AN ABSTRACT OF THE THESIS OF

Rhonda R. Wright for the degree of Master of Science in Forest Products and Industrial Engineering presented on June 30, 1986

Title: The Economic Feasibility of Locating an OSB Plant in Western Oregon.

Signature redacted for privacy.

Abstract approved: ______________________________

James B. Wilson

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Thomas West

The development of an OSB (oriented strand board) industry in Western Oregon would prove to be a real boost to the economy of an area that has suffered from the earlier recession of the forest products industry. Past studies have shown that it is technically feasible to produce OSB from alder which is a major hardwood species growing in Western Oregon, but the economic feasibility of producing OSB in Western Oregon is undetermined.

The purpose of this study is to determine if a sufficient raw material base is available, that a market exists or can be developed, and that the total costs of production would be competitive with other structural panels. It includes a raw material analysis, a market

analysis, and a financial analysis.

The raw material analysis involves analyzing detailed U.S. Forest Sevice timber inventory data to determine the volume, ownership, and availability of raw material. The market analysis involves the collection and analysis of data to identify and quantify the markets that are available or can be developed. The financial analysis includes raw material requirements, production costs, prices, and the analysis of an example case. The example case is an OSB plant with an annual capacity of 75 MMSF, 3/8-in. basis producing panels with a density of 40 pcf and resin and wax contents of 5% and 2%, respectively.

Sensitivity analyses on several major variables show that, although wood cost and labor cost are the largest components of cost, the selling price is the variable which has the greatest effect on the feasibility of the venture. In addition, the interest rate and capital costs have greater effect on the feasibility than do any of the production costs.

Based on the resource data, an area consisting of Clatsop, Columbia, and Tillamook counties is best suited to supply an OSB plant. The study also shows that a market can be developed and the project has a high probability of generating a profit.

The Economic Feasibility of Locating an
OSB plant in Western Oegon whoops!

by

Rhonda R. Wright

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The Economic Feasibility of Locating an OSB Plant in Western Oregon

I. INTRODUCTION

In the past ten to twenty years the timber resource in the U.S. has been changing. It is becoming much more difficult and costly to find and harvest large peeler logs to produce plywood. In addition, it is becoming increasingly difficult to find an available supply of peeler logs in one area to supply a plywood mill. Southern pine and hardwood timber resources have been increasing in volume when compared to Douglas-fir as shown by Figure 1 which shows the annual change in growing stock volume in the U.S. by species, region, and diameter class. This actually represents the annual rate at which the volume is changing. As can be seen by Figure 1, aspen and southern pine have positive rates of change in all diameter classes which means their volume is increasing in all diameter classes. On the other hand, Douglas-fir exhibits negative rates of growth in all diameters over eight inches. This signifies that Douglas-fir volumes are decreasing in all the larger diameter classes. However, this trend is now leveling off as many second and third growth Douglas-fir stands are reaching the larger diameter classes. As these stands mature and other stands are replanted, the growth of Pacific Northwest forests will be comparable to that of Southern forests. The ever decreasing numbers of available large diameter

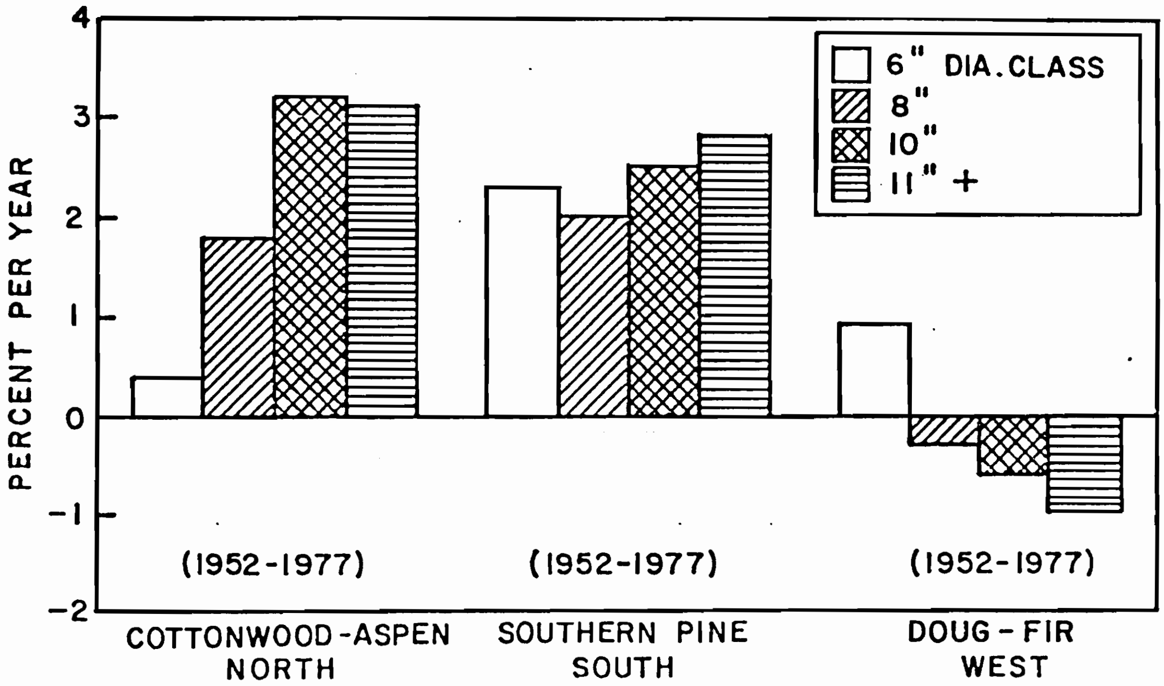

Figure 1. Annual change in growing stock in the U.S. by species, region, and diameter class.

Source: Youngquist 1981

Douglas-fir trees has had a dramatic effect on stumpage prices. Figure 2 shows drastic increases in the prices of Douglas-fir peeler logs while aspen stumpage prices have been very stable and southern pine stumpage prices have increased slowly (Youngquist 1981).

The decreasing availability of large peeler logs and the dramatic price increases for stumpage have had a large negative effect on the plywood industry and is the main reason for the rapid development of the reconstituted structural panel industry. Another factor which has helped the reconstituted panel industry is its high utilization of wood raw material. While plywood typically uses only 45-55% of the wood raw material, OSB utilizes up to 85% of the wood raw material (Koenigshof 1977). In today's world of decreasing raw material availability and escalating prices, the industry can't afford to waste nearly 50% of the raw material.

Hardwoods comprise a large percentage of the timber resource in the U.S. and, in particular, Western Oregon. Most of these hardwood stands are comprised of small, lower quality logs and are underutilized because of low demand for this type of log. Alder is the most abundant and important hardwood growing in Oregon with about 2.4 billion cubic feet growing on about 1.4 million acres (Gedney 1982). It grows primarily in the coastal counties of Oregon and has strength properties very similar to aspen. At the

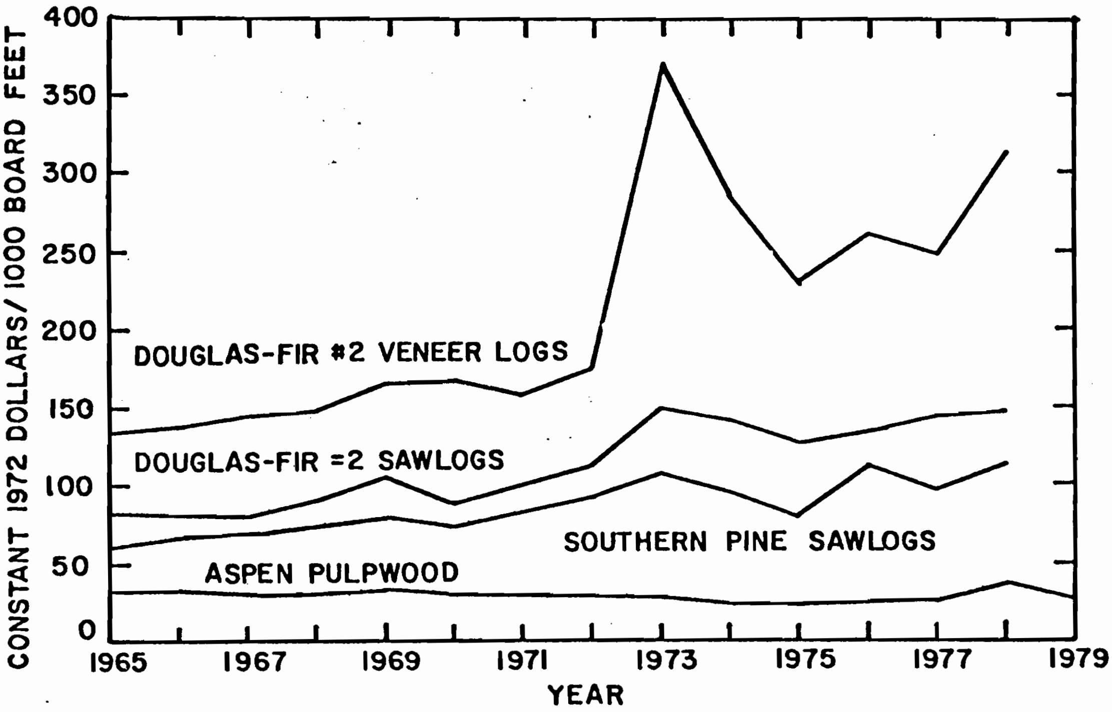

Figure 2. Sawlog, veneer, and pulpwood prices in the U.S., 1965-1979.

Source: Youngquist 1981

present time the growth rate of alder is much greater than the harvest rate. Many of the existing stands were started 40-50 years ago when Douglas-fir stands were cut and not replanted. There is a need to harvest these stands soon because after an age of 40 years alder begins to decay (Resch 1980).

Research done on the manufacture of OSB(oriented strand board) shows that low density woods are preferred with aspen being the most common species used. However, Maloney (1978) and Zylkowski (1983) report that alder can be successfully used in the manufacture of OSB and that the panels produced have performance properties very similar to panels produced from aspen. These panels have properties which are similar to plywood and can compete with plywood in the sheathing and roofing markets.

The fact that alder is currently underutilized, combined with the fact that it regenerates very easily and can be managed on a 30-40 year rotation, promises a steady raw material supply in Western Oregon for the production of OSB.

According to Forest Service (1980) estimates, consumption of softwood roundwood is expected to increase 1.6 times by the year 2000 while the consumption of hardwood roundwood is expected to increase 2.1 times. At the same time softwood stumpage prices are expected to increase 200% while hardwood stumpage prices are expected to increase only 10%. In view of these estimates it seems evident that the reconstituted structural panel industry can do nothing but grow as it becomes increasingly more economically attractive when compared to plywood.

Previous research by Murad (1985) on the economic feasibility of producing OSB in Western Oregon showed the venture to be feasible but the return on the investment was not overly large. However, the study was a preliminary study and the financial analysis was not extremely detailed. This study will use some of the data obtained by Murad, but will refine and expand much of that data to perform a more detailed financial analysis to determine the feasibility of producing OSB in Western Oregon.

II. OBJECTIVES

The objective of this study is to determine the economic feasibility of producing oriented strand board (OSB) in western Oregon. For the venture to be considered feasible, the operating revenues must exceed the operating costs with a sufficient margin to justify the risk of the investment.

The study consists of three phases. The first phase is the development of a computer program to analyze investment opportunities. This program is LOTUS 1-2-3 based to make it flexible and easy to use and uses inputs such as revenues, fixed and variable expenses, depreciation, interest rate, state and federal tax rates, and investment tax credits to calculate the internal rate of return, the net present value, and the payback period of the investment.

The second phase is the collection of the input values to be used in the program. This is accomplished through the completion of several steps.

1. The raw material availability must be thoroughly analyzed. From previous studies it is known that OSB can be successfully made with red alder or western hemlock as the primary species and Douglas-fir or mixed hardwoods as the secondary species. This study attempts to determine if there is a sufficient raw material base in Western Oregon to support the manufacture of OSB. This is accomplished by analyzing detailed inventory

data from the U.S. Forest Service. The data is analyzed to determine the volume of raw material that exists, the ownership of the raw material, and the availability of the existing volume. In addition, the future availability of raw material is considered.

