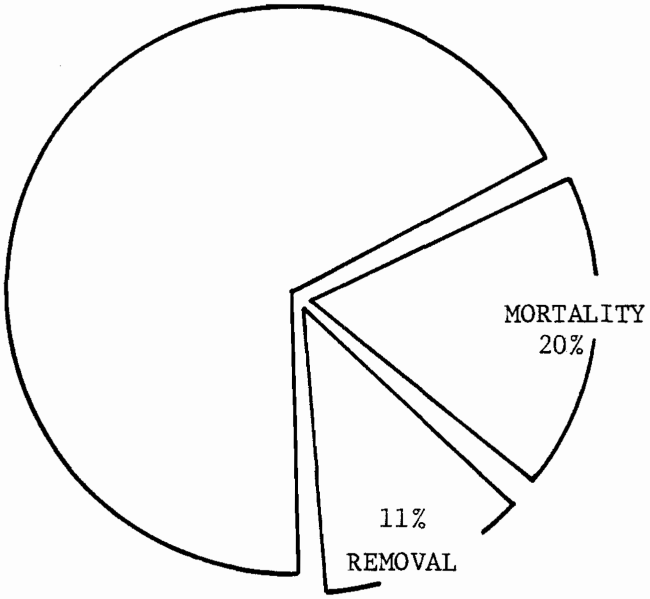


Figure 7. Comparison of removal and mortality rate from annual growth of hardwoods in Western Oregon.

Source: USDA Forest Service, 1977.

IV. MARKET ANALYSIS

Acceptance of OSB

Acceptance of OSB by the end-users is a challenging market problem faced by the producers. Builders, along with every one else are 'reluctant' to accept a new product when a known commodity (plywood) is readily available and relatively inexpensive. However, the experience in Canada, and in the midwestern, eastern, and southern US showed that structural reconstituted panels met with relatively quick acceptance when they came on the market (Irland 1982, Salomon Brothers 1983, Paper Tree Letter 1983 and Random Lengths 1984).

A limited survey made by Salomon Brothers in mid 1983, as well as the analysis by Random Lengths in mid 1984 and the market analysis of the Portland panel market (Kadera 1984), all showed acceptance of waferboard and OSB. The survey by Salomon Brothers were limited to 40 builders throughout the US, and was conducted to determine whether they use plywood or a substitute panel products -- either waferboard or OSB. It was found that 20 out of 40 builders are using waferboard and/or OSB. Tables 10 and 11 give survey results from a sample of builders in several regions of the US showing why they use or do not use the new structural panels as a substitute for plywood. Based on the survey, about 50% of the builders surveyed use OSB and/or waferboard and most of them stated its price advantage as well as its superior performance as the cause of their substitution. Also, there were a substantial percentage who stated they were not using the new product because it was not available locally (40%) or because of their own pre-conception that plywood is a much superior product (45%). (Please note that 50%-use is not synonymous with 50% of market share).

Table 10. Why builders use a substitute for plywood.

Region	Number of Users	Reason for use of substitute[1] Price	Average Savings	Superior Performance
Northeast	4	4	15%-20%	1
Northcentral	4	4	10 -15	1
South	3	3	10	2
West	1	0	NM	1
Southwest	4	3	10	2
Multiregional	4	4	NM	0
Total	20	18	12.5%	7

[1] Builders often had more than one reason
NM = Not meaningful
Source: Salomon Brothers (1983).

Table 11. Why builders do not use a substitute for plywood.

Region	Number of Non users	Reason for rejection of substitute Acceptance of Plywood	Price	Performance	Lack of Availability
Northeast	1	0	0	1	0
Northcentral	1	0	1	0	0
South	6	2	0	4	3
West	6	1	0	3	3
Southwest	5	3	0	1	2
Multiregional	1	1	0	0	0
Total	20	7	1	9	8

Source: Salomon Brothers (1983).

Competition between sheathing plywood and composite panels has spread among consuming markets as waferboard and OSB production began to steadily increase their shares of the market during the late 70's. Greater acceptance often initially came from attractive pricing, thus allowed them to take significantly greater portions of the structural panel market from plywood. According to Random Lengths (1984) the effect of increased OSB/waferboard acceptance has already been felt by plywood producers. Since 1980 the plywood industry has focused more on additional output of plywood specialties. Furthermore, the ready availability of an alternative to plywood sheathing has also affected product prices. Selling at a $35 discount to 3-ply plywood at the beginning of the year, waferboard sold in Dallas through much of the Spring 1984 much closer to the price of 3-ply CDX. Dallas and Atlanta, both prime Southern Pine plywood markets, have increased their share of reconstituted structural boards. Even in Portland, Oregon people are already starting to prefer OSB/waferboard (Kadera 1984).

Table 12 lists the current and projected end-uses of plywood and the new reconstituted panels and also shows that OSB has the potential to compete in most of the same markets presently dominated by plywood.

Table 12. Current and projected end-uses of structural reconstituted panels and plywood.

End - uses	OSB	Waferboard	Plywood
Roof sheathing	X	X	X
Wall sheathing	X	X	X
Sub floor	X	X	X
Underlayment	X	X	X
Interior paneling millwork	X	X	X
Exterior siding	X	X	X
Soffits	X	X	X
Foundations			X
Shelving			X
Steps			X
Cabinets			X
Nonresidential construction	X	X	X
Remodeling and repair	X	X	X
Mobile home decking	X	X	X
Musical instruments/toys			X
Pallets	X	X	X
Containers	X	X	X

Source: Pennington (1984).

So far, the market for reconstituted structural panels has been developed for the general utility application of the DIY homeowner, and for roof and floor decking. However, the scheduled expansion of production, as well as new uses, will develop new markets and surely will affect panel markets in other regions -- including the Pacific Northwest (Maloney 1981, Random Lengths 1984).

Market Description

The OSB market, as for most other wood products is essentially a free market. Panel products are sold in much the same manner as cattle, wheat, and other agricultural products. There is no set year-round prices. The seller usually sells at the highest attainable price, and the buyer purchases at the lowest possible cost. Production volume, price of substitutes, availability, and demand are the key determining factors. The US economy is in the early stages of a slow and tedious recovery from a recession (APA 1984). Many uncertainties still exist in both domestic and world outlooks. While inflation appears under control for the short term, an inadvertent move by the Federal Government could cause havoc. On the other hand, world politics could have a negative impact on the world banking system, an eventuality that needs to be fully considered (APA 1984).

Residential Construction

Housing has traditionally been the major market for structural panels and the cornerstone of the wood industry. The demand for housing is the result of many interacting forces. Housing continues to be a very interest rate sensitive industry -- reacting to a lower mortgage rate with positive growth, while slowing down when rates increase (Guss 1979). Statistics for housing starts from 1976 to 1983 show that the trend for housing consumption has gone down quite sharply since 1979 (Table 13).

However, the 1983 figure shows some improvement. 1983 is unique because it follows three years of housing depression. A backlog of ready-to-buy families is prepared to move at the first sign of affordability. According to APA (1983) the American dream still lives, families want a home of their own, and there are more families too! During 1982, 2.5 million couples got married, the largest number ever. And only 1.8 million got divorced, 3% below 1981 figures. Furthermore, housing is becoming more affordable due to FHA/VA funds, tax free housing bonds, buy downs, and work-sharing projects.

Table 13. Housing starts by type, 1976 to 1983 (privately owned units in thousands).

Year	One-family	Multi-family	Total
1976	1,163	379	1,542
1977	1,451	536	1,987
1978	1,433	587	2,020
1979	1,194	551	1,745
1980	852	440	1,292
1981	705	379	1,084
1982	663	400	1,063
1983[1]	922	534	1,456

[1] November and December data for 1983 not available

Source: Random Lengths Yearbook 1983

The APA prediction of housing starts for the near future are quite optimistic, as listed below:

Table 14. Housing starts forecast for 1984 to 1989 in thousand units.

Year	Single-family	Multi-family	Total
1984	1,100	600	1,700
1985	950	500	1,450
1986	1,000	550	1,550
1987	1,075	575	1,650
1988	1,100	600	1,700
1989	1,125	625	1,750

Source: APA (1984)

This prediction of housing seems to state that substantial and continuing demand for housing will exist over the next five years, despite the unprecedented high interest rates and lack of available mortgage funds in recent years. In other words, the demand is here and it is growing.

Structural Panel Usage in Housing

The addition of nonveneer structural panels will tend to hold back panel cost increases, thus expanding market usage. In addition, new uses, like the all-weather foundation, and the Plen-wood underfloor heating/cooling system are all economical and their use will expand panel use per unit. Table 15 below, shows the forecasted size and use of structural panels in housing for the next five years (APA 1984).

Table 15. Predictions of average floor area and use of wood panels per unit, for 1984 to 1989 (in square feet).[1]

Year	Average floor area		Use/sq.ft.floor		Use/unit		Average
	Single	Multi	Single	Multi	Single	Multi	All units
1984	1700	990	3.3	4.0	5610	3960	5044
1985	1650	980	3.3	3.9	5445	3822	4877
1986	1650	980	3.4	4.0	5610	3920	5010
1987	1675	990	3.5	4.0	5863	3960	5200
1988	1690	1000	3.5	4.1	5915	4100	5274
1989	1700	1050	3.6	4.1	6120	4305	5471

[1] Based on estimate of housing starts (Table 14).
Source: APA 1984

The size of the single family unit is expected to moderate slightly in the near term, and then recover to its 1983 level. After 1986, the size of multi-family unit is expected to gradually increase on the average as it has for the past five years. It also shows that the nature of housing will change in response to affordability and the basic cost of money. Builders are currently seeking ways to build energy efficient homes that first time buyer can afford. The effect will be smaller homes on the average for the next two years. Then, when the supply of starter houses has been met, builders will concentrate on building larger homes. In addition to conventional housing, APA (1984) estimates an average of 300,000 mobile home units will be built annually by the industry.

Other Markets

Although housing is the cornerstone of structural panel demand, other markets such as repair and remodeling, nonresidential construction, industrial markets, and exports are collectively its largest consumers. Fortunately, non-housing applications are less volatile.

Repair and Remodeling

The largest non-housing market for structural panels is also called the distribution market. This market consists mostly of homeowner uses, but also includes miscellaneous uses not easily quantified — those being served by the distribution trade. The very large direct consumer purchase markets include both DIY and small contractors or shoulder trade for a wide variety of tasks about the house. These range from minor repair to rather substantial remodeling and additions. Many of these expenditures are for fairly definable reasons such as re-roofing and re-siding, but many miscellaneous uses are not easily quantified. Home repair and remodeling dominates product uses in this market.

Uses for additions, alterations, and major replacements account for about 90% of panel consumption for this market category (Maloney 1981). Bureau of Census reported annual expenditures for 1973 and 1978 at $18.5 and $37.5 millions respectively, while for 1981 and 1982 it amounted to $42.1 and 45.3 millions (APA 1984). Guss (1981) offered reasons for growth of the home repair market. They include the high cost of housing, the difficulty of finding (or affording) conventional repair or remodeling contractors, and the increasing degree of pride in ownership. The increasing affluence of society and the wide variety and attractiveness of products designed for amateur installations also plays a big part. Wall paneling, tile flooring, and ceilings are the best examples.

Retail building material suppliers today include not only the traditional lumberyard, but also the mass merchandiser oriented to the DIY market and the paneling display stores. The recent growth of DIY oriented retail building material stores, open seven days a week, with individually priced items has stimulated this market. This market has a broader customer base, but a smaller purchase value per customer, when compared to other applications. With a broader family of products created by OSB and waferboard, more possibilities are expected.

The APA (1984) forecast that recovery in repair and remodeling is expected for 1984 and succeeding years; this should translate into a structural panel demand increase of 3% annually.

Nonresidential Construction

Nonresidential building construction slowed during 1983, but is expected to regain its upward thrust as the economy recovers. It has been affected by many factors such as surplus office spaces, fewer school children, lower college enrollment, underutilized capacity, and inflation. The APA in 1984 predicts that major growth for the near term will be in small commercial structures that follow new housing. An over-supply of office and institutional buildings is still in place and activity will continue to slow until the utilization rate is at an economically acceptable level. By 1985 this sector should begin to recover. Plants and warehouse structures should start to turn around by mid 1984 and continue strong through 1990.

The APA also expects structural panel use per unit to increase in the near future because more wood use occurs in small buildings which are expected to dominate the construction scene. Later, the impact of joint industry promotion is expected to be positive. The estimated private and public nonresidential construction expenditures and year-to-year changes are shown in Table 16.

Table 16. Prediction of nonresidential construction expenditures, from 1984 to 1989.

Year	$ Billion	Percent change from year earlier
1984	123.4	+ 4.7 %
1985	129.3	+ 4.7 %
1986	124.6	- 3.7 %
1987	127.1	+ 2.0 %
1988	129.5	+ 1.8 %
1989	132.8	+ 2.5 %

Source: APA (1984)

Industrial Market

The quantity of structural panel use changes in each of the many varied industrial markets, sometimes by activity levels related to economic conditions and sometimes by product substitution and change in practices. A gradually improving economy and increasing housing activity are positive for industrial market demand increases. More activity means more material handling devices, more transportation equipment, and more furniture, fixtures, and signs. These are the major applications for structural panels.

Material handling includes pallets, crates, industrial shelving, mezzanine decks, liquid storage and handling trucks, agricultural and industrial bins, and other devices that facilitate the handling and shipping of goods. These end-uses generally follow the economic growth cycle. However, increased market share is often obtained in down markets as material handling systems are designed to cut cost. On the upcycle, increased demand sometimes puts pressure on the supply side to delay orders and put a cap on the amount of increase. The outlook for material handling is optimistic as more industries turn to structural panels for use in devices to lower handling costs. The expected year to year changes are shown in Table 17.