2. All costs associated with the production of OSB must be identified and quantified. By identifying and quantifying the costs, the study determines whether OSB can be produced in Oregon at a cost which will make it competitive in the marketplace with OSB produced in other regions.
3. The availability of markets must be determined. This is accomplished through research to identify and quantify the existing and potential markets for OSB. Once these markets are quantified, it is possible to determine if there is sufficient demand in the Pacific Northwest to support the manufacture of OSB.
4. The plant location for a selected capacity of 75 MMSF 3/8-in. basis must be identified. This is done based on the data obtained in steps 1-3.

When phases one and two have been completed, an example case is analyzed to determine the economic feasibility of producing OSB in Western Oregon.

The third phase involves performing sensitivity analyses on pertinent variables to determine their effect on the profitability of the venture. The variables chosen for sensitivity analysis are: wood cost, labor cost, capital cost, interest rate, and selling price for OSB.

III. RAW MATERIAL ANALYSIS

Timber inventory data that had been collected by the U.S. Forest Service and compiled for the Pacific Northwest Biomass study being done at OSU's Forest Research Laboratory was used in this study to determine raw material availability. The data source covered the state of Oregon and had volume (cu.ft.) and growth (cu.ft.) figures by species, size class, slope class, and ownership within each county. In addition, standard error figures for the volume and growth were provided. For this study the only species of interest are those from which it would be technically feasible to produce OSB. These include: red alder, cottonwood, and western hemlock to be used as primary species and mixed hardwoods as secondary species. The mixed hardwoods include: bigleaf ~~Bigleaf~~ maple, Oregon ash, Oregon white oak, Pacific madrone, golden ~~Golden~~ chinkapin, California black oak, California laurel, and tanoak. It is important to note that the use of the mixed hardwoods would significantly change the properties of the panel produced and would have an effect on the manufacturing cost. For this reason, and because of the relatively low availability of most of these species, the only species which will be considered for the remainder of the study are red alder and western hemlock. The ownership classes of interest were: U.S. Forest Service, BLM, other public, and private.

To create the database for the study, all the original data was sorted by individual species, ownership and size class within each county. For each entry there is a volume in cubic feet, for each size class there is a total volume in cubic feet, and for each county there is a grand total volume in cubic feet. The size classes used are as follows:

1. saw timber	diameters > 9 in.
2. poles	diameters 5 in. - 8.9 in.
3. seedlings and sap	volume in this class consisting of poles.
4. non-stocked	volume in this class consisting of poles.
5. no break down	85-95% of volume is saw timber

The U.S. Forest Service volume figures had already been updated by the Forest Service to be in terms of 1984 acres and volumes. This was done using a computer program to grow the timber then subtracting the volume harvested, the volume lost due to acreage reductions, and the volume lost to mortality. However, the BLM, other public, and private figures are in terms of 1976 and 1977 acres and volumes. Trying to update these figures was considered. This would have been done by using a computer model to grow the timber and then adjusting for acreage losses, harvesting, and mortality. However, it was not possible to obtain harvesting figures broken down by county and mortality estimates are difficult to make. Considering the magnitude of the standard errors in the original data, adjusting the figures was not going to create a much more accurate data base, and because the adjustments are quite complex, it was not considered to be an efficient use of resources.

The data base that was created is not completely reliable due to several factors. The primary factor is the large standard errors present in the original data. Some standard errors were 90-100%. The only way to change this is to conduct a new inventory study which is far beyond the scope of this study. Another factor is the fact that for the purposes of this study, primarily hardwood data was needed, and the hardwood data available is less accurate than softwood data. This is most likely due to the fact that there are few commercial uses for most of the hardwoods and, therefore, there is little demand for detailed inventory data. In addition, the data needed for the study was broken down into very small segments which increased the error. The data was separated by individual species, ownership, and size class within each county. This is less accurate than looking solely at individual species over the entire county because as each segregation is made the standard error is compounded. Another factor is the significant reductions in BLM acres in the past five years which make the present BLM volumes less than the 1977 figures. However, the fact that the BLM volume is a small percentage of the total volume and there are large standard errors associated with these changes, they would not create a significant change in the overall volume figures.

Taking into consideration all of the above mentioned factors, the data base is still valuable, because although the volume figures are not precise, the magnitudes are accurate. It is the best and most complete information available and it provides a very good indication of how much raw material is available for OSB production, where it is located, and ownership.

Description

Red alder (Alnus ~~Rubra~~ rubra) grows on the Pacific coast from Alaska to California with the greatest volume growing in Oregon and Washington as shown by Figure 3. It is the most abundant and important hardwood in Oregon and usually grows in stands mixed with Douglas-fir, Western hemlock, Western redcedar, and Sitka spruce. ~~Alder~~ usually does not grow more than 100 miles inland or at elevations above 2,000 feet and it requires at least 25 inches of rainfall per year. It thrives in well drained alluvial soils and moist hillsides and occurs in pure stands along streams and bottom lands provided there is over 40 inches of rainfall annually. Alder is a prolific seeder with the ability to regenerate very rapidly and it exhibits very rapid juvenile growth. First year shoots average 6 to 8 inches and seed-

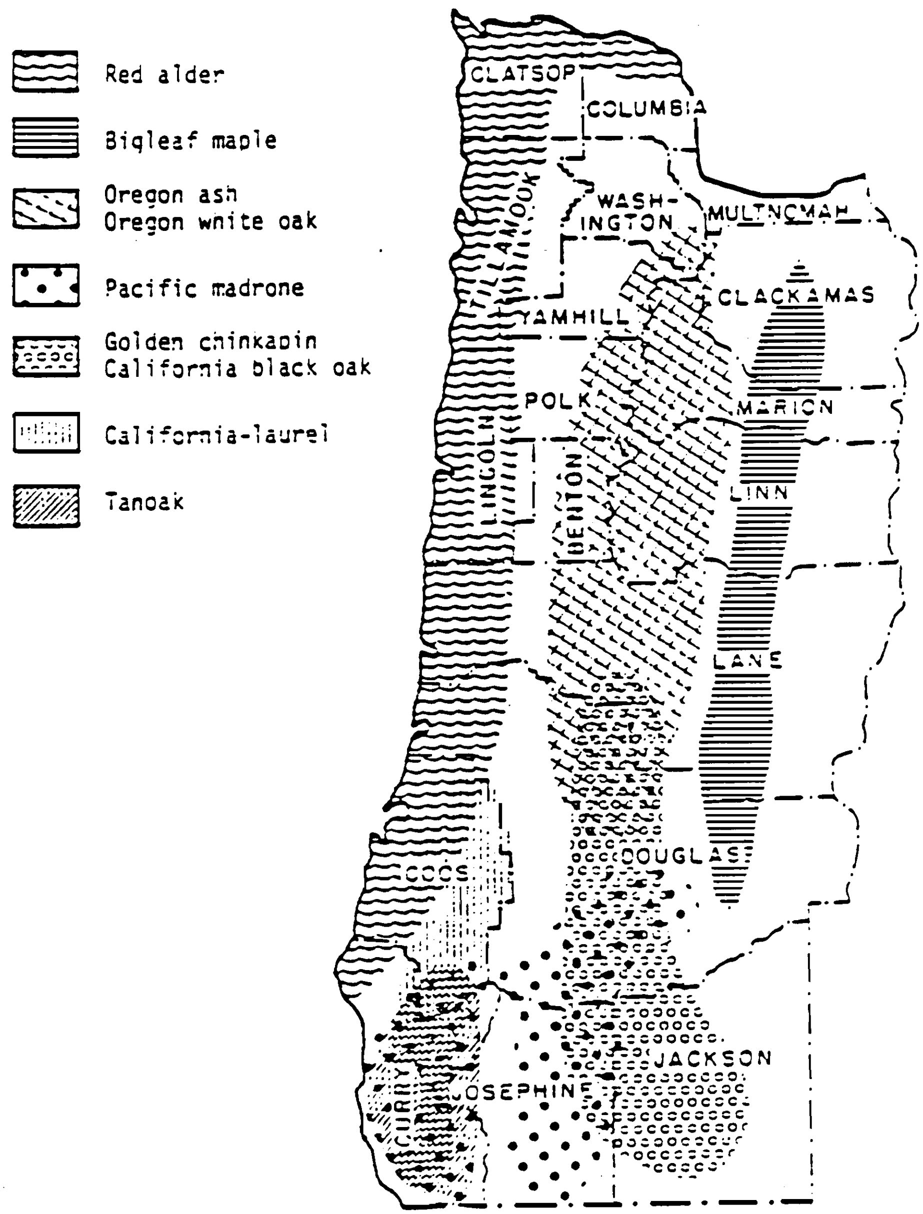

Figure 3. Distribution of hardwood species in Western Oregon counties.

Source: Murad 1985

lings can grow up to 3 feet in height during the first year. It is not unusual for trees to reach 30 feet by age 5 and 70 feet by age 20. Stands started from seeds begin with thousands of trees per acre and since most of these areas are not managed, many existing alder stands have large numbers of trees with small diameters and small log sizes (Resch 1980, Plank 1971).

Alder is a pioneer species. It is usually the first species to re-establish on cut-over or burned areas and helps enrich the soil of these areas by nitrogen fixation. Alder has organisms on its root nodules which process and return nitrogen to the soil by symbiosis. This process helps increase the productivity of the site (Resch 1980, Plank 1971). It is dominant on a site early, but conifers take over after about 40 years as shown by Figure 4. Alder outproduces conifers in volume for the first 20 years, however, after 20 years Douglas-fir and hemlock outproduce alder in volume and at 60 years hemlock volumes more than double those of alder. Figure 5 shows this relationship. Alder has a very short life. It reaches maturity in about 40 years and then begins to decay and die. At maturity the trees are between 18 and 24 inches in diameter and reach heights of 65 to 100 feet. It is not possible to attain as high a production of volume per unit of time with alder as with conifers because the trees are smaller and have a fairly low volume per acre as shown by Figure 6. However,

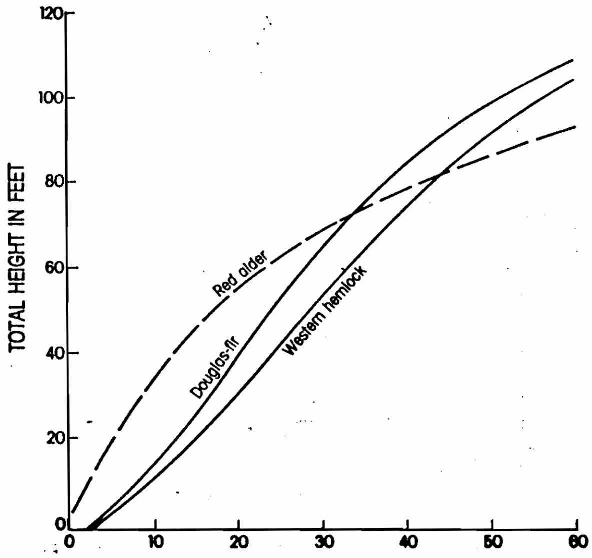

Figure 4. Comparison of heights of Western hemlock, Douglas-fir, and alder from age 0-60.

Source: Atterbury 1978

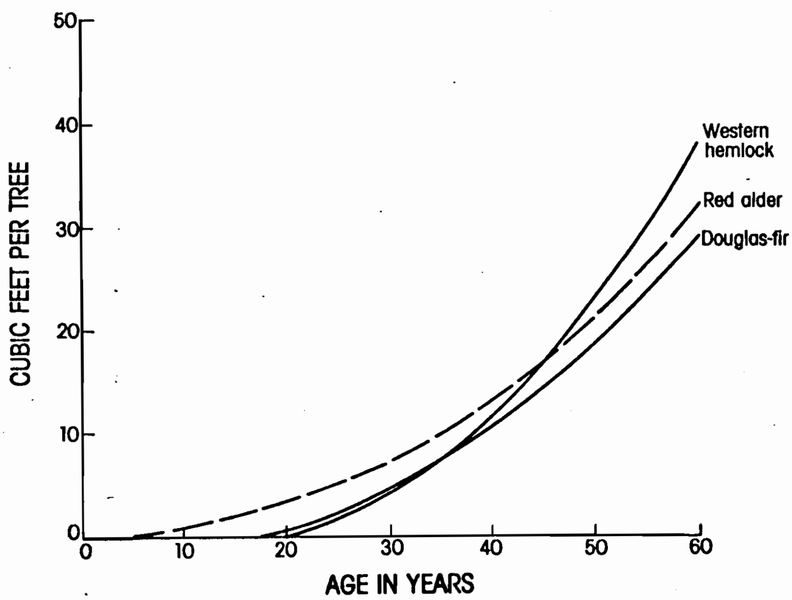

Figure 5. Comparison of volume per tree over age by species.

Source: Atterbury 1978

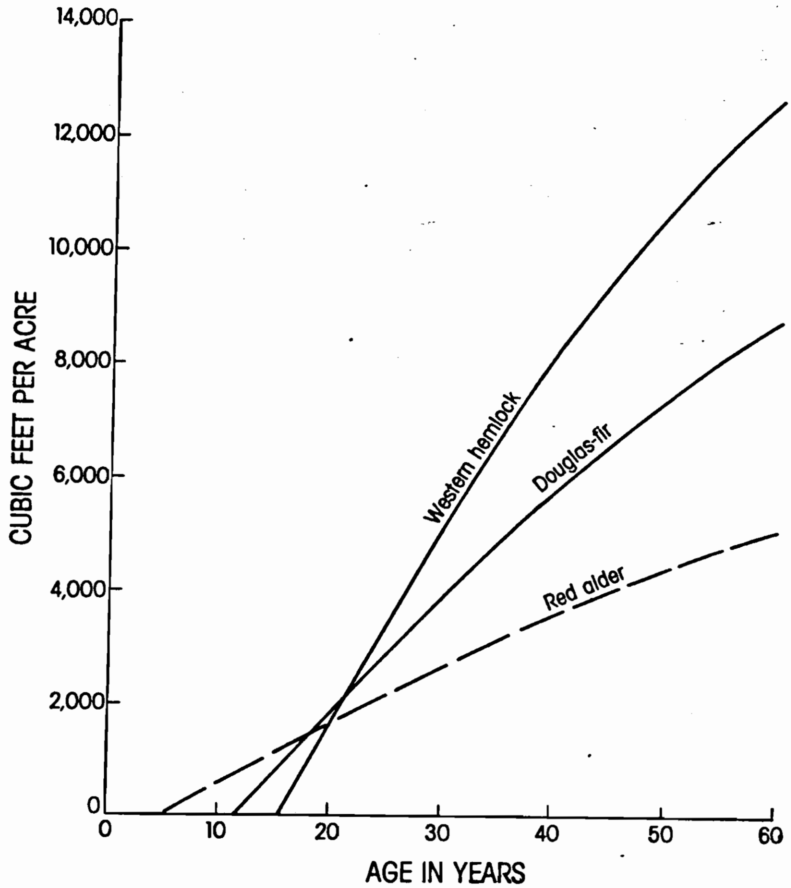

Figure 6. Comparison of yields over age by species.

Source: Atterbury 1978

alder produces a high percentage of clear wood. It is possible to grow alder on a 40 to 50 year rotation and produce clear wood which is something that is not possible with conifers (Atterbury 1978).

Many conifer sites cut-over in the 1940's and 1950's were not reseeded and were naturally seeded by alder so there are many alder stands at or near maturity in Oregon. These stands represent a much greater volume than the current demand for alder. In the future if alder stands are managed, it is possible to produce trees with diameters of 18 to 20 inches and heights of 65 to 90 feet with rotations of 30 to 40 years (Atterbury 1978).

Properties

Alder is classified as a diffuse-porous wood which means the pores are uniform in size and are distributed evenly across the growth rings. Alder exhibits no clear definition between early and late wood and has a uniform grain and smooth texture and is very easy to work. It machines and turns well, glues well, and takes coatings and finishes very well (Plank 1971). Alder has a whitish-gray color when first cut, but darkens upon drying. It usually dries to a light reddish-brown or honey color and there is no clear distinction in color between heartwood and sapwood (Plank 1971).

Alder has strength properties very similar to aspen.

It exhibits moderate shrinkage and is generally considered dimensionally stable after drying (Plank 1971).

Alder can be used for pulping, lumber, furniture manufacture, millwork, turnery, and fuel wood. Because of its low density and rapid growth, it is well suited for the manufacture of OSB (Resch 1980). Laboratory tests on OSB panels made from alder show it has values for MOE, MOR, and internal bond that equal or exceed those for OSB made with aspen. (Zylkowski 1983).

Harvesting

Harvesting and marketing alder presents several problems, among these are: availability of contractors, manpower, harvesting equipment, labor and overhead costs, and availability of a steady market.

Alder logging is not a high volume operation so it is difficult to find contractors to log alder stands. Most contractors usually produce 12 to 14 loads of conifers per day and it is difficult to convince them that it can be profitable to log alder which usually produces 4 to 6 loads per day.

It is also difficult to find experienced manpower, especially timber cutters. Much of the alder is located on steep slopes with dense underbrush which requires extra work to cut through. In addition, red alder tends to have unbalanced crowns and they often lean out over the slope. This requires that the trees be felled downhill instead of across the slope which entails considerable extra work for fellers and riggers.

Conventional cable yarding techniques may be used for alder operations. Skyline and slack line systems cause the least damage to the soil, but also do little damage to underbrush which results in higher slash disposal costs. There is also some difficulty in using cable systems due to a lack of suitable stumps for anchoring guylines because alder stumps are not as large and lack the holding power of conifer stumps.

Tractor and rubber tired skidders are used whenever possible in conjunction with cable systems to lower costs. With the use of wide tracked skidders, it is possible to use ground-based logging systems even during the wet season.

Alder decays rapidly after being cut so it must be removed as soon as possible. Sometimes this may pose a problem due to the lack of a continuous market for alder because there is not enough demand for all grades of logs produced. Most of the demand is for saw logs, however, in order for the logging operation to be profitable, all grades of logs must be removed and sold.

Because of high labor and overhead costs and low demand for many grades of logs combined with low volumes per acre, many times it costs more to harvest and transport alder logs than the market selling price as shown by Figure 7. However, the initiation of OSB production in Western Oregon would provide a large, continuous market for most grades of alder logs and would make it profitable to harvest the large volumes of alder now available.

Availability

Alder is the most abundant hardwood growing in Oregon and is mainly found in the coastal counties of western Oregon. There are approximately 2.7 million acres of hardwood stands in Oregon with about 4.8 billion cubic feet of volume growing in those stands and alder comprises over 50% of this acreage and volume. Of the 2.7 million acres of hardwoods, alder comprises about 1.4 million acres with a volume of about 2.5 billion cubic feet. Figure 8 shows the ownership of alder acreage in western Oregon and Figure 9 shows the ownership of alder volume in western Oregon These figures show that most of the alder acreage (71%) and volume (57%) is privately owned (Gedney 1982). This means that there is not a large percentage of alder available from public sales. The fact that there are not large volumes of alder available from public sales does not have to be a problem because it may be possible to negotiate long-term raw material contracts with one or more private owners. In fact, this arrangement may be more desirable and

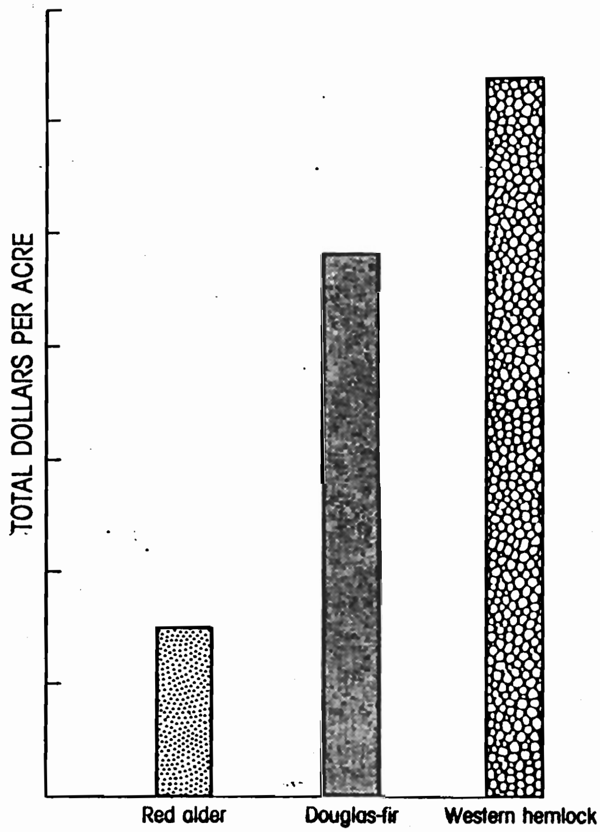

Figure 7. Gross realization per acre by species at age 60.

Source: Feddern 1978

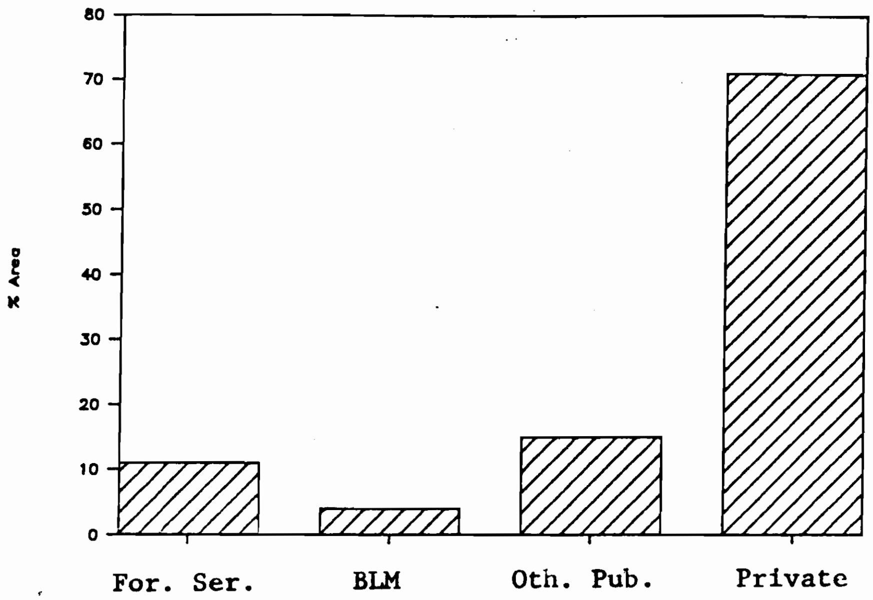

Figure 8. Ownership distribution of alder in Western Oregon by acreage.

Source: Farrenkoph 1984

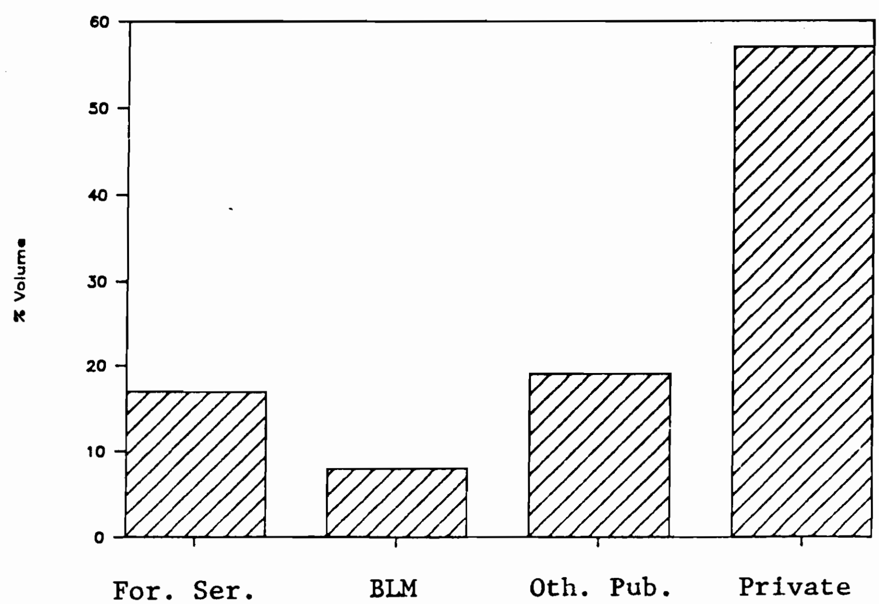

Figure 9. Ownership distribution of alder in Western Oregon by volume.