Table 17. Percent change in industrial consumption of structural panels, 1984 to 1989.

Year	Material handling	Transportation equipment	Products made for sale	Other industrials[1]
1984	+ 4	+ 6	+ 4	+ 3
1985	+ 2	+ 2	+ 2	+ 1
1986	+ 1	---	- 2	+ 1
1987	+ 3	+ 3	+ 3	+ 3
1988	+ 4	+ 2	+ 2	+ 4
1989	+ 4	+ 5	+ 2	+ 4

[1] Includes plant repair and maintenance.

Source: APA (1984)

Transportation equipment (Table 17) includes truck and bus bodies, rail cars, aircraft, boats, RV, and cargo containers. The trucking industry has been growing steadily at the expense of the railroads. Its growth expectations are reflected in the industrial consumption of structural panels (Table 17).

Products made for sale include furniture, fixtures, toys, games, signs, and many other items where panels serve as a part or a substrate. Material use in these fields is dominated by particleboard and medium density fiberboard (MDF). Shifts in use by these users often happens. There are trends to shift to softwood plywood and consequently some potential exists for OSB and waferboard. The general trends of furniture and fixtures sets the tone for consumption by this market (Guss 1981).

Other industrial uses include plant repair and maintenance, and miscellaneous other uses. The trends expected for this market category are also shown in Table 17.

International Market

The world market offers tremendous opportunities for increases in structural panel volume. Most countries can increase the number of housing units they build by increasing the structural wood components used. At the same time, continuous usage in concrete forming, crating, and utility markets consumes an increasing quantity of American structural panels. The European economy is currently coming out of its recession. New opportunities are being identified in Latin America, and building code blocks in Japan have been finally lifted. Despite a world recession since 1979, exports from the US have held steady near 500 MMSF, 3/8 in. basis, annually. About 70% of this amount goes to Europe and the rest to Caribbean/Latin America and Japan (APA 1984). Following a brief catch-up period in 1985, sharp increases in exports of structural panels are expected in 1986 and 1987.

Applications for OSB

Total consumption of waferboard in the US in 1978 was about 335 MMSF (3/8 in. basis), of which the US supplied about 80 MMSF and the balance of about 255 MMSF was produced in Canada (Maloney 1981). In 1983 the waferboard and OSB production soared to 1.2 BSF, all consumed in the US (Pease 1984). In 1978 the consumption of structural reconstituted panels was concentrated in the Northcentral states which used about 78% of the total amount. In early 1984 these had penetrated areas that are primarily Southern Pine plywood markets such as Dallas and, Atlanta (Random Lenghts 1984) as well as Portland, Oregon (Kadera 1984).

Residential Construction

New construction is obviously the largest market for structural panels, accounting for about 40% of total consumption (Maloney 1981). However, contractors often oppose new products because of resistance to change and the learning process required to adopt new products. Several experts even recommended changes in the current building codes in order to gain wider acceptance of reconstituted structural panels.

Roof Sheathing

Most building codes now approve the use of 7/16 in. thick waferboard for roof sheathing on residential construction. In order to be accepted, usually the product must be available at local levels and priced favorably in comparison to softwood plywood, that is, to 1/2 in. CDX for roof sheathing.

Wall Sheathing

Wall sheathing is a well established market for reconstituted structural boards in some parts of the country (Guss 1981, Irland 1982). However, there are many different kinds of acceptable wall sheathing, many costing less than OSB/waferboard. Most of them though, have no structural strength and nailability -- but do contribute to thermal insulation.

Floor System

This application represents a major opportunity in new construction that is still almost untapped. Even though, on a surface measurement basis, the roofing market is larger, floor systems usually utilize thicker components, thus consuming more volume. So far, only one brand of waferboard has qualified for subfloor use (Maloney 1981), but other producers are already qualifying their products.

Cladding (siding) Market

Like the floor system, OSB applications for siding market have also expanded in recent years. In particular, Lousiana-Pacific is bringing on new plants just to produce siding. To use panels for side walls, accents and gable ends, the panel usually has to be weatherproof and have an attractive appearance. Most siding does not contribute to the structural integrity of a house, although 5/8 in. plywood is sometimes used without sheathing for structural purposes (Maloney 1981). As a cladding, waferboard and OSB do not conform to traditional appearances. However, the relatively low price of reconstituted structural panels may make them suitable for cladding low-cost housing units or as a panel in Tudor construction (APA 1984).

Nonresidential Construction

In nonresidential construction, the application for OSB exists in roof decking, concrete forming, agricultural buildings and shelters, barricades, shoring, and other miscellaneous materials in construction (Guss 1981). These uses depend on trade promotion, code approval, and availability in local markets. Several firms are now making prefab agricultural buildings such as animal and machinery sheds from waferboard and OSB. Panels larger than 4 by 8 ft. are advantageous in some applications

Industrial Application

Mobile Home Construction

Waferboard and OSB usages that already penetrate mobile home construction markets, may increase modestly (Maloney 1981). The best opportunity lies in replacing plywood roof sheathing for double wide units (APA 1984). OSB in panels larger than 4 by 8 ft. would be an advantage, although the heavier weight of the larger panel may be a disadvantage. Mobile home decking is the largest structural panel application in mobile homes and this will remain dominated by particleboard, unless regulations to eliminate formaldehyde traces increase particleboard prices significantly (Guss 1981). Also, the increased cost of urea-formaldehyde bonded particleboard should permit the newer panels to be more competitive in mobile home decking.

Material handling

The material handling market offers potential for reconstituted structural panels, especially for pallets. According to Guss (1981), structural reconstituted panels can replace 25% of this market -- although it still needs further research to gain wide acceptance.

Recreational Vehicles (RV)

The RV market provides the best opportunity for OSB. Panels larger than 4 by 8 ft. have already achieved significant market penetration as single piece flooring, although the weight is a deterrent in some applications for smaller RV's.

Consumer Repair and Remodeling

Consumer repair, remodeling and additions provide one of the largest US markets for OSB/waferboard. The product is marketed through distributors and retailers and is sold for paneling and other types of remodeling and construction purposes. In additions and alterations, contractors would ordinarily use the same type of material as used in new construction. However, the DIY homeowner may substitute available OSB/waferboard for plywood. The increasing growth of these markets should assist the marketing of OSB.

We can see that while a major amount of reconstituted structural panels will be used in structural applications, an important share will be used for semi-structural ones such as siding or for non-structural ones such as wall paneling. This also implies the further expectation that OSB/waferboard based products will open the way for a class of overlayed or otherwise finished panels suitable for a broad array of uses. To better grasp the range of applications of OSB in recent years, as well as its potential, Table 12 lists the current and potential uses while Table 18 lists uses in the near future and by the year 2000.

Demand for OSB/waferboard in the future will be based on three big markets as follows (Guss 1981, Maloney 1981):

1. Replacement of sheathing grade softwood plywood and some underlayment particleboard in on-site construction application.
2. Developing a new market as a utility panel for the DIY and small contractor markets.
3. Replacement of conventional particleboard and softwood plywood in several industrial applications.

Building codes, lack of knowledge, and availability are the main limiting factors usually cited as influencing wider use of OSB. To overcome the current barrier, Maloney (1981) put forward some basic requirements to be met by OSB and its producers. The panel should be well manufactured with properties at least equal to plywood, priced at 10 to 15% below the prevailing price of 1/2 in. CDX 3-ply sheathing, agency stamped and supported by a modest but well-planned promotional effort. As the barriers are lowered, the demand for reconstituted structural panels should increase -- providing a favorable pricing structure is retained. The situation will also change when OSB waferboard plants in the South and the West are completed. Locally produced OSB will have ready availability, low transportation cost and increasing marketing availability. This somewhat rosy picture is also shared by APA from their forecast of future demand in all of its major markets for the year 1989 (Figure 8).

Table 18. Potential replacement of softwood plywood by structural reconstituted panels by the year 2000.

USE	POTENTIAL
Roof sheathing	Up to 50% of West Coast and Southern 1/2 and 3/8 in. CDX replaceable.
Side wall sheathing	75% of all plywood potentially replaceable, but usage relatively low.
Floor systems	Just qualified. After approvals, from 1/2 to 1/3 of this use obtainable.
Miscellaneous uses storage, shelves, counters, fascias, soffits, decks, fences, screens, inset panels, etc	None of these are load bearing, and for many waferboard's good-two-face characteristic is advantageous. Some require smooth surfaces and are not available without it. Up to a half of the market available.
Nonresidential roof deck	Requires code approval. Ability to obtain 10 ft. panel useful. About 25% of plywood's market obtainable.
Shelters, barricades, ramps, general facilitating	OSB/waferboard meets all uses better. Up to a half replaceable.
Materials handling	Some uses require high structural strength and/or are government specified for plywood. Others are readily penetrable. A fifth of plywood is replaceable.
Utility panels for shoulder projects, etc	A very large market for plywood which is a trade: repairmen and consumers prefer plywood, but for many applications will accept OSB/Waferboard, especially if it is promoted. Up to a third of this plywood is replaceable, plus growth in its own right.
Furniture, fixtures, and industrial parts	Small volumes of softwood plywood used. An estimated third is replaceable by OSB/waferboard, based on its solid core, even with its surface disadvantage.

Source: Maloney 1981.

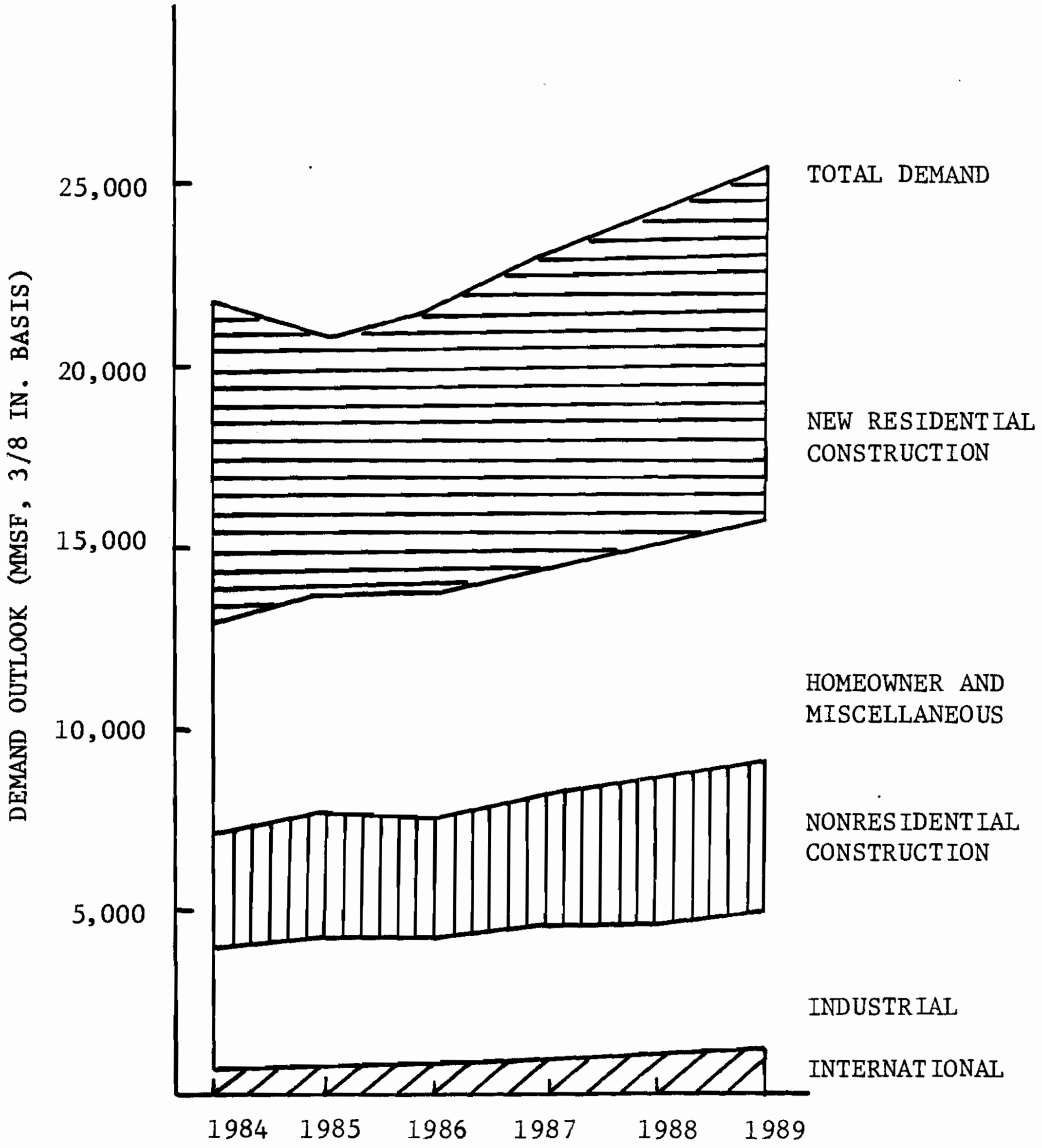


Figure 8. Total demand outlook of structural panels by end-use market, 1984 to 1989, in MMSF, 3/8 in. basis.

Source: APA, 1984.

Market Share

The outlook for the next five years for reconstituted structural panels is reasonably bright. An estimated increase in market demand for structural panels will reach 15.45 BSF by 1989 (Table 19). The annual increase in each market is shown in Figure 8.

Table 19. Estimated increases in market demand for structural panels 1983 to 1989 (MMSF, 3/8 in. basis).