Source: Farrenkoph 1984

stable than having to continually bid on public sales.

Because most of the alder growing in Oregon is located along the coast, Oregon was separated into three regions for analysis in this study. These regions are: Northwest Oregon, West-Central Oregon, and Southwest Oregon. Figure 10 shows these three regions and the counties which comprise each region. Table 1 shows the acreage of alder stands by ownership for each of these three regions of Oregon, while table 2 shows the volume and growth of alder stands by ownership in those same regions. Tables 1 and 2 show that the Northwest region contains the largest acreage and volume of alder followed by the West-Central region and the Southwest region. In addition, the Northwest and Southwest regions have the largest percentage of acreage and volume in private ownership while the West-Central region has a significant percentage of acreage and volume owned by public agencies.

Based on the volume of alder available, one location was selected in each region as a tentative plant site.

Site 1 : The plant would be located at Tillamook with raw material obtained from Clatsop, Columbia, and Tillamook counties.

Site 2 : The plant would be located at Newport/Toledo with raw material obtained from Lincoln and Lane counties.

Site 3 : The plant would be located at Coos Bay with

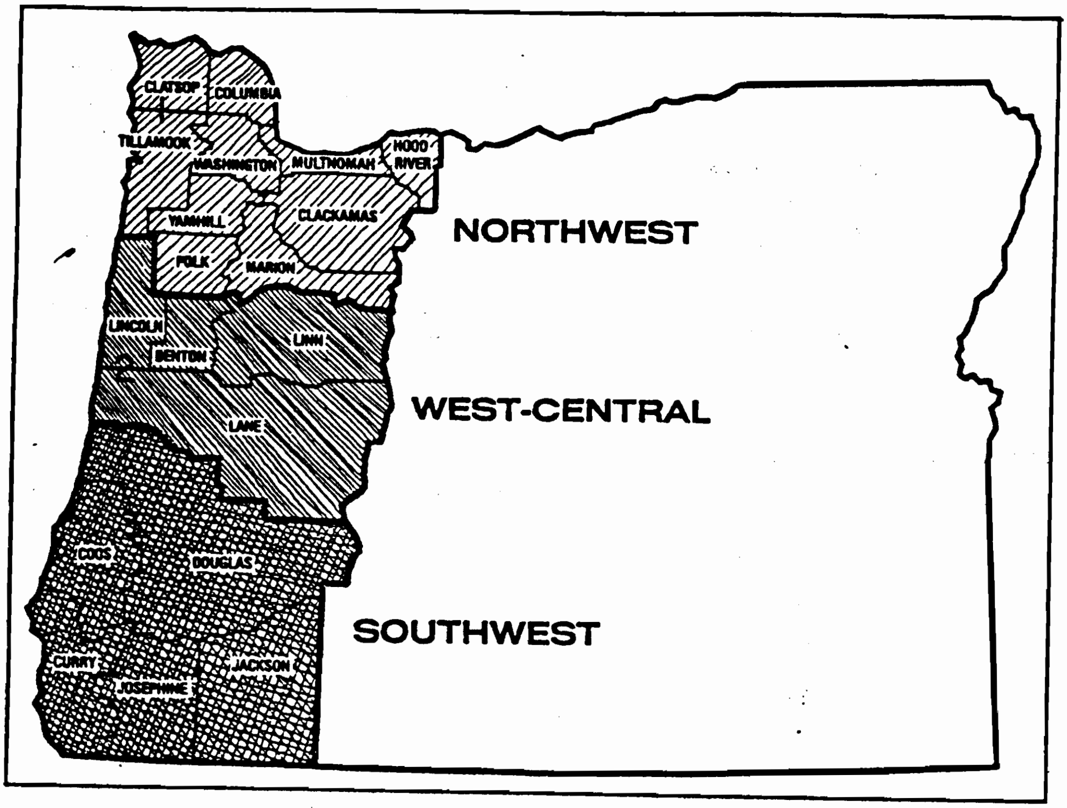

Figure 10. Western Oregon inventory units and three proposed alder supply regions.

Source: Gedney 1982

Table 1. Ownership of Alder acreage in three regions in Oregon.

	NW Region	WC Region	SW Region
	Area in thousand acres		
Forest Service	39	82	16
BLM	22	17	15
Other Public	110	35	44
Private	383	256	276

Source: Farrenkoph 1984.

Table 2. Volume and growth of Alder by ownership in three regions in Oregon.

	NW Region		WC Region		SW Region	
	volume (MMCF)	growth (MCF)	volume (MMCF)	growth (MCF)	volume (MMCF)	growth (MCF)
Forest Service	129	146	246	106	54	40
BLM	69	221	64	182	63	70
Other Public	234	1605	82	292	160	2
Private	682	3080	362	1640	404	2170

Source: Farrenkoph 1984

raw material obtained from Coos and Douglas counties.

Table 3 shows the volume and growth in each of the three areas and table 4 shows the volume and growth in each of the three areas by ownership and size class. Tables 3 and 4 show that region I has the most growth and the lowest mortality rate. Region II has the most volume, but has only about one-half the growth of region I. Regions II and III have double the mortality rate of region I which means that many of the trees in regions II and III are over mature and dying. Alder begins to decay after 40 years so there are probably a relatively large number of trees beyond this age in regions II and III. On the other hand, the tables show that region I has a relatively large number of younger, healthier trees. The figures in tables 3 and 4 do not take into account the loss due to mortality or the amount of alder presently being harvested annually. Figure 11 shows the percentage of alder currently being harvested annually and the percentage of mortality annually. As the figure shows, the mortality rate is currently almost 1 1/2 times the removal rate. This is mainly because alder is underutilized. In addition to being underutilized, some alder is inaccessible due to its location either on slopes over 35% or along stream beds. Table 5 shows the volume and growth of alder in each area after subtracting the mortality and amount of the annual harvest. The current low utilization of alder combined with the volumes shown in

Table 3. Volume, growth, and motality of Alder in each of the proposed regions in Western Oregon.

	Volume (MMCF)	Growth (MMCF)	Mortality (%)
Region I	718	35	17
Region II	963	16	38
Region III	540	17	32

Source: Farrenkoph 1984

Table 4. Volume and growth of Alder by ownership and size in each of the proposed regions in Western Oregon.

	size	Region I vol. (MMCF)	Region I growth	Region II vol. (MMCF)	Region II growth	Region III vol. (MMCF)	Region III growth
Forest Service	1	43	.3	183	1	26	.3
	2	---	---	.3	.01	1	.08
	3	---	---	---	---	---	----
	4	---	---	---	---	---	----
BLM	5	17	.5	414	1	41	.45
Other Public	1	93	4.1	38	1	165	.02
	2	123	10.5	---	----	---	----
	3	3	.3	---	----	---	----
	4	---	----	---	----	---	----
Private	1	316	7	239	3	189	7
	2	115	10	82	9	97	8
	3	14	.5	4	.4	19	1
	4	---	----	1	.1	---	----

1 - sawtimber diameters > 9"
2 - poles diameters 5"-8.9"
3 - seedlings and sap volume in this class consisting of poles.
4 - non-stocked volume in this class consisting of poles.
5 - no break down 85-95% sawtimber

Source: Farrenkoph 1984

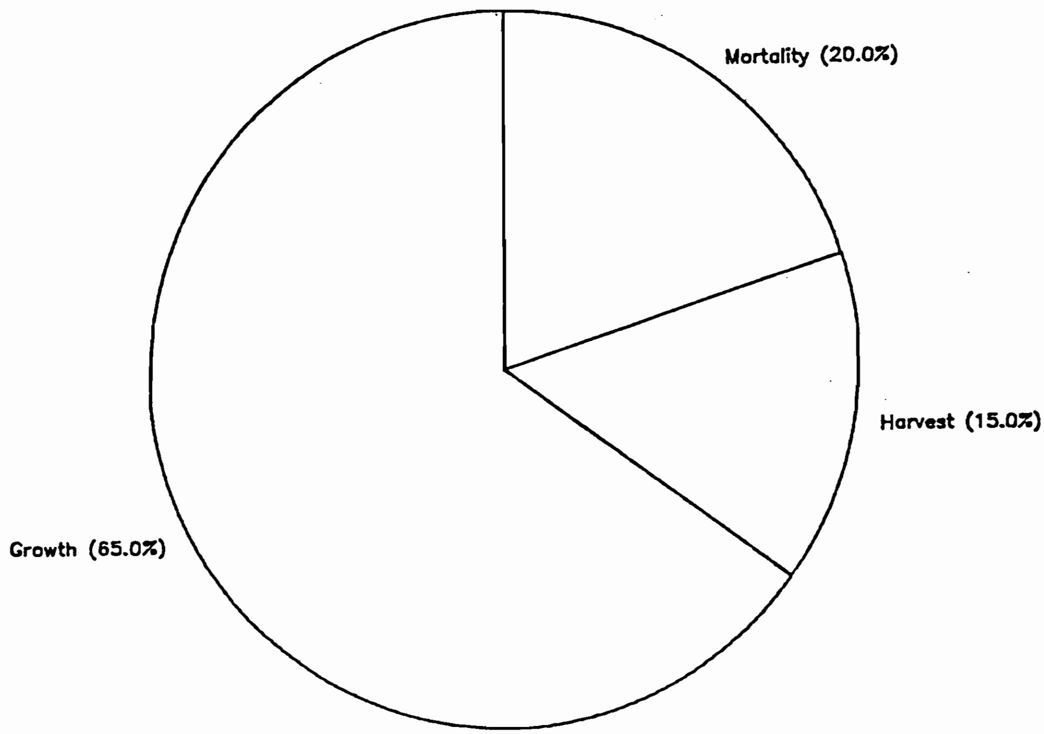

Figure 11. Comparison of harvest and mortality rates of alder from the net annual growth in Western Oregon.

Source: Farrenkoph 1984

Table 5. Volume and growth of Alder in each of the proposed regions in Western Oregon after subtracting annual harvest and mortality.

	Volume Growing Stock (MMCF)	Net Growth (MMCF)
Region I	718	29
Region II	963	10
Region III	540	11

Source: Farrenkoph 1984

table 5 indicate an abundance of alder available. However, it is important to note that much of this volume is located in areas with slopes greater than 35%. Generally cable logging systems must be used to harvest trees located on slopes greater than 35% which means that harvesting will be difficult and costly. Figure 12 shows the percentage of alder in each region that is located on slopes greater than 35%. As can be seen by Figure 12, both region I and region II have between 70 and 75% of the alder volume located on slopes less than 35%, however, almost 50% of the alder volume in region III is located on slopes over 35%. Because logging costs are a relatively large portion of overall costs, the attractiveness of region III is diminished greatly by its large percentage of stands on steep slopes.

For this study two different sizes of plants will be considered. They are 75 and 150 MMSF (3/8-in. basis) annual capacity. Figure 13 shows the raw material requirements for each plant size contrasted with the raw material supply available in each region. The raw material supply available in each region consists of the net annual growth after subtracting the annual mortality rate, the annual harvest rate, and the volume of material located on slopes greater than 35%.

As can be seen from Figure 13, only region I is capable of supplying a 150 MMSF plant. However, all three regions are capable of supplying at least one 75 MMSF

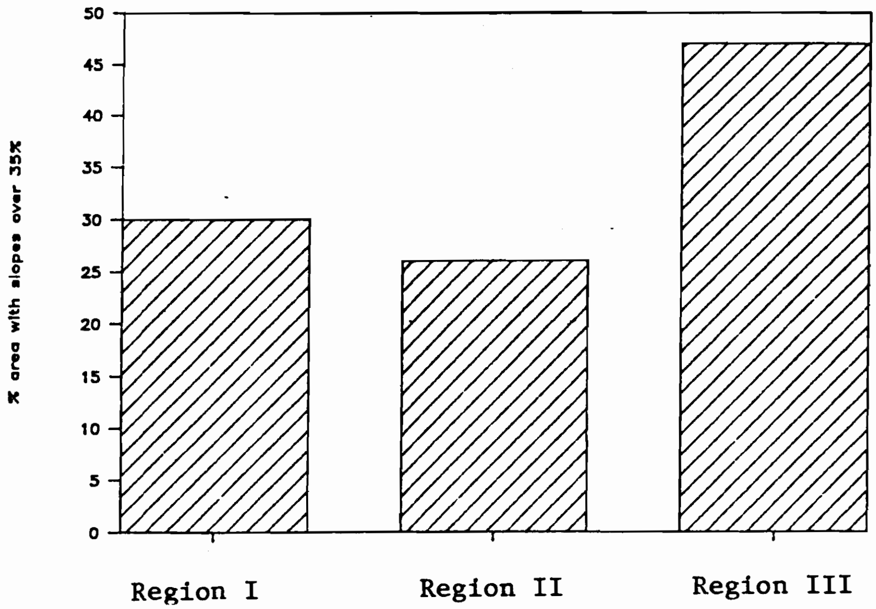

Figure 12. Percentage of alder located on slopes over 35% in each of the proposed regions.

Source: Farrenkoph 1984

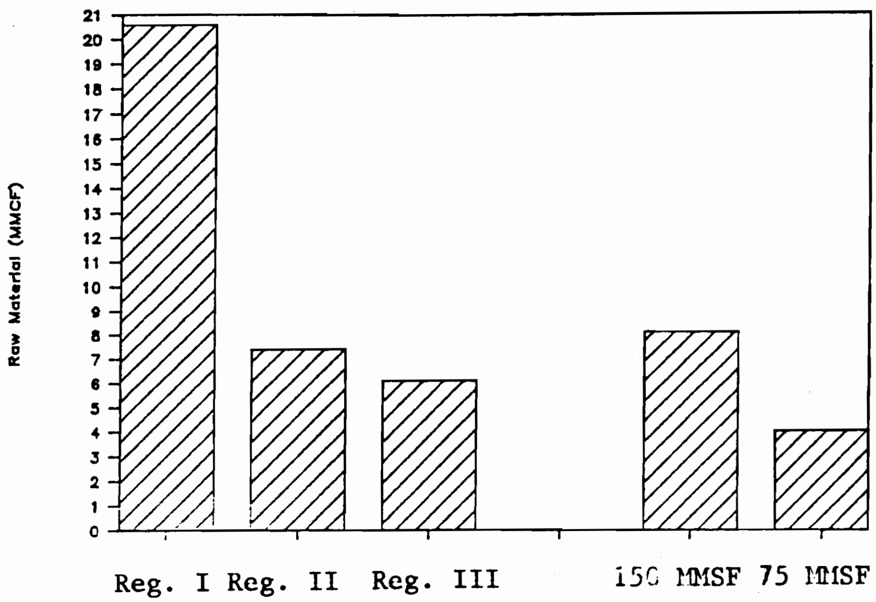

Figure 13. Comparisons of net annual growth of alder in each of the proposed regions with raw material requirements of two OSB plant sizes.

Source: Farrenkoph 1984

plant. From this data it is obvious that region I has the largest raw material base and is best able to support an OSB plant. However, it should be noted, as is shown by Figure 14, that over 60% of the volume in region I is privately owned and most of that volume is owned by the forest industry. This means that a sufficient raw material supply may not be available from public sales alone. However, it may be possible to negotiate long-term raw material contracts with one or more private owners or to enter into some type of joint venture in order to secure sufficient raw material. In fact, these solutions may be more desirable and stable than depending on public sales.

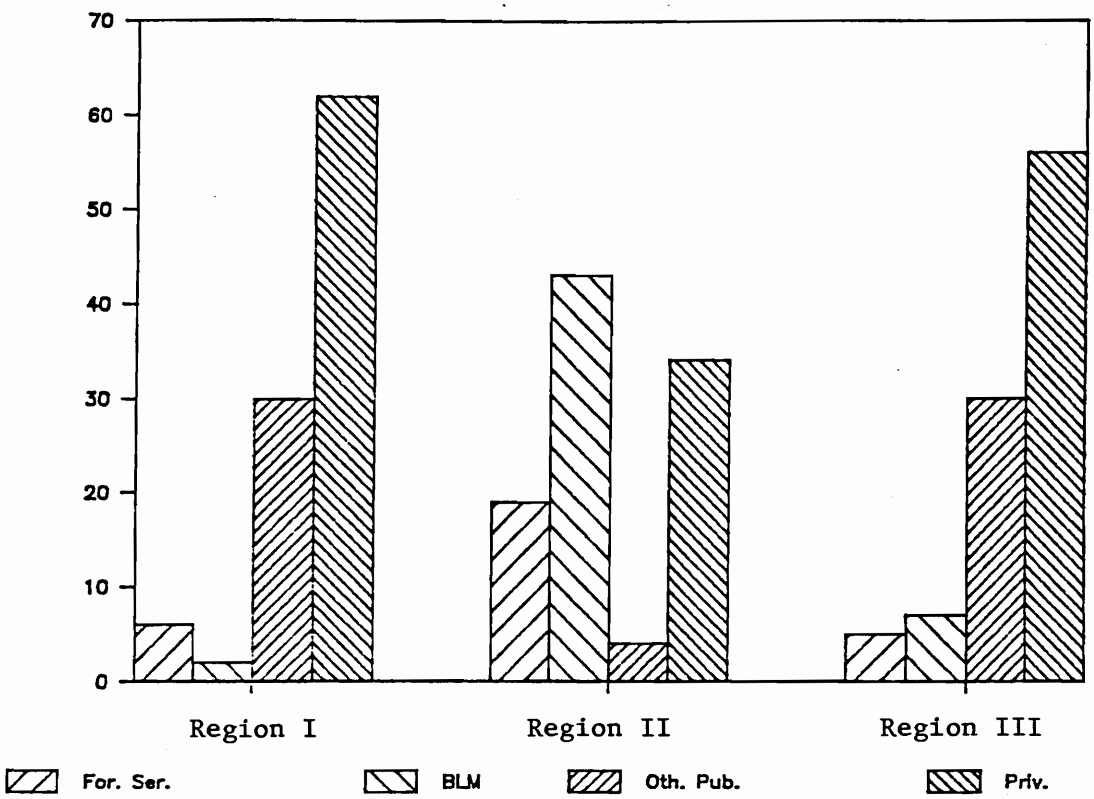

Figure 14. Ownership distribution of alder in each of the proposed regions.

Source: Farrenkoph 1984

OSB

Oriented strand board (OSB) may be defined as a reconstituted structural wood panel. It is reconstituted because the wood raw material is broken down into flakes or strands then glued back together to produce a panel. The strands are oriented along the panel in the face and back layers and across the panel in the core. By orienting the strands it is possible to attain strengths and dimensional properties that are very similar to plywood. OSB panels are usually three layers with common thicknesses being 3/8, 7/16, 1/2, and 5/8 inches and panel size being 4 feet by 8 feet (Vadja 1980, Bucking 1980).

The strands which make up OSB are flakes of wood that have a length to width ratio of approximately 2:1. The minimum strand length is about 3/4 inches with the preferred length being 2 to 3 inches and the preferred width being between 1/4 and 1/2 inches (Vadja 1980, Bucking 1980).

OSB was first proposed by Elmendorf in the late 1950's. In the early 1970's Potlatch built a pilot plant at Lewiston, Idaho which was followed by commercial production of OSB. Since that time several OSB plants have begun operations in the U.S. (Vadja 1980, Moeltner 1980).

Waferboard

Waferboard was developed before OSB and is also a reconstituted structural wood panel. However, it is made from non-oriented flakes which are approximately 1 1/2 to 2 inches long and wide and have a thickness of about .025 to 0.035 inches. Waferboard has properties similar to plywood across the panel length, but plywood properties along the panel length are almost twice those of waferboard (Carroll 1976, Vadja 1980).

J. d'A. Clark and A.L. Mottet were both instumental in the development of waferboard in the early 1950's and they both presented papers describing waferboard products in 1954 (Vadja 1980). One of the first waferboard plants was put into operation in 1958 at Sandpoint, Idaho. However, this plant was not successful primarily due to the fact that there was an abundant supply of low cost raw material from which to produce plywood. Another early waferboard plant was started in 1961 at Hudson Bay, Sasketchewan. It was not successful initially and was sold to MacMillan Bloedel who turned it into a successful venture competing with western softwood plywood. By 1969 capacity at that plant was doubled and between 1971 and 1979 several more plants were brought on-line in Canada (Guss 1980). By this time two plants were operating in the U.S. and during the 1980's several new operations have been added in the U.S. (Guss 1980).

Waferboard vs. OSB

Both OSB and waferboard were developed to compete with softwood plywood, but OSB provides a method of achieving dramatic improvement in strength and stiffness properties through orienting the strands (Vadja 1980). OSB and waferboard are both used in roof decking, floor decking, wall sheathing, and general utility applications as a substitute for plywood (Bucking,et.al.1980, Guss 1980, Vadja 1980).

In 1980 there were no OSB plants in operation in the U.S., but by 1986 over half of all waferboard and OSB plants in the U.S. are OSB plants. There are five major factors which have contributed to the recent dominance of OSB. They are as follows:

1. By orienting the strands, much higher MOE and MOR properties are obtained. In addition, linear expansion is improved. These factors are very important if the panel is to be used in structural applications to compete with CDX plywood.
2. With the orientation of the strands and the layering of the panel, it is possible to have much greater control over strength properties. It is also possible to reduce the differences between across and along panel strength properties.
3. The preparation, conveying, blending, and forming of strands for OSB is easier than wafers because the

strands are smaller.

4. OSB can successfully utilize lower grade wood forms and different wood species. It is possible to use high density species to produce a high-grade structural panel with moderately low density.
5. With properties closer to plywood it is easier to market OSB as a substitute for plywood.

All of the future growth in the reconstituted panel market will be provided by OSB due to its superior strength properties compared to waferboard and its ability to compete more completely with softwood plywood. In fact, all reconstituted panel plants built in the U.S. in the past couple of years have been OSB plants.

IV. MARKET ANALYSIS

Softwood plywood has been the leading structural panel product in the U.S. since the late 1940's. Until the mid 1970's output growth for softwood plywood was very high. This was due to the following factors: plywood exhibited good structural performance, labor cost savings during installation were realized over lumber, and good grading and marketing programs were employed. In the early 1970's the housing market peaked and an increase in the real price for plywood soon followed. In addition to the housing market peaking, several other changes were also occurring. For several years the timber supply had been gradually changing. As more timber was cut, there was a shift in the available supply from large to small timber. There were also changes taking place in the capital costs associated with plywood production and resin costs were increasing due to a shortage of petroleum products. All of these factors combined to alter the economics of the softwood plywood industry. Between 1970 and 1978 the producer price index for softwood plywood tripled and as the plywood market peaked, reconstituted structural panels began to appear in the market place. These panels were able to compete with plywood because they were produced from an abundant, low-cost wood supply (Irland 1982). The stumpage price of this wood supply was stable and the production facilities could be located near the end user so the

freight costs were lower (Irland 1982).
The major obstacle for these reconstituted structural panels was to gain market acceptance. Structural panels are basically a commodity item. This means that in a free market situation price is the determining factor. If there are two products which perform to specification for a particular end use, then the consumer will choose the product with the lowest cost. Once it was proven that OSB had strength properties similar to softwood plywood and could perform the same job at a lower cost, OSB began to be substituted for softwood plywood. Initially OSB was primarily used for roof sheathing as a substitute for 1/2 inch 3-ply CDX plywood, but in the past few years OSB has expanded its markets to include many other uses previously dominated by plywood (APA 1984).