Market	1983	1989	Increase		Percentage of total increase
			Volume	%	
New residential	8350	9600	1250	15	27
Repair, remodeling	5600	6500	900	16	19
Industrial	3200	3800	600	19	13
Nonresidential construction	3050	4250	1200	39	26
Exports	600	1300	700	11	15
Total	20800	25450	4650	22	100

Source: APA (1984).

Experts estimate that in five years there will be a 4.65 BSF increase in demand for structural panels -- with the largest increase of 27%, 26%, and 19% forecasted for new residential, nonresidential, and DIY markets, respectively. Table 2 showed production estimates for OSB/waferboard that amounted to 1.85 BSF or 8.6% of the total production of 21.6 BSF for 1984. The 1989 figures show 3.5 BSF or about 12.8% of the total structural demand of 25.45 BSF. The above figures are more optimistic when compared to other forecasts. Another estimate (Table 20) shows a total demand of 24.49 BSF by 1989. Pennington assumed an estimate for house construction starts of 1.5 MM units annually. He also made assumptions for annual increases in nonresidential and industrial construction of 3% each, with increases for export and remodeling/repair of 5 and 6%, respectively. Figure 9 shows the alternative projections for structural panel demand when compared with current capacity.

Specific data about the current market share for reconstituted panels is not readily available.

Table 20. Housing starts[1] and structural panel market[2] projections, 1984 to 1990.

	1984	1985	1986	1987	1988	1989	1990
Housing starts	1750	1750	1785	1820	1850	1890	1930
Residential construction							
Single-family	4980	5040	5100	5150	5220	5280	5340
Multi-family	2390	2445	2500	2555	2610	2665	2720
Mobile-homes	230	235	240	245	250	255	260
Total	7600	7720	7840	7960	8080	8200	8320
Remodeling	7400	7640	7880	8120	8360	8600	8840
Nonresidential construction	3080	3180	3280	3380	3480	3580	3680
Industrial	2920	3010	3100	3190	3280	3370	3460
Total consumption	21000	21550	22100	22650	23200	23750	24350
Exports	750	800	850	900	950	1000	1050
Imports	210	220	230	240	250	260	270
Production	21540	22130	22720	23310	23900	24490	25080

[1] In thousand units

[2] In MMSF, 3/8 in. basis

Source: Pennington 1984.

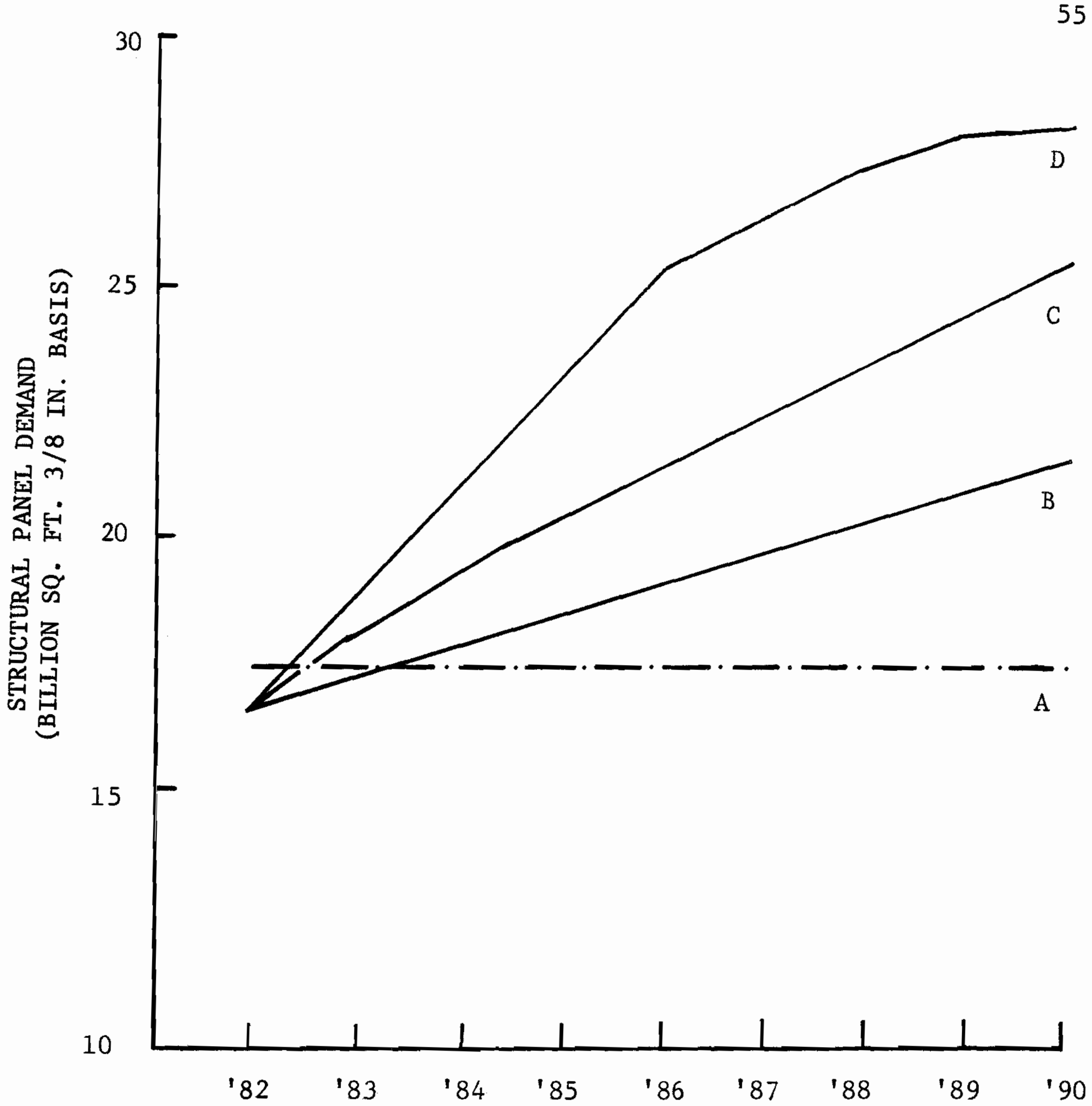
Table 21. The top five markets for plywood in the Western region based on reported shipments, 1983 figures (MSF, 3/8 in. basis).

Trading area	Western region shipments	Western percent of total shipment to area
Los Angeles	736,482	87.8
Portland	586,902	85.7
San Francisco	532,835	85.7
Seattle	308,271	78.2
Phoenix	192,442	89.1
Subtotal	2,356,932	85.3
Total Western shipment to all markets:	4,394,155	
% of total Western shipment to 5 trading areas:	54%	

Source: APA 1984.

Table 21 shows the total shipment of structural plywood from Western production areas to the top five market regions (Los Angeles, Portland, San Francisco, Seattle and Phoenix) which amounted to 2.357 BSF in 1983. If we assume a penetration basis of 20%, there will be a 470 MMSF market share available for reconstituted structural panels.

In order to meet the increased demand of 5 BSF, APA (1984) estimates the need for 13 new nonveneer structural panel plants with a total capacity of roughly 2.5 BSF by 1989. When we consider the Western portion of this market as 20% (a very rough estimate), then there will arise a demand for 500 MMSF or about 5 additional mills with an average capacity of 100 MMSF. This estimate does not take into account the possibility of a decrease in plywood capacity of the West because of a need to close some marginal operating plants, as well as the volume that will come from the waferboard plant in Chilco, ID (which started operation in mid 1984 with a 70 MMSF capacity) and the proposed plant in North California (with a planned capacity of 75 MMSF).



A = current capacity
B = 1.3 million annual housing starts
C = Morgan-Stanley 1982 predictions
D = 1.9 million by 1985; 2.0 million 80's average

Assumptions for annual increase in

Nonresidential construction	3%
Industrial uses	3%
Exports	5%
Remodeling and repair	6%

Figure 9. Alternate projections of U.S. structural panel demand, 1982 to 1990.

Source: Pennington, 1984.

An OSB plant starting up in 1985, with an annual capacity of 150 MMSF could claim a potential share of almost one-fourth of the total estimate for reconstituted structural board markets of the top five destinations of the Western region market share.

In later years, other opportunities for secondary markets as well as export will become available. On the consumer level, increases should be expected because of improved properties and the availability of OSB in the local market. Our assumption of a 20% market share for structural reconstituted panels is similar to percentages that already have been obtained in Dallas and Atlanta (Random Lengths 1984) and much lower than the market shares for Eastern Canada, Mideast and Midwest US (Irland 1982).

OSB produced in Western Oregon would have one basic advantage over other OSB from plants located in the East and the South. It will be in a better position to serve the Western market. For the near future, we are not considering the proposed Western Oregon plants to serve other regions because of freight disadvantages. Furthermore, reconstituted structural panels are better suited for regional markets. However, further assurance of the market share needs a more specific study, especially one that deals only with OSB/waferboard and not with structural boards in general.

V. FINANCIAL ANALYSIS

Emphasis in the financial analysis is on raw material requirements, production costs and also on preparation of financial statements to evaluate the commercial feasibility of manufacturing OSB in Western Oregon. We will also conduct sensitivity analyses of those factors most affecting production cost and internal rate of return.

In this study, based on the results of the study by Zylkowski (1983), we propose to manufacture an OSB panel with a density of 40 pcf using alder with an average specific gravity (ovendry) of 0.41 and resin and wax contents of 5% and 2% respectively. Our base case is for a plant using alder wood as its raw material, has an annual capacity of 150 MMSF (3/8 in. basis), and is located in a coastal county of Western Oregon. Table 22 shows the financial summary of the proposed OSB plant in our base case as well as employee and raw material requirements.

Table 22. Financial summary for one year operation of a 150 MMSF (3/8 in. basis) OSB plant using alder (1984 cost figures).

Capital investment	$34,000,000
Annual operating cost	18,529,350
Annual sales	24,150,000
Annual gross profit	5,620,650
After tax profit (50%)	2,810,325
Depreciation	2,400,000
Cash flow	5,210,325
Return on sales	21.57%
Return on investment (before tax)	15.32%
IRR for 10 year operation (after tax) . . .	15.10%
Payback period (in years)	5.18
Employees	112
Energy requirement:	
Electrical	28.125 MMKWH
Other	68,716 MCF
Wood requirement	8.145 MMCUF green or 104,167 ODT

Raw Material and Energy Requirement

Raw material and energy requirements for the specified OSB capacity were computed using the Parvcost computer program developed by Harpole (1977). Parvcost is a mathematical model of wood, chemical, and energy flows within an operating board plant. It computes physical requirements and cost of wood, chemicals, and energy per unit of finished panel output of various thicknesses as well as finished panel weight statistics for the proposed base case. The input data as well as assumptions for the computations are listed in Appendix B.

Table 23 shows board statistics of the finished panels, while Table 24 lists the raw material and energy requirements for various panel thicknesses. The value for wood, resin, and wax in Table 24 included the waste factor and other losses of raw material during production. The waste factor for wood, resin, and wax are 16%, 28%, and 7% respectively. Almost all of these waste could be recycled back in to production. All the undesirable fine particles, panel edge and end trims, dust from sanded panels, and any reject furnish at the forming stations could be utilized as a source of fuel.

Table 23. Board statistics for varying thicknesses using alder.

Specifications	LBS/ CUF	LBS/MSF			
		3/8 in. basis	7/16 in. basis	1/2 in. basis	5/8 in. basis
Gross board weight	42.4	1325	1544	1767	2208
Weight of water (6%)	2.4	75	88	100	125
Ovendry weight of board	40.0	1250	1458	667	2083
Weight of resin (5% liq.)	2.0	63	72	83	104
Weight of wax (2% solid)	0.8	25	29	33	42
Weight of wood	37.2	1163	1356	1550	1938

Table 24. Raw material and energy requirements for OSB production (based on a plant size of 150 MMSF, 3/8 in. basis).

Raw material and energy	Requirement per				
	CUF	MSF 3/8"	MSF 7/16"	MSF 1/2"	MSF 5/8"
Wood (OD. SG = .41)					
O.D. wood (lb)	44.5	1389	1620	1852	2315
Green wood (lb)[1]	80.0	2500	2917	3334	4167
Solid wood (CUF)	1.7	54	63	72	91
Resin (lb. liq.)	2.2	87	80	91	114
Wax (lb. solid)	.9	27	32	37	46
Heat energy (MCF)	.015	.46	.53	.61	.76
Electric power (KWH)	6.0	188	219	250	313

[1] Average moisture content = 80%.

An average of about 0.69 ODT of alder raw material is needed to produce 1 MSF, 3/8 in. basis. Table 25 shows the annual raw material and energy requirements for various sized plants ranging from 75 MMSF to 250 MMSF.

Table 25. Raw material and energy requirements for OSB plants of various capacities.

Raw material and energy	Capacity (MMSF 3/8 in. basis)				
	75	100	150	200	250
Wood (OD SG=.41)					
OD wood (Ton)	52084	69445	104167	138890	173612
Green wood (Ton)	93754	125005	187507	250010	312512
Solid wood (MMCUF)	4.072	5.430	8.145	10.860	13.575
Resin (Ton liq.)	2569	3425	5138	6851	8564
Wax (Ton solid)	1027	1370	2055	2740	3425
Heat energy (MCF)	34358	45811	68716	91621	114527
Electricity (MKWH)	14062	18750	28125	37500	46875

An average of 104,165 ODT of wood is needed to supply a plant with an annual capacity of 150 MMSF, 3/8 in. basis. The current alder wood price used in this study is based on information collected from several members of the Northwest Hardwood Association. From telephone interviews conducted in July 1984, the price for alder pulpwood delivered to mills along the Oregon coast ranges from $16 to $20 per wet ton, while prices for sawlogs with diameters of 8 to 9 in., as well as 10 in. and larger, are slightly higher. For our base case we use the price of $20 per wet ton of alder pulpwood with an average moisture content of 80% when green. Based on the above assumptions, we arrived at a price of $36 per ODT of alder. From Table 12, 1 ODT of alder is equal to 78.125 cubic feet of alder. By using this equation, we arrived at a price of $0.46 per cubic foot of green alder or $46 per cunit.