When reconstituted structural panels first appeared in the market place, waferboard was the dominant product. In fact, OSB did not appear in the U.S. until 1980 and during the early 1980's, waferboard remained the dominant reconstituted panel product. However, in the past three years this situation has reversed and all future growth in the reconstituted panel market will be provided by OSB due to its superior strength properties and its ability to compete more completely with plywood.

The following section provides a brief overview of the uses for structural panels and is divided into five categories. Within each category is a description of the specific markets and the role OSB plays in each of these markets. The five market categories are: new residential construction, distribution, nonresidential construction, industrial, and international.

New Residential Construction Market

The housing market is the single largest market for structural panels. The number of housing starts is determined to a large extent by the cost of money. It has been estimated that 100,000 potential buyers are prevented from purchasing a home for each 1% increase in the mortgage rate (APA 1984). The high interest rates in the early 1980's had the effect of closing out many people from purchasing homes and caused housing starts to drop to some of their lowest levels. However, the economy has been growing steadily for the past three years and the interest rates have declined resulting in a significant increase in housing starts since 1983.

The demand for housing is related to the number of new households formed plus the number of replacement units. During the 1980's household formation has been slower than during the 1970's and is currently about 1.7 million annually. The U.S. census bureau has predicted a continued decline in the formation of new households during the 1990's. This decline in new households could mean a decline in housing starts during the next decade. However, this decline could be offset by increased demand for replacement housing.

Table 6 shows the estimated housing starts for the next five years (APA 1986).

Table 6. Estimated housing starts for the next five years.

Year	Single-family	Multi-family	Total
	housing starts in 1000 units		
1986	1215	600	1815
1987	1075	550	1625
1988	1050	550	1600
1989	1150	575	1725
1990	1220	600	1820

Source: APA 1986.

Within the housing market there are several markets which warrant individual discussion. These are as follows: floor systems, roof systems, siding, wall sheathing, and mobile home construction.

Floor Systems

The flooring market consists of all single and double floor systems. The size of this market has been expanded considerably with the development of the permanent wood foundation system. Residential floor surface is estimated to total 2.3 billion square feet in 1986 and at the present time wood floors are used in 51% of all single-family units and in 60% of all multifamily units. The main competition comes from concrete slab systems (APA 1986).

There is very good growth potential for OSB in this market once it gains product approval. At the present time there are only a few manufacturers who have qualified their OSB or waferboard products for flooring use, however, many more manufacturers are in the approval process now.

Roof Systems

The roof sheathing market is the largest segment of the residential construction market with a volume estimated to be 3.3 billion square feet in 1986. Presently structural panels comprise about 90% of all sheathing and OSB and waferboard have been very successful in penetrating this market due to their favorable price compared to softwood plywood; 7/16 inch waferboard and OSB have replaced 1/2 inch CDX plywood. The growth of this market is dependent on housing starts and is estimated to be only moderate because of the already high percentage of structural panel use (Random Lengths 1986).

Siding

The siding market consists of material used for side-walls, accent walls, gables, and privacy screening. The market has not been penetrated to any great extent by OSB or waferboard, but more manufacturers are starting to produce OSB siding. The panel used in these applications must be waterproof and have an attractive, durable surface. The relatively low price of reconstituted panels has made them more attractive for use as siding especially in low-cost housing. However, according to APA estimates, the siding market is nearing maturity after a relatively rapid expansion in the past two years and is expected to decrease during 1986 and 1987 (Random Lengths 1986, APA 1986).

Wall Sheathing

OSB is used for wall sheathing although many other materials which cost less are more often used. These other materials include: fiberboard with plastic foam, foil-faced paperboard, and gypsum. Unlike OSB, most of these materials do not have any structural strength and are not nailable, but are used for thermal insulation (APA 1986).

Mobile Homes

Mobile and modular home construction is another large market within residential construction. Good growth potential exists for waferboard and OSB in this market. Probably the most promising area is as a replacement for plywood as roof sheathing. Although mobile home decking comprises the largest volume of panel products in mobile home construction, particleboard is still used for the majority of decking and, unless federal regulations on formaldehyde emissions are imposed, OSB will not be able to replace particleboard due to the price differential (APA 1986).

Distribution Market

The largest non-housing market for structural panels is the distribution market. The distribution market consists primarily of homeowner uses. It includes direct consumer purchase markets consisting of do-it-yourselfers (DIY) and small contractors. The uses for the panels range from minor repairs to major additions or alterations. Additions, alterations, and major replacements comprise approximately 90% of all structural panel consumption in the distribution market.

The distribution market has grown substantially in the past five years. There are three reasons for this growth; they are: due to the high cost of new housing, people are remodeling instead of moving; due to the difficulty and high cost involved in hiring contractors to do the remodeling, they are doing their own work; and pride in ownership and the desire to do the job themselves. In addition there have been many products introduced which make it easy for amateurs to do their own work. Examples of these products are floor tiles and wall paneling (APA 1986).

Retail building material suppliers have grown from the traditional lumberyard to now include many DIY oriented marketers. These stores cater to the DIY by carrying a wide range of products and remaining open seven days a week. The distribution market affords a great opportunity for growth for OSB and waferboard particularly in the DIY market.

Nonresidential Construction

The main uses for OSB and waferboard in the nonresidential market have been in roof decking, concrete forms, agricultural buildings, and various other types of shelters. The possibility for panel sizes greater than 4 feet by 8 feet is an advantage over plywood in some of these uses.

Many of these uses depend on local building codes and on the state of the economy. In the past few years, the economy has been good and there has been a resurgence in the construction of new plants, warehouses, and office buildings. The greatest opportunity for growth in this market is in roof applications. Almost half of the one billion square feet of roof sheathing used in this market is used in the West. If the rest of the nation used structural panels for nonresidential roof sheathing at the same rate, the total volume would double (Random Lengths 1986, APA 1986).

Industrial Market

There are many different industrial markets for structural panels and the quantity of panels used is different for each of these markets. In general most of the industrial markets are heavily tied to economic conditions. In periods of economic growth more products are produced which require more shipping containers and plant improvements. The growth in the industrial markets has been good due to a strong economy and an increase in housing starts. The major opportunity for growth in the industrial market is in the materials handling area. The APA estimates that 1.45 billion square feet of structural panels will be consumed by 1987. Table 7 shows the estimated percentage change in industrial consumption of structural panels (APA 1986).

Table 7. Estimated percentage increases in the use of structural panels in industrial markets.

Year	Materials Handling	Transportation Equipment	Products Made For Sale	Other Industrial
1986	+ 1%	----	+ 2%	+ 1%
1987	+ 3%	+ 3%	+ 3%	+ 3%
1988	+ 4%	+ 2%	+ 2%	+ 4%
1989	+ 4%	+ 5%	+ 2%	+ 4%

Source: APA 1984.

Material Handling

This market consists of pallets, skids, crates, industrial shelving, trays, liquid storage and handling trucks, and industrial bins. There is excellent potential for OSB in this market especially in pallet construction as structural panels are being used more frequently in order to reduce handling costs (APA 1986).

Transportation Equipment

This market includes truck and bus bodies, rail cars, trailers, recreational vehicles (RV), boats, and cargo containers. RVs provide the best opportunity for OSB. The availability of panel sizes greater than 4 feet by 8 feet has proved to be an advantage for RV flooring although the weight of these panels has posed a problem in smaller vehicles. Another promising area for OSB is in the trucking industry. The trucking industry has experienced growth over the past several years as it replaces rail transportation and a large percentage of the growth in structural panel use will come in this area (APA 1986).

Products Made for Sale

This market consists of furniture, fixtures, toys, games, and signs. Particleboard and medium density fiberboard dominate this area, and although there is the potential to shift to OSB, it probably will not occur in great volume due to the higher cost of OSB (APA 1986).

International Market

The international market has great opportunity for growth. Presently the majority of the structural panels purchased in the international market are being used for crating, packaging, and concrete forming. Most countries in the world do not use large volumes of wood in their construction, however, progress has been made in gaining code and technical acceptance for the use of structural panels in domestic and industrial construction. In addition, the economic climate in Europe is becoming more healthy which will increase the demand for structural panels.

The APA predicts that the export market is on the verge of a large expansion. Demonstration projects using wood construction are currently stimulating interest in South America and the Caribbean. In addition, Japan has said they will be reducing tariffs in 1987 and China has demonstrated interest in a wood construction demonstration project. According to APA estimates, the international market could double by 1991 (APA 1986).

Overall the APA is predicting an increase in demand for structural panels in all major markets over the next five years. Figure 15 shows the estimated total demand for structural panels by end-use for the next five years.

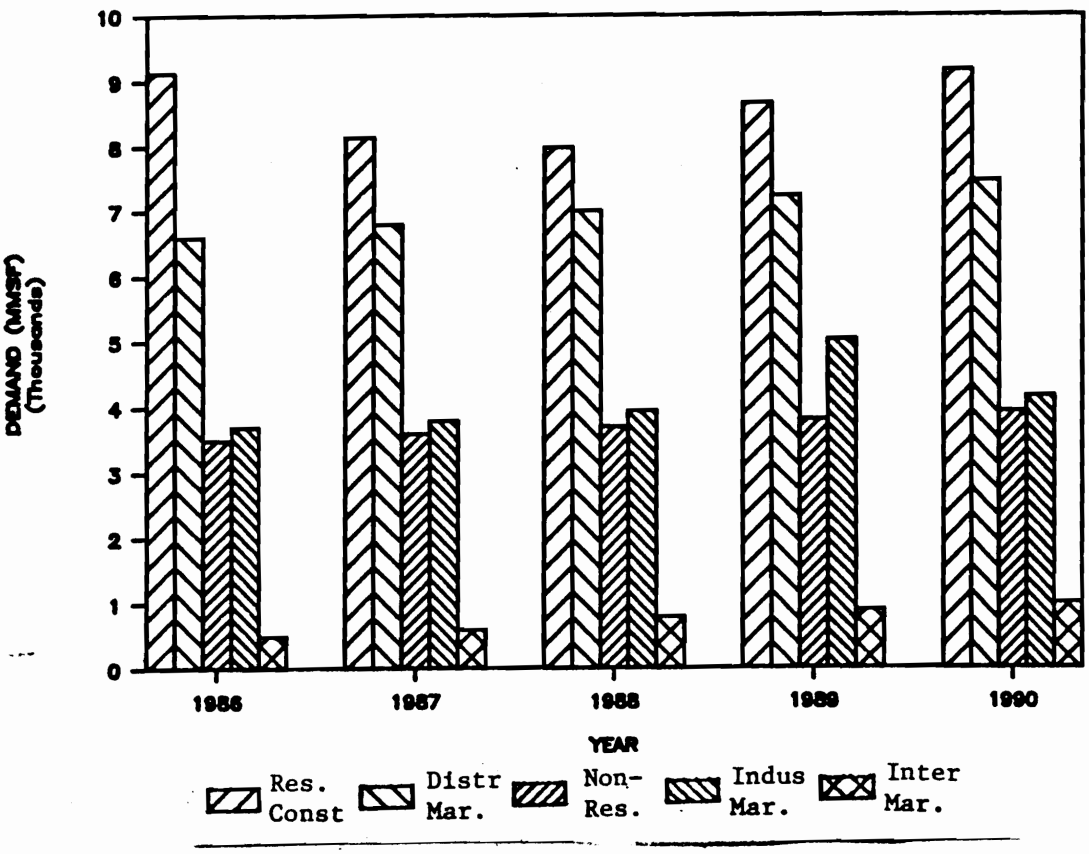

Figure 15. Estimated total demand for structural panels by end-use, 1986-1990.

Source: APA 1986

Future Markets

OSB has been successful in penetrating several markets previously dominated by plywood and the future for OSB looks very bright. However, there are still many markets for which OSB is suitable that have not been tapped.

One factor which will help OSB penetrate some of these new markets more easily is the development of performance standards for structural panels in residential markets. In the past all standards for structural panels have been product standards. Product standards are prescriptions of how the minimum acceptable product is to be manufactured. These standards do not define product uses or take into account applications of the product. Alternatively, performance standards do not prescribe the method used to manufacture the product. Instead they are oriented to the end use of the product. Performance standards state what is required for a particular end use and then provide test methods and criteria for measuring conformance. Under this design any product, regardless of how or from what it is made, may be used if it meets the performance standard (Lewis 1981, O'Halloran 1979).

The use of product standards limits technological innovation because the method of manufacture is prescribed. On the other hand, the use of performance standards allows the manufacturer to innovate and use raw material as he wishes as long as the finished product conforms to the standard.

Performance standards are used extensively in the electronics industry, the auto industry, and in building aircraft. However, they are not very common in the building industry with the exception of their use in fire classification for thermal insulation. The APA is developing performance standards for structural panels with the criteria and test methods designed to reflect end-use conditions. With the development and adoption of performance standards, OSB will be able to be rated for new uses much more quickly and this will make the penetration of new markets easier.

Market Share

Historically waferboard and OSB prices have been considerably lower than softwood plywood prices in an effort to penetrate the market and gain acceptance. However, this price differential has been slowly disappearing as OSB has gained acceptance as a substitute for plywood, and as plywood manufacturers have become more cost conscious (Random Lengths 1985). The spread between Western plywood sheathing prices and OSB prices has become much smaller as is shown by Figure 16. During the first nine months of 1984, the price differential between 1/2-inch 3-ply CDX Western plywood and 7/16-inch OSB from Northeastern mills averaged 46 dollars. During the next ten months, the average differential dropped to 36 dollars, and the average price diffe

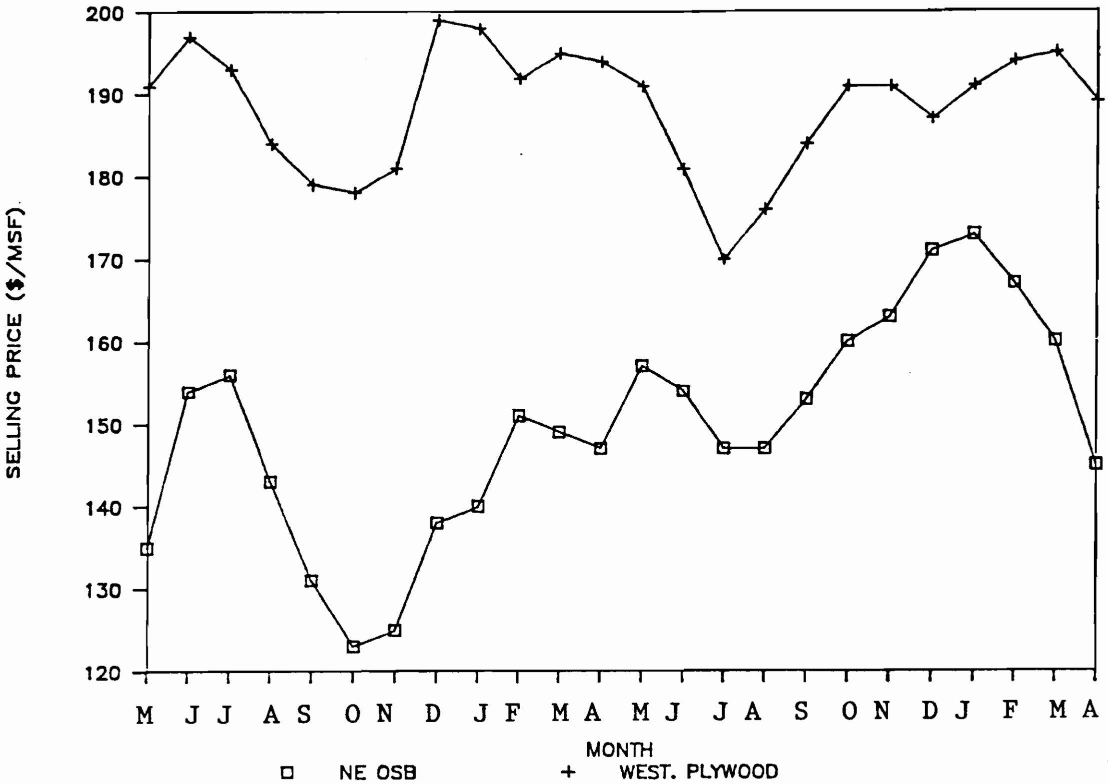

Figure 16. Price comparisons of OSB from Northeastern mills and Western plywood.

Source: Random Lengths 1985

rential between July 1985 and June 1986 was 32 dollars. These shifts in the price differentials are primarily due to recent production increases for OSB and the fact that OSB has gained much more widespread acceptance for sheathing (Random Lengths 1986).

Nonveneer production capacity is expected to increase by 50% by the end of 1986 which would bring the total production capacity to 4.6 billion square feet (3/8-in. basis). This would mean that non-veneer panels would have over 20% of the total structural panel market. The 1985 non-veneer output is estimated to exceed 3.75 billion square feet which represents a 20% increase from the 1984 production of 3.1 billion square feet. (Random Lengths 1985).

Figure 17 shows the OSB production capacities of the major producing regions in 1984 and 1985. At the present time, the Northcentral U.S. is the leading producer of OSB and waferboard with an annual production capacity of 1.5 billion square feet. However, the greatest expansion is taking place in the South which will become the second largest producing region by the end of 1986 when several new plants are on-line and production capacity reaches 1.14 billion square feet. By the end of 1987, the South is expected to be the leading region in production capacity. Canadian production accounts for 29% of the total North American output, but no major expansions or additions are expected in Canada (Random Lengths 1985).

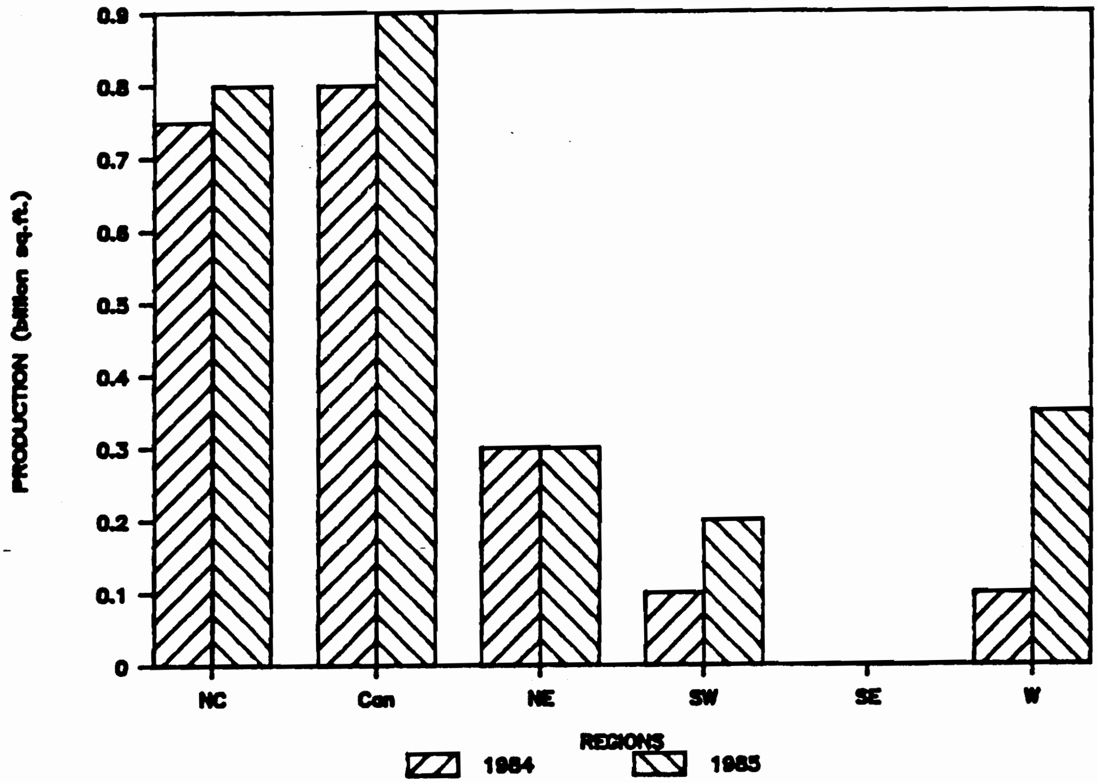

Figure 17. OSB production by region in 1984 and 1985.

Source: Random Lengths 1985

The product mix varies greatly among regions and individual plants. For example, 70% of the output of 3/4 inch panels comes from the Northcentral while the South does not produce any 3/4 inch panels. Also, several mills are beginning to produce lap siding, channel and groove panels, and other specialty products (Random Lengths 1985).

Distribution

In the early stages of OSB and waferboard development almost all the production went to major distributers. These major distributers handled large volumes and had wide geographical coverage. The office wholesalers and small distributers did not want to take the risk of handling a product that had not yet been established in the market place. This situation changed as OSB and waferboard gained acceptance. Figure 18 shows the OSB/waferboard shipments as a percentage of total production. In 1984 43% of the OSB and waferboard production was sold through wholesalers. Producer-owned warehouses and major distributers accounted for 44% of the total mill sales, while direct sales accounted for 13% of the total sales. Canadian markets use 50% of the Canadian production with the remainder exported to the U.S. The construction of new mills in the South and East will have the effect of reducing the markets for the Northcentral and Canadian mills, both of which used to ship a large portion of their production to these regions,

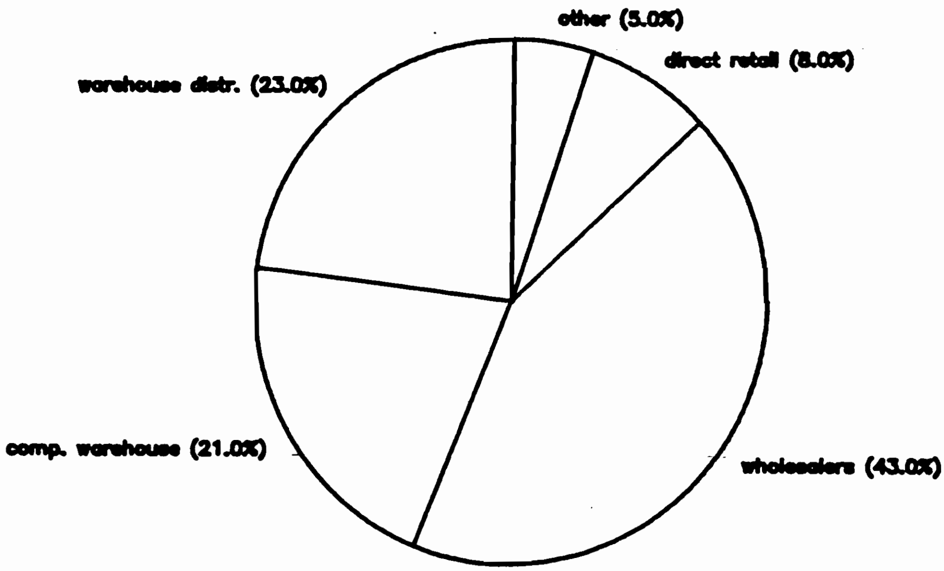

Figure 18. Waferboard/OSB shipments by region as a percentage of total production.

Source: Random Lengths 1985

Random Lengths (1986).