Based on an alder cost of $46/cunit or $36/ODT and other major variable costs as of 1984, Table 26 shows the gross variable costs for raw material and energy requirements for varying thicknesses. Table 27a and 27b list a limited sensitivity analysis of the major variable costs to the total cost of raw material and energy, based on the current raw material and energy requirements presented in Table 26.

Table 26. Major variable cost -- raw material and energy -- for producing OSB panels of varying thicknesses using alder.

Requirement	Cost	Cost ($/MSF)			
	$/CUF	3/8 in.	7/16 in.	1/2 in.	5/8 in.
Wood ($.46/cunit)	.78	25.0	29.1	33.1	41.6
Resin ($.35/lb/liq)	.77	24.0	28.0	32.0	39.9
Wax ($.20/lb solid)	.18	5.5	6.4	7.3	9.1
Heat energy ($3/MCF)	.04	1.4	1.6	1.8	2.3
Electricity ($0.05/KWH)	.30	9.4	10.9	12.5	15.6
Total gross variable cost	2.09	65.2	76.0	86.9	108.6

Table 27a. Sensitivity of gross variable cost (wood, resin, and energy) per MSF of finished product output.

Var. cost/MSF = 40.197 + 0.6945 X (wood cost/ODT)
Var. cost/MSF = 40.197 + 54.290 X (wood cost/CUF)
Var. cost/MSF = 41.201 + 68.481 X (resin cost/lb)
Var. cost/MSF = 59.691 + 27.373 X (wax cost/lb)
Var. cost/MSF = 55.795 + 187.50 X (electricity cost/KWH)
Var. cost/MSF = 63.796 + 0.458 X (price of natural gas/MCF)

Table 27b. Sensitivity of total production cost to major material cost per MSF of finished product output.

Production cost/MSF = 98.56 + 0.6945 X (wood cost/ODT)
Production cost/MSF = 98.56 + 54.290 X (wood cost/CUF)
Production cost/MSF = 99.56 + 68.481 X (resin cost/lb)
Production cost/MSF = 118.05 + 27.393 X (wax cost/lb)
Production cost/MSF = 114.15 + 187.50 X (electricity cost/KWH)
Production cost/MSF = 122.16 + 0.458 X (price of natural gas/MCF)

Capital Cost

Table 28 shows the estimated capital cost of various sized OSB plants. The estimates were provided by Columbia Engineering using 1984 figures. In this study, we selected a total capital cost (excluding land) of $34 million for our base case with a plant capacity of 150 MMSF, 3/8 in. basis.

Table 28. Estimated capital cost and other requirements for OSB plants of various capacities (1984 cost figures).

	Plant size (MMSF, 3/8 in. basis) 75	100	150	200	250
Capital cost (in million $)	18-21	24-27	33- 36	40 - 44	45 - 50
Manpower					
Total number (4 shifts)	65-70	75-85	95-110	110-125	120-135
Energy use[1]	burn bark, fines and board trims				
Maintenance cost ($)	10-15 per MSF, 3/8 in. basis				

[1] Most plants use some gas, possibly 1 to 2 MMBTU/hr for pilot.

Source: Columbia Engineering 1984.

The investment breakdown for the proposed plant is as follows:

Buildings	$12 million
Machinery	$18 million
Engineering and contingencies	$4 million

Engineering and contingencies category includes project management, delays and unforeseen cost increases, and provision for working capital. This estimate is based on a four shift, 312 day production schedule. Because of inexperience with the installation of OSB plants, the figures listed should be used as orders of magnitude only.

Production Cost

To calculate production cost, we use a plant capable of producing 150 MMSF of OSB on a 3/8 in. basis, based on a four shift operation for 312 operating days per year. The production schedule is listed in Table 29.

Table 29. Production schedule assumptions for an OSB plant with a 150 MMSF annual capacity (3/8 in. basis).

a.	Net operating hours/day	:	22 or 1320 minutes.
b.	Nonoperating days/year		
	1. two weeks vacation	:	14 days.
	2. eleven holidays	:	11 days.
	3. loss average 2 hrs/day	:	28 days.
	Subtotal	:	53 days.
c.	Net operating days/year	:	312 days.

The annual cost of materials as well as the cost of materials per MSF, 3/8 in. basis, is presented in Table 30. The total material cost per MSF is $54.42. The crew needed for hourly production is listed in Table 31, while Table 32 lists the calculated total cost for wages and salaries which amounts to $21.74 per MSF. This figure for total wage includes the wages for hourly production personnel, maintenance, administration, and supervision/technical salaries. Energy and maintenance costs amount to $18.49 (Table 33).

Table 30. Material cost data for an OSB plant with 150 MMSF of annual capacity (3/8 in. basis).

Material cost	Cost/MSF ($)
1. Wood	
a. Consumption 54.3 CUF/MSF or .69 ODT/MSF	
b. Cost $46/cunit or $36/ODT	
c. Cost/MSF	24.97
d. Cost/year : $3,745,500	
2. Resin	
a. Consumption 68.5 lbs/MSF	
b. Cost $.35/lb	
c. Cost/MSF	23.97
d. Cost/year : $3,595,350	
3. Wax	
a. Consumption 27.4 lbs/MSF	
b. Cost $.20/lb	
c. Cost/MSF	5.48
d. Cost/year : $821,850	
4. Total raw material cost	
a. Per MSF	54.42
b. Per Year : $8,162,700	

Table 31. Crew requirements for hourly production of OSB for 150 MMSF of annual capacity (3/8 in. basis).

a. Wood yard crane operator	1 (day shift only)
b. Flake operator	2
c. Knife grinder	1
d. Hammermilling, screening, air classification, reducing 'overs'	2
e. Weighing and blending	2
f. Forming machine operator	2
g. Caul and stacking station, hydraulic press operator	1
h. Conditioning chambers, caul separating and cleaning	1
i. Saw operator and stocking	2
j. Forklift in production area	1
k. Climatizing chambers operator	1
l. Relief operator	1
m. Quality control technician	1
n. Guard and scale operator	1
o. Shipping area (forklift, helper and clerk)	3 (day shift only)

Table 32. Wages and salaries

		Cost/MSF (3/8 in. basis)
1. Wages (per 8 hr. shift).		
a. Semi skilled (4)		
b. Unskilled (15)		
c. Assumed labor cost per hr. average $9.00 plus 30% for payroll charges, incl. 10% overtime premium. The $9.00 is average for semi and unskilled labor plus shift differentials.		
d. Cost/MSF		$ 14.70
e. Cost/Year	$2,205,000	
2. Maintenance wages.		
a. Mechanics (6) one leadman		
b. Electrician (6) one leadman		
c. Helper (4)		
d. Machinist (1)		
e. Mechanics for rolling stock (1)		
f. Average labor cost per hr - $11.00 plus 30% payroll charges		
g. Cost/MSF		4.26
h. Cost/Year	$639,000	
3. Administration salaries.		
a. Office manager (1)	$ 22500	
b. Ass'n accountant + purchasing or receiving (2+2)	12000	
c. Clerk/typist/receptionist (2)	9000	
d. Janitor (1)	7500	
Total	$ 96000/Year	
e. Payroll charges 30%	28800	
Grand total	$124800	
f. Cost/MSF		.83
4. Supervisory and technical salaries.		
a. General manager (1)	$ 37500	
b. Marketing manager (1)	31500	
c. Plant engineer + technical director (1+1)	22500	
d. Shift foreman + woodyard shipping superintendent(4+1+1)	18500	
Total	$225600/Year	
e. Payroll charges 30%	67500	
Grand total	$292500	
f. Cost/MSF		1.95
5. Total wages and salaries.		
a. Per MSF		21.74
b. Per Year	$3,261,300	

Table 33. Energy and maintenance cost based on an 150 MMSF, 3/8 in. basis annual capacity.

		Cost/MSF (3/8 in. basis)
1. ELECTRICITY		
a. Consumption 187.5 KWH/MSF		
b. Cost $.05/KWH		
c. Cost/MSF		9.38
d. Cost/Year	$1,406,250	
2. THERMAL ENERGY		
a. Consumption 2.657 BTUS/MSF or .458107 MCF/MSF		
b. Unit price : $.517/MMBTU or $3.00/MCF		
c. Cost/MSF		1.37
d. Cost/Year	$206,100	
3. MAINTENANCE (Parts)		
a. Per MSF		7.74
b. Cost/Year	$1,161,000	
4. TOTAL ENERGY & MAINTENANCE COST		
a. Per MSF		18.49
b. Cost/Year	$2,773,350	

Sales and general administration costs are assumed to be 7% and 1%, respectively, of the sales price, which amounts to $11.27 and $1.61, using $161 for a 3/8 in. thick panel as the basic selling price. We used sum-of-the-year method to calculate the depreciation charge for internal rate of return calculation, with a life of 20 years for buildings and 10 years for equipment, with no salvage value. The amount of depreciation for the typical 10 year operation period is listed in Table 34.

Table 34. Depreciation schedule using sum-of-the-year method for a 10 year operation ($).

Year	Machinery	Facilities	Total Depreciation
1	3,272,727	1,142,857	4,415,584
2	2,945,454	1,085,714	4,031,168
3	2,618,182	1,085,571	3,646,753
4	2,290,909	971,429	3,262,338
5	1,963,636	914,286	2,877,922
6	1,636,364	857,143	2,493,507
7	1,309,091	800,000	2,109,091
8	981,818	742,857	1,724,675
9	654,545	685,714	1,340,259
10	327,273	628,571	955,844

For the manufacturing cost calculation, we used the straight line method, which gave an annual depreciation cost of $16 per MSF. From the summary of production costs in Table 35, we get a total production cost of $122.54 per MSF, 3/8 in. basis. The figure for wood cost in an OSB plant is just a little over 20% of total production cost excluding capital cost.

According to Pennington (1984), the typical wood cost for plywood panels is 60% of the total panel cost, and most projections indicate that this could be as high as 70% of the total cost in the near future. On the other hand, the total wood cost for OSB, according to some published sources (Salomon Brothers 1983, Pennington 1984), lies somewhere around 25% to 30% of total panel cost.

Table 35. Summary of production costs for the proposed OSB plant.[1]

ITEMS	Cost/Year ($)	Cost/MSF ($)
Material		
Wood	3745500	24.97
Resin	3595350	23.97
Wax	821850	5.48
	8162700	54.42
Energy and maintenance (parts)		
Electricity	1406250	9.38
Thermal energy	206100	1.37
Maintenance (parts)	161000	7.74
	2773350	18.49
Wages and salaries		
Wages	2205000	14.70
Salaries	639000	4.26
Supervisory salaries	292500	1.95
Administration salaries	124800	.83
	3261300	21.74
Advertisement + sales expenses (7% of sales price)	1690500	11.27
General administration cost (1% of sales price)	241500	1.61
Depreciation		
Assume 10 yrs on equipment	1800000	12.00
Assume 20 yrs on facilities	600000	4.00
	2400000	16.00
TOTAL PRODUCTION COST	18529350	123.53

Note:

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[1] Does not include cost of capital and taxes.

When we compare the results with cost assumptions made by Salomon Brothers (1983) as listed in Table 36, then the estimated production cost for alder OSB from Western Oregon (before tax and interest rate costs) is still in the same ball park as costs in other regions.

Table 36. Estimated comparative production costs for plywood, waferboard, and OSB ($/MSF, 3/8 in. basis).

Item	Southern Pine Plywood	Waferboard	OSB
Wood	$ 54	$ 34	$ 36
Resin	35	25	31
Total raw material	89	59	67
Total labor	23	19.5	20
Depreciation	23	17.5	20
Others	15	15	15
Total cost	150	111	122

Source: Salomon Brothers (1983)

Effects of Wood Cost and Panel Price on Revenues

Variable costs are those costs that change directly in proportion to changes in production volume. These costs include the cost for raw material (wood, resin, and wax), labor costs associated with production, and several overhead costs such as energy and sales expenses. In addition to variable costs, Table 37, which is a summary of Table 35, also lists fixed costs, that do not change in proportion to changes in production volume for our case study. These are the costs of administration, supervisory, maintenance (material cost) and depreciation.

Table 37. Production cost breakdown per MSF for an alder OSB plant with 150 MMSF annual capacity (1984 cost figures).[1]

Variable Cost	
Wood	$24.97
Resin	23.97
Wax	5.48
Energy	10.75
Labor	18.96
Sales expense	11.27
Total variable costs	95.40
Fixed Cost	
Supervisory salaries	1.95
Administration salaries	.83
General administration cost	1.61
Maintenance cost/material	7.74
Depreciation	16.00
Total fixed cost	28.13
Total production cost per MSF	$123.53

[1] Does not include capital cost and taxes.

Wood cost is analyzed separately from the other production costs. An average of about 0.6945 ODT of alder wood raw material is needed to produce 1 MSF, 3/8 in. thick panels with a gross shipping weight of 1,325 lbs/MSF at 6% moisture content (Table 23 and Table 26). After computing the cost of production exclusive of the wood cost, and then after computing the coefficient for converting wood per ODT to the production cost (before tax), production cost can be expressed in equation form as

$$PC = a + bX$$

where

PC is production cost ($/MSF, 3/8 in. basis)

a is production cost excluding wood cost ($/MSF)

b is coefficient of wood cost per ODT ($/ODT)

X is the amount of wood needed in ODT to produce 1 MSF (ODT/MSF)

With the input from Table 10 and Table 36 we can then calculate the production cost as a function of the highly variable wood cost, where

$$PC = 98.56 + 0.6945X$$

Figure 10 shows the relationship between production cost (before tax) against wood cost, as well as the leeway available for profit and other costs compared to the base case sales price. It is extremely difficult to accurately predict OSB panel price because it fluctuates with economic conditions; but some price had to be assumed for this study. In this analysis, the price of an OSB panel with a 7/16 in. thickness, was assumed to compete with 3-ply 1/2 in. CDX Douglas-fir sheathing plywood, FOB Portland. To obtain the average selling price of 3-ply Douglas-fir CDX we used the average price for five years (1979 to 1983) compiled by Random Lengths Yearbook, 1983 (Figure 11). We arrived at a price of $188 per MSF, 7/16 in. basis, or $161 per MSF, 3/8 in. basis.

The break-even chart in Figure 12 illustrates the relationships among sales, costs, and the resulting profits. The production output where total costs (before tax) and sales income are equal is the break-even point. It is illustrated by the intersection of the total costs and income lines. For a 150 MMSF plant, the break-even point is 64.32 MMSF. The break-even point is where sales are sufficient to cover all costs (before taxes) which must be paid currently as well as the cost of replacing fixed assets through a depreciation charge.

Table 38 presents profit and return on investment (ROI) for a typical operating year, using 1984 cost figures and input data from Table 35. For ROI calculations we use a straight line depreciation method. The cash flow from sales was computed by multiplying the assumed FOB mill price of $161 per MSF, 3/8 in., times square footage of panels produced (150 MMSF). It shows a positive cash flow of $5,210,325 before taxes, and a ROI of 15.32% after taxes.

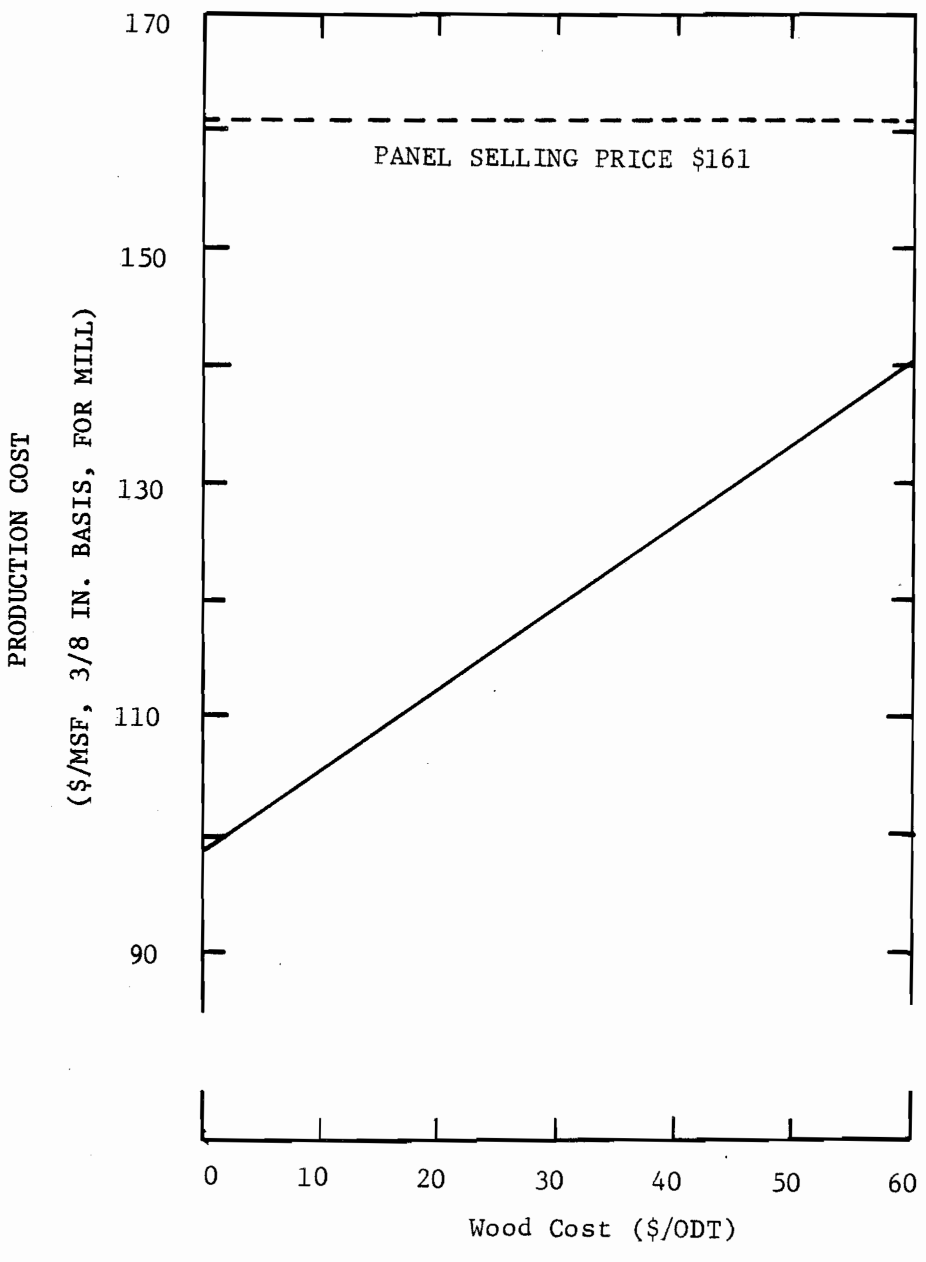

Figure 10. The relationship between total production cost and wood cost (excluding taxes, profit, and capital cost) for producing 3/8 in. OSB.

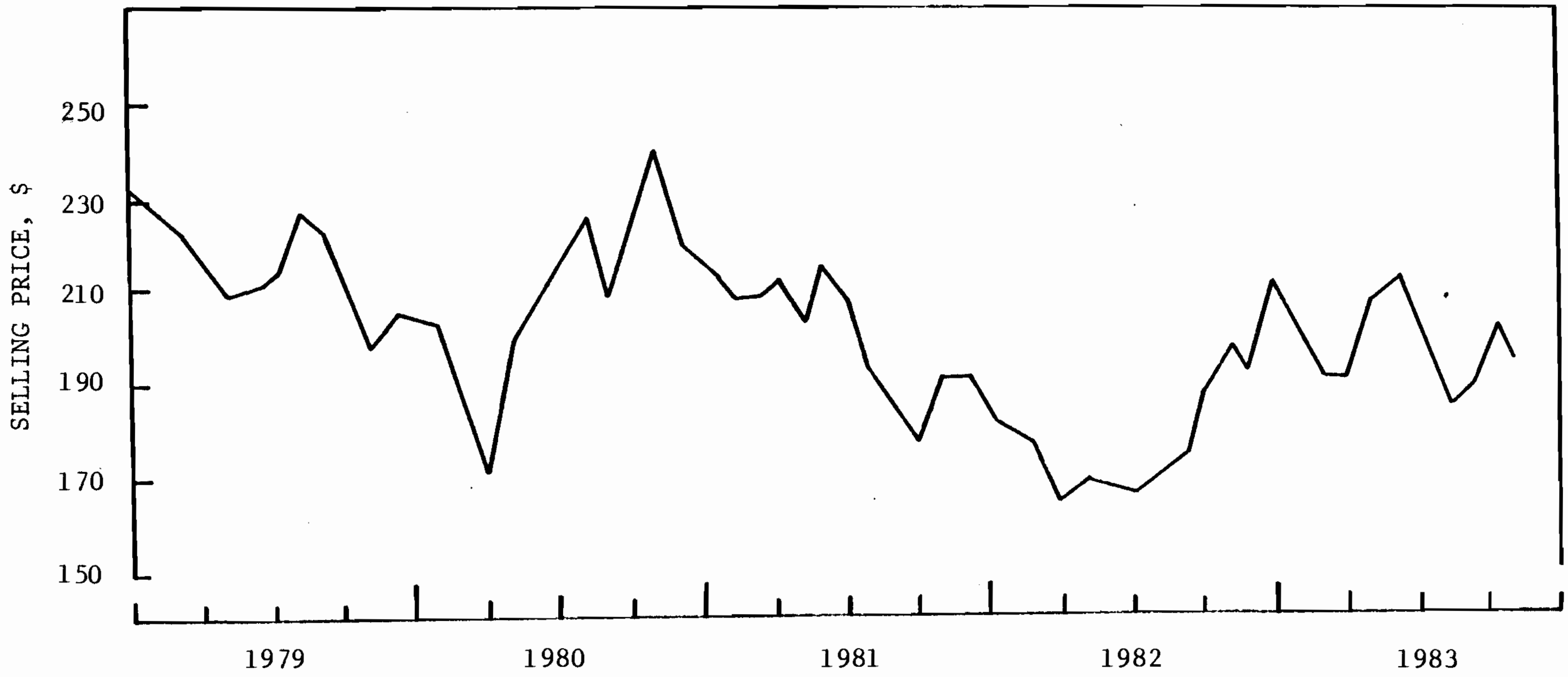

Figure 11. Five-year wholesale price trend of Douglas-fir plywood, 1/2 in. standard exterior (3-ply).

Source: Random Lengths Yearbook 1983.

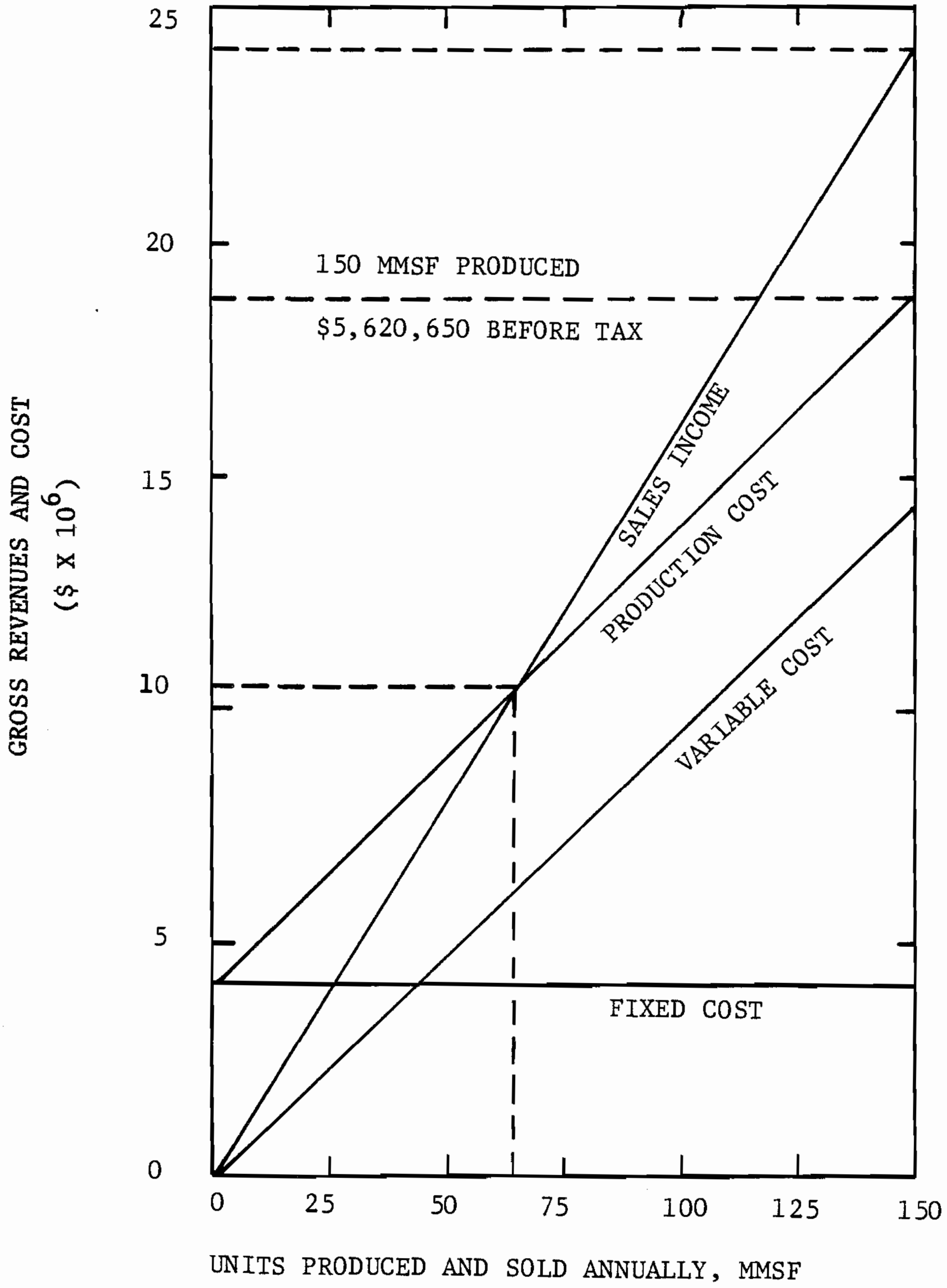

Figure 12. Annual gross revenue and cost (before taxes) for an OSB plant producing 150 MMSF, 3/8 in. basis per year (assuming the wood cost is $36/ODT and FOB sales is $161/MSF).

Table 38. Sales, profit, and ROI for a typical year (based on 1984 cost figures).

SALES, PROFIT, AND ROI

1. Gross revenue per year at sales price of $161/MSF, net return to mill	24,150,000
2. Minus total manufacturing cost	18,529,350
Gross profit	5,620,650
3. Tax (50%)	2,810,325
4. Net operating profit	2,810,325
5. Plus depreciation	2,400,000
Positive cash flow	5,210,325
6. ROI	15.32%

Figure 13 illustrates income before taxes as a function of wood cost if we assume the sale price of panels is constant at $161/MSF. Wood price plays a major part on the income generated, because wood cost represents about 20% of the OSB manufacturing cost. However, OSB producers have one distinct advantage over plywood in that the wood cost represents a smaller proportion of total costs. According to Salomon Brothers (1983) as shown in Table 36, wood cost in plywood production represents from 50 to 60% of the total panel cost, while in the reconstituted structural panels it represents only around 25 to 30% of the total panel cost.

Figure 14 shows the effect of panel sales price on gross income for a 150 MMSF capacity plant, assuming the cost of wood is constant at $36/ODT. This shows the major impact that sales price could generate for an OSB venture.

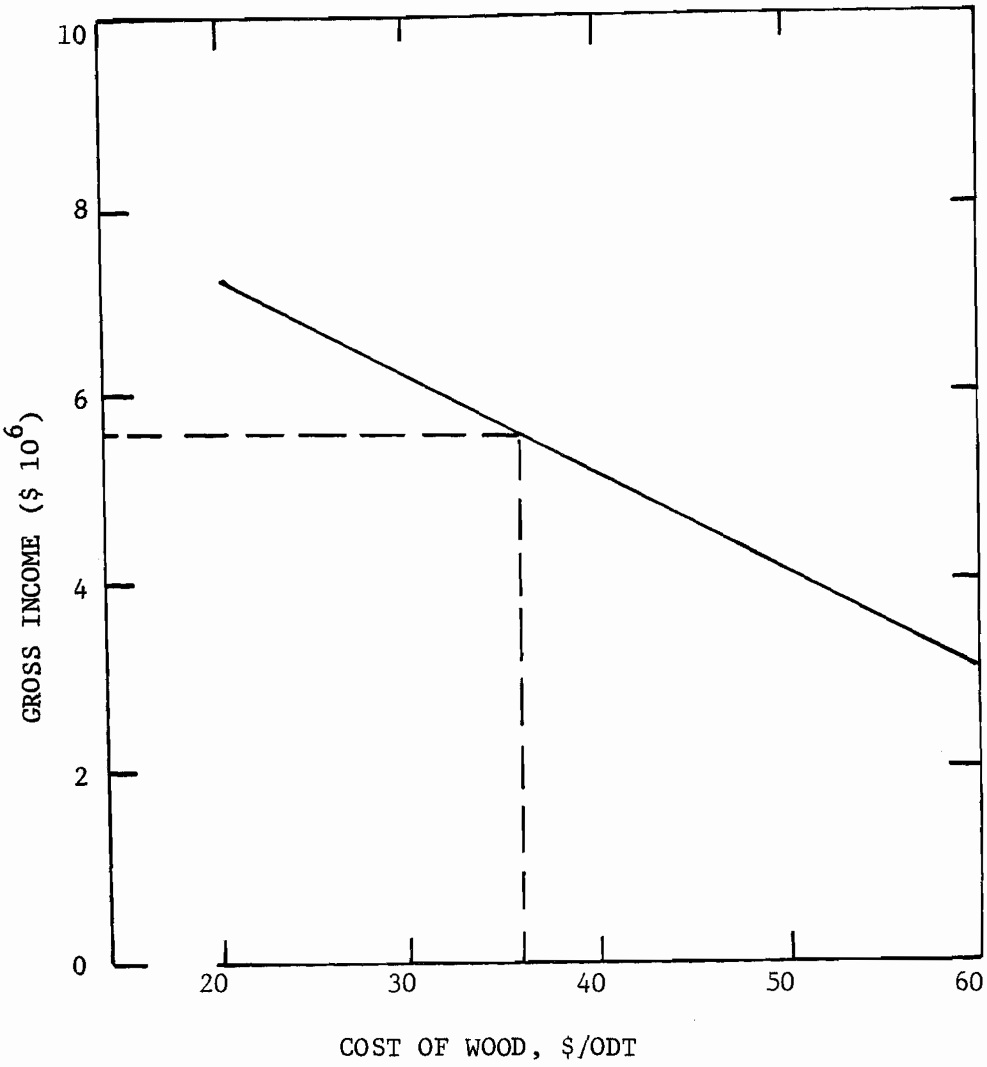

Figure 13. Annual gross income before taxes as a function of price paid for wood for a 150 MMSF plant (assuming the panel sales price is $161/MSF, 3/8 in. basis).

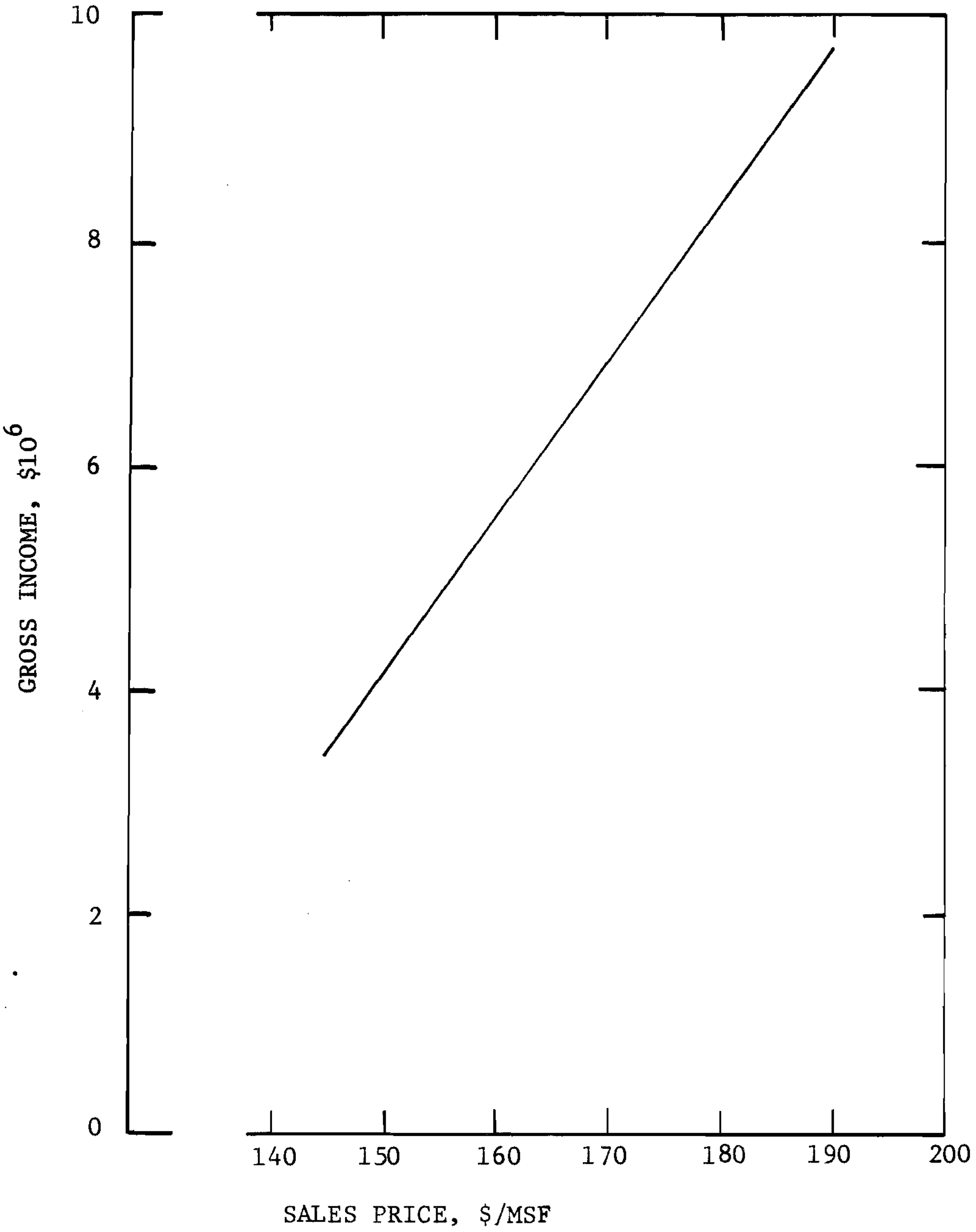

Figure 14. Gross income as a function of price charged for finished product for a plant of 150 MMSF (3/8 in. basis), assuming the cost of wood is $36/ODT.

Cash Flow Analysis

The investment cash flow analysis was used as an aid in evaluating and analyzing the feasibility and the attractiveness of the OSB venture. Cash flow projection for a 10-year operation was prepared using a program compiled by Ince (1980). Data in Appendix C was used as input to run the program . Table 39 shows a detailed summary of the annual cash flows along with the calculated annual profit before taxes, after-tax profit, after-tax earnings, and after-tax net cash flows. In computing the cash flow we used $161 per MSF, 3/8 in. basis, as the basic selling price, and we estimated that OSB panel price as well as the other costs of production would increase at a growth rate of 5% annually during the whole investment period. In calculating the annual depreciation charge we used the sum-of-the-years method, and a tax charge of 50% was used for both federal and state taxes. The total investment is $34 million, while for capital cost we used a discount rate of 15%.

Table 39. Cash flow analysis for a 10-year operation of base case.

OSB ANALYSIS
CASH FLOW ANALYSIS - NEW OSB ALDER MILL
150 MMSF THROUGHPUT, HYPOTHETICAL DATA

INITIAL INVESTMENT REQUIREMENT $ 34000000

YEARS	1	2	3	4	5	6	7	8	9	10
OSB 3/8 IN.(MSF)										
UNIT SALES	150000	150000	150000	150000	150000	150000	150000	150000	150000	150000
UNIT PRICE	$ 161.00	$ 169.00	$ 178.00	$ 186.00	$ 196.00	$ 205.00	$ 216.00	$ 227.00	$ 238.00	$ 250.00
GROSS REVENUE	$24150000	$25350000	$26700000	$27900000	$29400000	$30750000	$32400000	$34050000	$35700000	$37500000
RAW MATERIALS COSTS										
WOOD	$ 3745500	$ 3932800	$ 4129400	$ 4335900	$ 4552700	$ 4780300	$ 5019300	$ 5270300	$ 5533800	$ 5810500
RESIN	3595350	3775100	3963900	4162100	4370200	4588700	4818100	5059000	5312000	5577600
WAX	821850	862900	906100	951400	999000	1048900	1101400	1156400	1214200	1275000
TOTAL	$ 8162700	$ 8570800	$ 8999400	$ 9449400	$ 9921900	$10417900	$10938800	$11485700	$12060000	$12663100
OTHER VARIABLE COSTS										
ELECTRICITY	$ 1406250	$ 1476600	$ 1550400	$ 1627900	$ 1709300	$ 1794800	$ 1884500	$ 1978700	$ 2077700	$ 2181600
THERMAL ENERGY	206100	216400	227200	238600	250500	263000	276200	290000	304500	319700
LABOR	2844000	2986200	3135500	3292300	3456900	3629700	3811200	4001800	4201900	4412000
SALES EXPENSE	1690500	1774500	1869000	1953000	2058000	2152500	2268000	2383500	2499000	2625000
TOTAL	$ 6146850	$ 6453700	$ 6782100	$ 7111800	$ 7474700	$ 7840000	$ 8239900	$ 8654000	$ 9083100	$ 9538300
FIXED COSTS										
SUPERV. SALARIES	$ 292500	$ 307100	$ 322500	$ 338600	$ 355500	$ 373300	$ 392000	$ 411600	$ 432200	$ 453800
ADM. SALARIES	124800	131000	137600	144500	151700	159300	167200	175600	184400	193600
GEN. ADM. COST	241500	253500	267000	279000	294000	307500	324000	340500	357000	375000
MAINT. COST/MAT.	1161000	1219000	1280000	1344000	1411200	1481800	1555900	1633600	1715300	1801100
TOTAL	$ 1819800	$ 1910600	$ 2007100	$ 2106100	$ 2212400	$ 2321900	$ 2439100	$ 2561300	$ 2688900	$ 2823500
CAPITAL INVESTMENT										
WORKING CAPITAL	$ 43130	$ 45414	$ 47685	$ 50069	$ 52573	$ 55202	$ 57962	$ 60860	$ 63903	$-1277895
TOTAL	$ 43130	$ 45414	$ 47685	$ 50069	$ 52573	$ 55202	$ 57962	$ 60860	$ 63903	$-1277895
SALVAGE VALUE										$ 3142857
DEPRECIATION	$ 4415584	$ 4031168	$ 3646753	$ 3262338	$ 2877922	$ 2493507	$ 2109091	$ 1724675	$ 1340259	$ 955844
PROFIT BEFORE TAXES	$ 8020650	$ 8414900	$ 8911400	$ 9232700	$ 9791000	$10170200	$10782200	$11349000	$11868000	$12475100
(THE TAX RATE IS .50)										
AFTER TAX PROFIT	$ 3602533	$ 2191866	$ 2632324	$ 2985181	$ 3456539	$ 3838347	$ 4336555	$ 4812163	$ 5263871	$ 5759628
AFTER TAX EARNINGS	$ 8018117	$ 6223034	$ 6279077	$ 6247519	$ 6334461	$ 6331854	$ 6445646	$ 6536838	$ 6604130	$ 9858329
A.T. NET CASH FLOW	$ 7974987	$ 6177620	$ 6231392	$ 6197450	$ 6281888	$ 6276652	$ 6387684	$ 6475978	$ 6540227	$11136224

Table 40. Discounted net cash flows for a 10-year operating period.

Year	After tax net cash flow	Present value factor at R = 15%	Present value of net cash flow	Cumulative net cash flow
0	$-34000000	1.00000	$-34000000	$-34000000
1	7974987	.86957	6934771	-27065229
2	6177620	.75614	4671168	-22394061
3	6231392	.65752	4097241	-18296820
4	6197450	.57175	3543412	-14753408
5	6281888	.49718	3123208	-11630200
6	6276652	.43233	2713569	-8916631
7	6387684	.37594	2401367	-6515264
8	6475978	.32690	2117008	-4398256
9	6540227	.28426	1859140	-2539116
10	11136224	.24718	2752704	213588

Based on cash flow generated through the investment period and the discounted cash flow in Table 40, the present net worth is positive ($213,588) at 15% discount rate while the payback period (PBP) based on after-tax net cash flow is 5.18 years. The IRR based on after-tax net cash flows resulting from the investment is 15.10%, while the present net worth to initial investment ratio is 0.63%. This investment analysis does not show a spectacular result, but seems feasible enough, because the present value of the return is positive and greater than the capital requirement of the project.

Sensitivity Analysis

Recognizing that the venture profitability depends on future developments which are difficult to predict and also to gauge the viability of the venture, we did a sensitivity analysis. The analysis is based on changes in wood, resin, wax, labor costs, and panel sales price to measure their effects on several investment criteria.

Table 41. Sensitivity analysis of IRR, PBP, PNW, PNW/initial investment.

Percent of base case	80	90	100	110	120
			IRR in %		
Sales price	3.40	10.10	15.10	19.90	24.60
Wood cost	16.80	15.90	15.10	14.20	13.40
Resin cost	16.70	15.90	15.10	14.30	13.40
Wax cost	15.50	15.30	15.10	14.90	14.70
Labor cost	16.40	15.80	15.10	14.50	13.80
			Payback period in years		
Sales price	9.05	6.38	5.18	4.35	3.73
Wood cost	4.86	5.02	5.18	5.36	5.55
Resin cost	4.87	5.02	5.18	5.35	5.54
Wax cost	5.11	5.14	5.18	5.22	5.26
Labor cost	4.93	5.05	5.18	5.32	5.46
			PNW at 15% discount in dollars		
Sales price	-14122348	-6120111	213588	6797721	13672871
Wood cost	2451012	1323644	213588	-926070	-2066022
Resin cost	2361333	1287453	213588	-880373	-1974572
Wax cost	704504	459012	213588	-36264	-286396
Labor cost	1912477	1062991	213588	-651731	-1517286
			Present net worth/initial investment in %		
Sales price	-41.54	-18.00	0.63	19.99	40.21
Wood cost	7.21	3.89	0.63	-2.72	-6.08
Resin cost	6.95	3.79	0.63	-2.59	-5.81
Wax cost	2.07	1.35	0.63	-0.11	-0.84
Labor cost	5.62	3.13	0.63	-1.92	-4.46

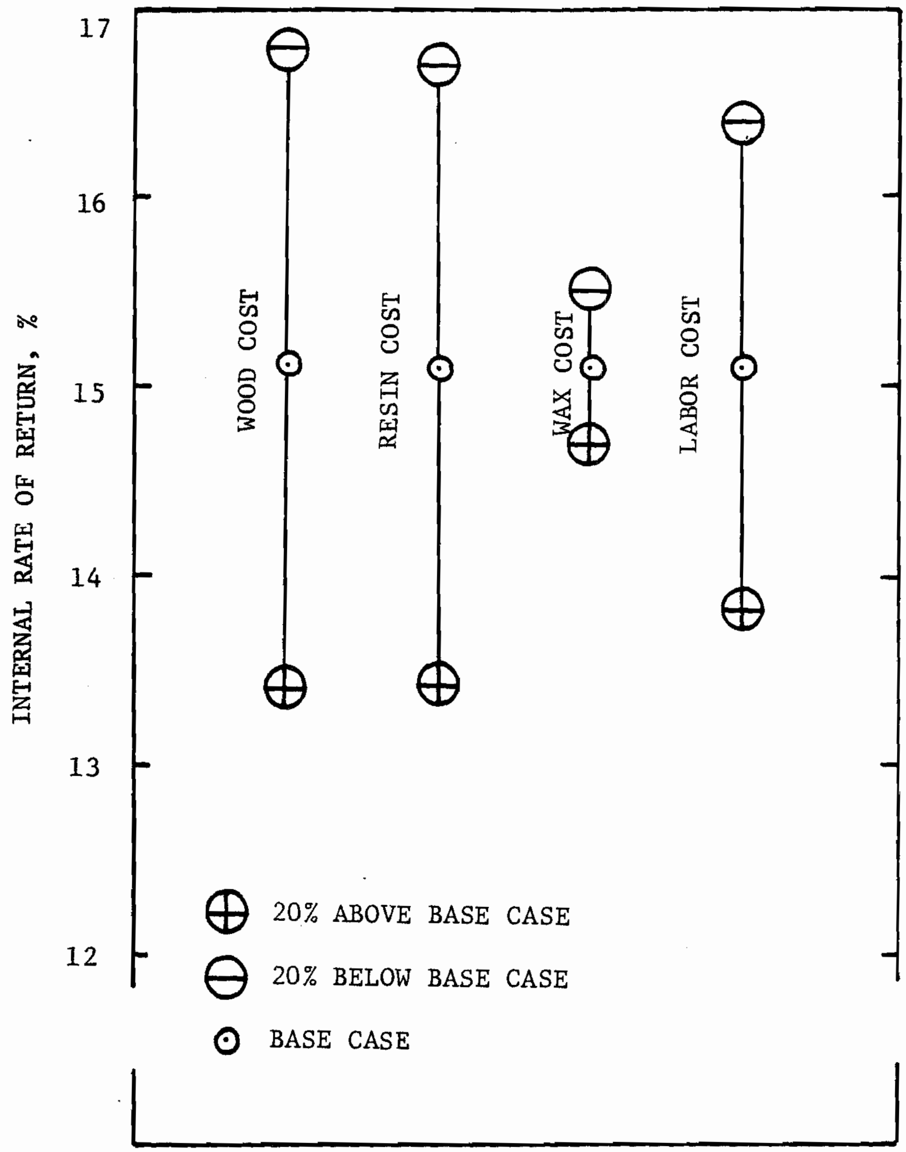

Figure 15. Sensitivity analysis of IRR as a function of several major variable costs.

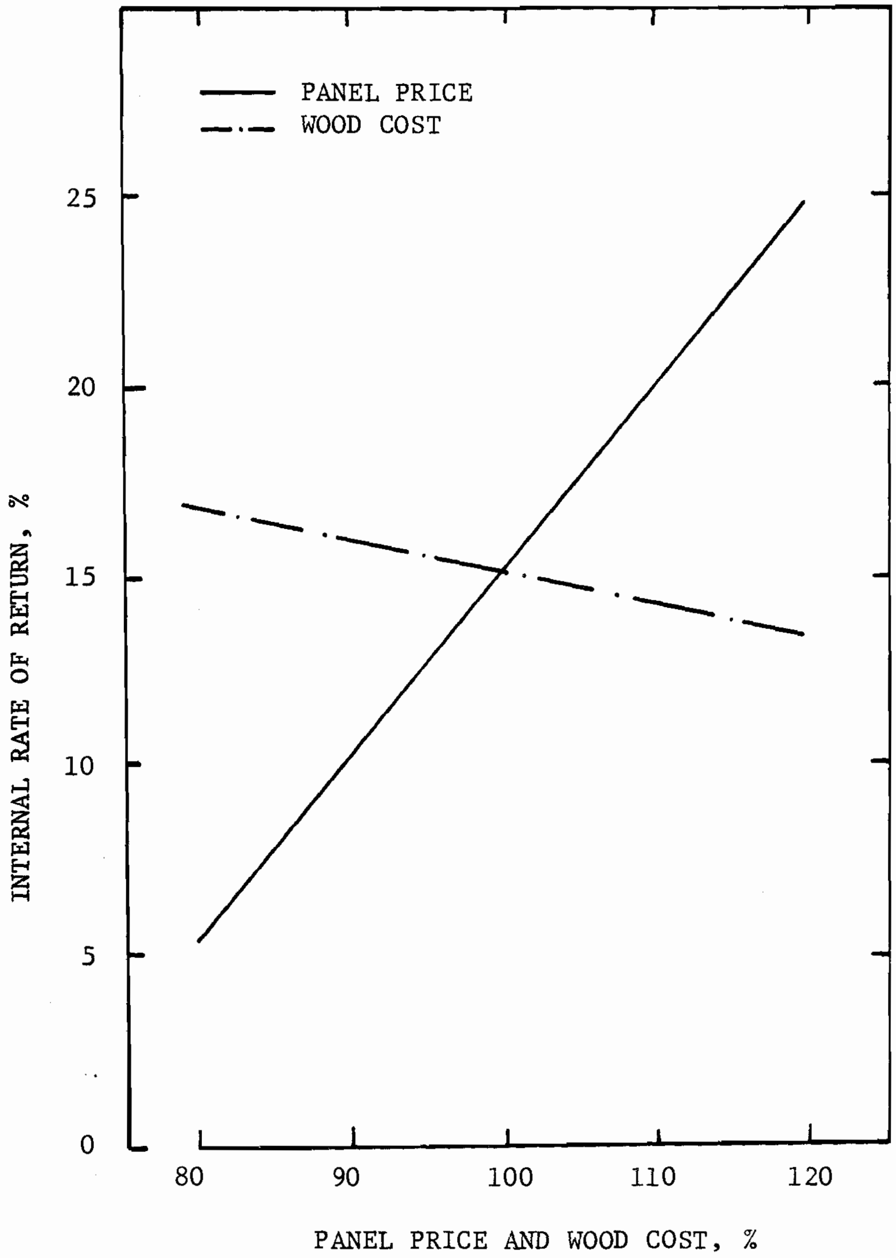

Figure 16. Sensitivity analysis of IRR as a function of panel sales price and wood cost.

Table 41 shows the effect of the major variable costs and panel selling price for values 10 and 20% above and below the 1984 assumed price. Figure 15 summarizes the predicted effects of selected independent major variable costs on IRR for our base case. Within the range of cost changes examined, the wood cost has the greatest effect on IRR. Next in decreasing order of importance, came the resin, labor, and wax costs. Figure 16 illustrates the sensitivity of wood cost and panel price on the IRR. A reduction of 20% in wood cost will only result in a rise of 1.8% in the IRR, while a 20% increase in the selling price resulted in a 9.5% rise in IRR. Similarly, a 10% increase in wood cost results in a drop of less than 1% of IRR, but a 10% panel price drop decreases IRR by 5.5%. The analysis shows that even though wood cost is the largest single component of the total cost, panel selling price tends to have a much bigger effect on the overall feasibility of the venture.

However, we can take solace in the fact that wood cost represents a much smaller share of the total production cost when compared to plywood, and that the assumed panel price is still below the reasonable price. With a steady market, improvement in alder management as well as efficiency and innovation in day-to-day OSB operation, the figure for financial investment criteria could improve. Opportunities to improve the returns might also be facilitated by some modifications in plant size as well as in equipment specifications and selection.

VI. DISCUSSION AND CONCLUSION

There are four major objectives of this study that need to be answered affirmatively in order to assess the economic feasibility of manufacturing OSB in Western Oregon using alder as its raw material base. The four major considerations are as follows:

> Is there sufficient demand for OSB panel in the surrounding market area to justify the establishment of OSB plant(s)?

The market analysis shows that the demand for OSB panels can likely be d~~e~~eveloped in the Western regional market area. The analysis from other regions of the US as well as the West and South shows that reconstituted structural panels received a relatively quick acceptance when they were introduced into the market (Irland 1982, Salomon Brothers 1983, Paper Tree Letter 1983, Random Lengths 1984, Kadera 1984). In 1978 the consumption of reconstituted structural panels was concentrated in the Northcentral states, but in early 1984 they had penetrated market areas that were primarily held by Southern Pine plywood, such as Dallas and Atlanta, as well as Douglas-fir softwood plywood markets such as Portland. By a conservative estimate, around 400 MMSF of market share is available for reconstituted structural panels in the Western region or about 10% of total Western plywood market shipments in 1983. The market share for reconstituted structural panels could show rapid growth, and by 1990 it is assumed that 20% of market share will be available, at least for the top five destinations in the Western plywood market: Los Angeles, Portland, San Francisco, Seattle, and Phoenix areas. The 1990's share of the market for OSB/waferboard is similar to the percentages that had already been obtained in Dallas and Atlanta. Experience in Portland (Kadera 1984) shows that the market is presently available and could provide the prospect of immediate sales , provided OSB/waferboard is locally available and priced competitively.

An OSB plant starting up in 1985 with annual capacity of

150 MMSF could claim a potential share of almost one-fourth of the estimated total market for reconstituted structural panels in the top five destinations of the Western region market.

Rising wood cost and the regional limitations of the market can force the closure of plywood businesses because of marginal operations. On the other hand, the ready availability of OSB with its plywood-like properties as well as the improvements in strength and internal bond could attract a larger market share. Therefore, we may make the conclusion that there would be sufficient demand to justify the output of the proposed OSB plant.

The market analysis also points out that OSB will serve first as a substitute for plywood in the Western regional market, while later it could develop and penetrate new markets as well as some secondary geographic areas. The growing market acceptance of reconstituted structural panels should be able to help the structural panel industries' ability to meet any foreseeable demand in the future.

> Is there sufficient supply of wood raw material, and what part of Western Oregon is better suited for the proposed facility based on available wood supply?

There is an abundance of alder raw material for the proposed facility. The outlook for alder resources in Western Oregon is very optimistic. Growth exceeds removal, and the abundant supply exceeds current consumption. In Western Oregon there are 2.5 billion CUF of alder spread over 1.3 million acres of alder stands. Alder availability, based on an average net annual growth for current acreage of Western Oregon, totals 51.7 MMCUF, while the wood supply needed for a proposed plant with 150 MMSF of annual capacity is approximately 8.15 MMCUF of solid wood or 104,167 ODT. Even though each region of the Western Oregon coast could supply the necessary requirement for one 150 MMSF facility, region 1 (Northwest Oregon) and region 2 (Westcentral Oregon) are more favorable because of their larger alder resources.

The above estimate does not take into account the increase of usable yields that could be obtained with managed alder stands as well as the availability of other hardwood species in Western Oregon that could be used as additional raw material resources. The alder resource in Western Oregon is underutilized. Improved utilization of alder requires that trees and logs be put to their best uses (Resch 1980).

> Can the proposed facility produce at a cost level that would be competitive with OSB produced in other region?

The total production cost from the base case shows a total cost of $123.53 per MSF (3/8 in. basis) while the estimated production costs for OSB made from aspen range from $113 to $130. The cost figure from this study is basically similar and competitive with available cost data from several OSB/waferboard production facilities in the northeastern and southern regions. The analyses also show that wood cost represents a much smaller share (20%) of the total production cost when compared to plywood (60%).

> Will the profit realized from the venture justify the investment?

The cash flow analysis from the 10-year operation shows an IRR of 15.1%, based on assumptions for the base case. Even though this is not a spectacular return, it still produces an IRR in excess of 15%.

Since the present value of the returns is greater than the capital requirement of the project, the OSB investment is economically feasible. The selling price of the panel has a major effect on the OSB profit margin. If the product price stabilizes at 10 to 20% above the present market price level, then the facility should be able to operate at a better than average profit margin, provided they have sound and secure arrangements to purchase wood raw materials. It is also likely that OSB prices will improve only when demand for all wood products improves.

OSB manufacturing using alder resources is an important step for efficient utilization of alder in Western Oregon. It could reduce building costs, utilize the so called "weed" species to the best uses available in today's technology, reduce demand on other valuable forest land in Western Oregon, as well as providing employment. The venture will be one that should be able to meet today's need as well as tomorrow's challenge for the forest resources of Western Oregon.

The study also shows the assurance that the market can be developed, that raw material can be obtained, and that the overall costs are of an acceptable level. The study also gives assurance that income will exceed cost, even though an IRR of 15.1% is not sufficiently attractive or spectacular.

It can also be pointed out that Western Oregon seems to have several basic requirements for a successful venture in OSB production ie., an adequate present market as well as a predicted growth market, sufficient alder resources, and a somewhat more regionalized market.

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APPENDICES

APPENDIX A.

OSB Product Rating

(Cliffton et al 1976)

1. Present market

* Market size (number of potential customers)

Production has widespread uses, many prospective customers	Customer restricted to a special class, few in number

```
.---------X--------------.------------------------.
10        8              5                        0
```

* Product's relation to need

Product always needed, satisfies basic need	Luxury product, not really needed

```
.---------X--------------.------------------------.
10        8              5                        0
```

* Strength and dominance of competition

Competitors relatively small, field not crowded	Well established, large competitors dominate the market

```
.--------------X---------.------------------------.
10             7         5                        0
```

* Quality-price relationship

Special product features, better value than competitive products	Carbon copy of products now on the market

```
.-------------------X----.------------------------.
10                  6    5                        0
```

* Availability of sales-distribution system

Easily marketed through existing jobbers or wholesalers	Special sales and distribution system required

```
.---------X--------------.------------------------.
10        8              5                        0
```

* Sales effort required

Product will literally sell itself, repeat sales likely	Intensive sales effort required for every sale

```
.------------------------X------------------------.
10                       5                        0
```

* Export possibilities

Can be exported competitively, large international market	Domestic market only

```
.-------------------X----.------------------------.
10                  6    5                        0
```

2. Market growth potential

* Increase in number of potential customers	Population trends indicate increasing customer population	Declining customers population	X----------.----------. 10 5 0
* Increase in need	Projected increase in demand for associated products	Declining demand for associated products	.---X-------.----------. 10 9 5 0
* Increase in customer acceptance	Demand is certain to grow as customers become acquainted with product	Multiple sales not possible, customer acceptance will have minimal effort on sales	.-----X-----.----------. 10 8 5 0
* Product newness and design protection	New product can be protected by patent	Difficult to protect, can be easily copied	.--------X--.----------. 10 6 5 0
* Economic trends	Projected economic trends will increase demand and/or value	Projected economic trends will seriously reduce demand and/or adversely effect cost	.--------X--.----------. 10 6 5 0
* Social and political trends	Trends appear stable and imply an increasing need	Indicators unstable, social or political changes could produce market decline	.-----------.--X-------. 10 5 4 0
* Competitive advantage	High value added, industry not easily entered. process innovations easily protected	Low value added, easy to start new venture in this field	.------X----.----------. 10 7 5 0

3. Costs

- Cost of raw materials

Ensured supply of raw materials available at stable low cost

Premium cost for raw materials because of location or availability

```
.---------X---------------.-------------------------.
10        8               5                         0
```

- Labor cost

Good supply of skilled labor available, wage rates nominal

High wage-rate area, will have to outbid present industry for needed skills

```
.--------------X----------.-------------------------.
10             7          5                         0
```

- Distribution costs

Distribution will not require large inventory and high handling costs, transportation available

Large stocks must be maintained, market widely dispersed

```
.--------------------X----.-------------------------.
10                   6    5                         0
```

- Selling costs

Product easily sold with minimal sales effort

Large sale force needed, demand heavily dependent on sales effort.

```
.-------------------------X-------------------------.
10                        5                         0
```

- Efficiency of production processes

New process will provide long-term cost advantage

Processes standard, competitor's cost unknown —may have a cost advantage

```
.---------X---------------.-------------------------.
10        8               5                         0
```

4. Risks

- Market stability in economic cycles

Market not greatly affected, product needed in good times and bad

Demand will drop quickly in bad times

```
.-------------------------.--------X----------------.
10                        5        3                0
```

- Technological risk

Technology stable or else product and processes easily modified in response to new technology

Product locked to present technology, technological advances are being made rapidly

```
.--------------X----------.-------------------------.
10             7          5                         0
```

* Import competition	Product nature precludes imports, no forseeable threat from import	Product require imported raw materials, labor content high, easily shipped long distances	.---------X--------------.------------------------. 10 8 5 0
* Size and power of competition	No single competitors can affect market share substantially	Powerful competitors could at any time reduce prices to capture market	.-----X------------------.------------------------. 10 9 5 0
* Quality and reliability	Proven quality and reliability	Product design not fully tested, unknown reliability	.------------------------X------------------------. 10 5 0
* Predictability of demand	Demand estimate easily and accurately made, data readily available	No data available for demand estimating, estimate is largely a guess	.--------------X---------.------------------------. 10 7 5 0
* Initial investment costs	Relatively low investment, can be liquidated at little or no loss	High investment required, special buildings or machinery can be liquidated only with great loss	.------------------------.----X-------------------. 10 5 4 0
* Vulnerability of inputs	Raw materials widely available, no forseeable shortages	Raw materials in short supply and closely controlled.	.---------X--------------.------------------------. 10 8 5 0
* Legislation and control	Product does not affect health or environment, no controls likely	Product in area of controversy, controls pending	.---------X--------------.------------------------. 10 8 5 0
* Time required to show profit	Cash flow projections indicate profit in first few months of operation	Profit delayed	.------------------------.----X-------------------. 10 5 4 0

```
* Inventory requirements   Short distribution chain        Long lead times
                           inventory requirements          on input material.
                           minimal                         customer needs
                                                           require large
                                                           finished good
                                                           inventories
                           .------------------------.----X--------------------.
                           10                       5    4                    0

* Seasonal demand                                          Demand highly seasonable,
                                                           will not sustain
                           Steady demand in all season     full-time production
                           .-------------------------X-------------------------.
                           10                        5                        0

* Exclusiveness of design  Exclusive design not easily     Design innovation
                           copied or 'leapfrogged'         easily accomplished,
                                                           not easy to maintain
                                                           design leadership
                           .-------------------------.----X--------------------.
                           10                        5    4                    0
```

APPENDIX B.

List of OSB input data for PARVCOST Program (Harpole 1977)

Wood raw material cost per cubic foot
CCUF = 0.46

O. D. specific gravity of the wood raw material
SGRW = 0.41

Moisture content O.D. basis of the green wood raw material
GRMC = 0.80

Ratio of bark to wood in wood raw material
PCTB = 0.12

Moisture content O.D. basis of green bark material
WBMC = 1.00

O.D. specific gravity of the bark
SGBK = 0.700

Cost of resin per pound
CRES = 0.35

Percent resin required in face
PRRF = 0.05

Percent resin required in core
PRRC = 0.05

Cost of wax per pound of wax
CWAX = 0.2

Percent of wax required in face
PWRF = 0.02

Percent of wax required in core
PWRC = 0.02

Moisture content wood out of dryer
ODMC = 0.04

The recoverable percent of fines loss (weight percent of wood raw material)
PCTF = 0.08

Percent of product in face furnish
PCFF = 0.70

Percent of product in core furnish
PCCF = 0.30

O. D. weight of pressed panel/CUF
ODWP = 40.0

Moisture content of wood in product
FPMC = 0.06

Panel trims along length (inches)
PTLG = 1.5

Panel trims along width (inches)
PTWD = 1.5

Percent of wood raw material lost as green residue (recovered as fuel)
PWSR = 0.05

Value for mill process generated wood and bark residues (average $/pound)
CODR = 0.00

Cost of electricity per KWH
CKWH = 0.05

BTU in wood fines and residues (MMBTU/Lb O.D. higher heating value)
BTUF = 0.0085

BTU in bark (MMBTU/Lb O.D. higher heating value)
BTUB = 0.0095

Dryer BTU demand at boiler---MMBTU/CUF panels
BTRD = 0.0017

Process steam press BTU demand at boiler---MMBTU/CUF panels
BTRP = 0.0192

Thaw pond steam BTU demand at boiler---MMBTU/CUF panels
BTRT = 0.0020

Heating steam BTU demand at boiler---MMBTU/CUF panels
BTRH = 0.0032

Miscellaneous steam BTU demand at boiler---MMBTU/CUF panels
BTRM = 0.0032

Electric usage---KWH/CUF panels
RKWH = 6.00

Pressed panel width (inches)
PPWD = 48.0

Pressed panel length (inches)
PPLG = 96.0

The net sales value ($/CUF)
SALE = 4.64

Average anticipated price of natural gas per MCF
PGAS = 3.00

Average anticipated price of oil per barrel
POIL = 35.00

Average anticipated price of wood to be used as fuel per ton
PWOD = 25.00

Average anticipated price of coal per ton
PCOL = 40.00

MMBTUS available per MCF of natural gas
BTUG = 1.00

MMBTUS available per barrel of oil
BTUO = 5.00

MMBTUS available per ton of wood
BTUW = 18.00

MMBTUS available per ton of coal
BTUC = 28.00

APPENDIX C.

Input Data for
EVALUE Program
Ince (1980)

```
10

OSB 3/8 in.(MSF) 1
161.00  169.00  178.00  186.00  196.00  205.00  216.00  227.00  238.00  250.00
150000  150000  150000  150000  150000  150000  150000  150000  150000  150000

Wood            0
3745500 3932800 4129400 4335900 4552700 4780300 5019300 5270300 5533800 5810500

Resin           0
3595350 3775100 3963900 4162100 4370200 4588700 4818100 5059000 5312000 5577600

Wax             1
821850  862900  906100  951400  999000  1048900 1101400 1156400 1214200 1275000

Electricity     0
1406250 1476600 1550400 1627900 1709300 1794800 1884500 1978700 2077700 2181600

Thermal energy  0
206100  216400  227200  238600  250500  263000  276200  290000  304500  319700

Labor           0
2844000 2986200 3135500 3292300 3456900 3629700 3811200 4001800 4201900 4412000

Sales expense   1
1690500 1774500 1869000 1953000 2058000 2152500 2268000 2383500 2499000 2625000

Superv. salaries 0
292500  307100  322500  338600  355500  373300  392000  411600  432200  453800

Adm. salaries   0
124800  131000  137600  144500  151700  159300  167200  175600  184400  193600

Gen. adm. cost  0
241500  253500  267000  279000  294000  307500  324000  340500  357000  375000

Maint. cost/mat. 1
1161000 1219000 1280000 1344000 1411200 1481800 1555900 1633600 1715300 1801100

Working capital 1
43130   45414   47685   50069   52573   55202   57962   60860   63903   -1277895

4415584 4031168 3646753 3262338 2877922 2493507 2109091 1724675 1340259 955844
1800000 0.500   34000000
3142857 0.15
```

APPENDIX D.

List of Abbreviations

APA	American Plywood Association.
BF	Board foot.
BTU	British thermal unit.
BSF	Billion square feet.
CUF	Cubic feet.
cunit	Hundred cubic feet.
DIY	Do-it-yourself.
IB	Internal bending.
LE	Linear expansion.
IRR	Internal rate of return.
KWH	Kilowatt hour.
MBF	Thousand board feet.
MC	Manufacturing cost.
MCF	Thousand cubic feet (gas).
MDF	Medium density fiberboard.
MOE	Modulus of elasticity.
MOR	Modulus of rupture.
MSF	Thousand square feet.
MMCUF	Million cubic feet.
MMBTU	Million BTU.
MMSF	Million square feet.
OSB	Oriented strand board.
PBP	Payback period.
pcf	Pounds per cubic foot.
PNW	Present net worth.
psi	Pounds per square inch.
ROI	Return on investment.
SG	Specific gravity.
TS	Thickness swelling.
VPS	Vacuum-pressure-soak.
2HB	Two hour boil.