The Western market for structural panels is about 5.0 billion square feet. Table 8 shows the total shipment of structural plywood to five major western markets. If we assume the 20% market penetration that OSB has acheived in other regions, there will be a 500 MMSF market share avai lable for reconstituted structural panels. These figures show that there would easily be enough demand to support a 75 MMSF mill located in Western Oregon. Because of the weight of OSB and the high freight costs, the best distribution system for OSB is a regional one. OSB produced in Oregon would enjoy an advantage over OSB produced in the South or Northcentral in that it would be in a position to serve the Western market (APA 1986).

Table 8. Total shipments of structural panels to five major western markets.

Trading Area	Western Region Shipments (MMSF 3/8" basis)	% of Total from Western Shipments (%)
Los Angeles	731	71.2
San Francisco	720	91.3
Portland	664	81.9
Seattle	244	67.5
Phoenix	190	76.3
Subtotal	2,549	
Total Western Shipments	5,057	

Source: APA 1986.

V. FINANCIAL ANALYSIS

The decision as to whether or not to make an investment is one of the most crucial decisions any business can make. Investments that are made today determine what a business will be in the future. Most major investments commit a business for a long period of time to one particular area. Because the investment process has such a long horizon, it naturally must rely on future forecasts. The farther into the future a business attempts to forecast, the greater the uncertainty and therefore the greater the risk (Helfert 1982).

Capital budgeting, which includes the financial evaluation of investments, is an important part of any business's operations. There are basically three steps involved in the evaluation of any investment opportunity. These are: first estimate the cash flow, second calculate the figure of merit, and finally compare the figure of merit to the criterion. The second two steps are relatively easy as they simply consist of performing calculations and comparisons. The first step is the most difficult because it involves estimating cash flows which are uncertain. Once the cash flows have been estimated, the figure of merit must be calculated. There are several methods available to calculate the figure of merit and each has advantages and disadvantages (Higgins 1983).

Payback Period Method

The payback period method is one of the simplest measures of the worth of an investment. Put simply, it is the determination of the number of periods required to recover the initial investment. Once this has been done for all alternatives under consideration, a comparison is made based on the respective payback periods. Although this method is used quite extensively in industry to evaluate investment opportunities, it has some serious shortcomings. The most important shortcoming is that this method does not take into account the time value of money. By not taking into account the fact that a dollar today is worth more than a dollar in the future, this method can make an investment look more attractive than it actually is. This method also does not consider any stream of income beyond the payback period and it does not adjust for different scales or sizes of investments (Johnson and Melicher 1982, Helfert 1982).

Net Present Value Method

The net present value method discounts all cash inflows and outflows to a base point, which is the present, at an interest rate which is determined by the opportunity cost of capital for an organization. The net present value is the change in wealth caused by the investment. If the net present value is positive, this means the investment has returned the initial outlay, has earned the standard return, and has returned an excess on top of that. As the interest rate goes up, the number of years required to obtain a positive net present value also increases. The interest rate used should reflect the opportunity cost of capital for the firm. In other words, it should be the rate which the firm would be getting if it had not made the investment. The net present value method is the most widely used method for evaluating investment opportunities (Johnson and Melicher 1982, DeGarmo,et.al.1984).

Internal Rate of Return Method

The internal rate of return is frequently used as a measure of the worth of an investment. It is simply the interest rate at which the net present value of the investment is zero. It is a measure of the rate at which the money in an investment grows. It is soley based on the amounts and timing of the cash flows and has no relationship to external factors. The major problem with the IRR is that it implicitly assumes that there can be reinvestment at the calculated rate of return. This is not always a valid assumption, because a high rates of return there may be no other way of investing to obtain that same rate (Helfert 1982, DeGarmo,et.al. 1984).

The three methods described above are the most common methods used to evaluate investment opportunities. The only problem is that they do not provide an effective means for accounting for risk and uncertainty. There are several causes of risk and uncertainty and these include:

1. not enough similar investments
2. bias in data and assessments
3. changing external economic environment
4. misinterpretation of data
5. errors in analysis
6. managerial talent availability
7. obsolescence

There are several methods available for incorporating risk into the investment analysis process (Canada and White 1980). Brief descriptions of three of these methods will be included as a sample of how these methods work. These three methods are: risk adjusted discount rates, sensitivity analysis, and Monte Carlo simulation.

Risk Adjusted Discount Rates

Some analysts favor simply increasing the minimum attractive rate of return to compensate for risky investments. This operates as a kind of safety factor to compensate for some investments which do not turn out as well as expected. The major problem with this approach is that it does not take into account the degree of risk associated with specific alternatives. The increase in the interest rate penalizes all alternatives equally which may not be accurate. However, this method is one of the easiest ways of dealing with risk (Fleischer 1984, Fabrycky and Thueson 1984).

Sensitivity Analysis

This is the process where one or more of the input variables are changed and the change in the output value is observed. If a decision based on an output value is changed after an input is varied, then the decision is sensitive to that input. Using this approach, one can determine the possible range of the uncertain input values and then test them to see if the decision is sensitive to those inputs. If the decision is sensitive, the decision maker may decide that the risk is too great and the investment will not be made (Fleischer 1984, Fabrycky and Thueson 1984, DeGarmo,et.al. 1984).

Monte Carlo Simulation

Monte Carlo simulation generates random outcomes for probabilistic factors which reflect the randomness in the original problem. To perform a simulation analysis, the first step is to construct an analytical model which describes the investment opportunity and the second step is to develop a probability distribution for each uncertain factor in the model. Sample outcomes are randomly generated using the probability distributions and then evaluated to obtain a trial outcome. This process is repeated a large number of times to create a frequency distribution of the measure of merit, such as net present value. The major limitation of this method is that it cannot be any more accurate than the estimates used. Therefore, it is very important to obtain realistic estimates of the cash flows and the distributions which will be used to describe them in the model (Fleischer 1984, Canada 1980, DeGarmo 1984).

Model Description

For the purposes of this study it was determined that, since many of the input values had a great deal of uncertainty associated with them, it would be best to use a method of analysis which handled risk. A program was developed by the author which uses monte carlo simulation to perform investment analysis. This program is called INVEST. It is a menu-driven, probabilistic investment analysis program which runs on LOTUS 1-2-3. It is designed to perform a complete analysis of an investment opportunity, yet is flexible and easy to use. Although the program was designed to analyze this particular OSB investment problem, it is general enough to be used to analyze any type of investment opportunity. In addition, it was designed to perform either deterministic or probabilistic analyses and can handle a wide range of lengths of investment periods.

Risk is represented by triangular and uniform distributions. The triangular distribution is used to model all the operating cash flows and the resale value of the assets at the end of the investment period. The uniform distribution is used to model the initial investment, the depreciable and non-depreciable property, the plant capacity, and the initial working capital. The triangular and uniform distributions are good distributions to use when there is not much information available about the actual distributions of the data. Because it was not possible to obtain data on what the actual distributions would be for any of the input values, a combination of uniform and triangular distributions was used.

In order to define a triangular distribution, three values must be defined. These three values are called the low, mode, and high values for the distribution. The low value is defined as a value such that there is only a 5% chance of obtaining a lower value, the high value is defined as a value such that there is only a 5% chance of obtaining a higher value, and the mode is the value most likely to be obtained. In order to define a uniform distribution, only two values are defined. These are a low and high value. The use of the uniform distribution assumes there is an equal likelihood of obtaining any value between the low and high value. The more certain the user is of the actual input values, the tighter the distribution and the smaller the range of possible net present values.

During the execution of the program, the distributions are randomly sampled and the NPV, IRR, and payback period are calculated. This process is repeated 30-100 times and an average NPV, IRR, and payback period is calculated. When performing probabilistic analyses, it is important to perform enough iterations to generate an accurate distribution of NPV's and IRR's. In order to obtain valid results with this program, it is important to have at least 30 iterations and somewhere between 60 and 80 iterations is preferred. These values were determined by running the program at 5 iteration intervals from 5 to 100 and comparing the distributions of NPV's and IRR's that were obtained. When the number of iterations was greater than 30, there were not significant differences in the distributions of NPV's and IRR's that were obtained so 30 was determined to be the minimum number of iterations necessary to obtain valid results. However, it should be noted that between 30 and 60 iterations there were some differences in the final distributions. Between 80 and 100 iterations, there were no observable differences in the final distributions. Therefore, 80 was determined to be the upper limit on the number of iterations. The main reason for having an upper limit is that the program takes considerable time to execute and if there is no significant difference in the final distributions when using more iterations, there is no point in using the extra time. In addition to the average NPV, IRR, and payback period, histograms of the NPV, IRR, and payback period are obtained. These histograms represent the range of NPV, IRR, and payback periods possible for the given inputs. From these histograms, it is possible to calculate the probability of a positive NPV or an IRR greater than the cost of capital. This type of analysis differs from deterministic analysis in which only one value is used for each flow and the NPV, IRR, and payback period is calculated only once. While a positive NPV may be obtained, it is only valid for those specific inputs. It is unlikely that anyone knows exactly what cash flows will be in the future, so the actual NPV of the investment may be larger or smaller. The advantage of probabilistic analysis is that it accounts for the uncertainty of future flows and provides a better picture of what the chances of success are for a particular investment.

Table 9 shows the main menu for the INVEST program. From this menu it is possible to make a new run of the program, make changes in any one of the five input screens, view the results of the most recent run, print the results of the most recent run, perform recalculations after changes have been made, go to the graph menu to create histograms, or exit the system. In order to execute any one of these options, the user presses the corresponding key sequence. For example, to make a new run of the program, the user would simultaneously press the alternate key and

Table 9. Main menu screen from the INVEST program.

MAIN MENU

HELP MENU..................[Alt-H]	CHANGE CASH FLOWS.....[Alt-F]
CREATE INITIAL WORKSHEET...[Alt-W]	RECALCULATE...........[Alt-C]
CHANGE VALUES OF DEPR......[Alt-D] AND NON-DEPR. PROP.	VIEW RESULTS..........[Alt-R]
CHANGE VALUES OF 3 YR......[Alt-T] EQUIP. REPLACEMENTS	PRINT RESULTS.........[Alt-P]
CHANGE VALUES OF 5 YR......[Alt-E] EQUIP. REPLACEMENTS	GRAPH MENU............[Alt-G]
CHANGE INIT. ASSUMPTIONS...[Alt-I]	EXIT..................[Alt-X]

Press correct pair of keys to execute your choice..........[ ]

the W key. This would cause all user inputs from any previous run to be erased, each of the five input screens would appear in sequence allowing the user to fill them, and the program would automatically execute after the final input screen is filled.

Table 10 shows the graph menu for the INVEST program. From this menu, it is possible to make histograms of the range of NPV's, IRR's, and payback periods of the most recent run. It is also possible to view these graphs and save them for printing or to return to the main menu. Because of the manner in which LOTUS 1-2-3 operates, it is not possible to print the histograms that are created directly. Any graph which the user wants to print must be saved and then printed later using the Printgraph disk which is part of LOTUS 1-2-3. In order to execute any one of the options on the graph menu, the user must press the corresponding key sequence. If any of the options require any input from the user, prompts are provided.

The advantage of this type of menu system is that it allows the user to change every value at each input screen or change only one or a few values with equal ease. This feature makes sensitivity analysis very rapid and easy.

In order to run the program initially, the user must input several pieces of information. This information is input using five input screens which are accessed from the main menu. At each input screen, the cursor can only be

Table 10. Graph menu screen from the INVEST program.

GRAPH MENU

CREATE HISTOGRAM OF NPV....[Alt-N]	HISTOGRAM OF PAYBACK....[Alt-J]
CREATE HISTOGRAM OF IRR....[Alt-Q]	VIEW GRAPH..............[Alt-V]
CREATE XY PLOT OF NPV......[Alt-U]	SAVE GRAPH..............[Alt-S]
CREATE XY PLOT OF IRR......[Alt-Y]	MAIN MENU...............[Alt-M]

Press correct pair of keys to execute your choice..........[ ]

moved to cells which may be filled or altered by the user. The information in these cells is displayed at a higher light intensity to signify that it may be changed. In order to enter a value or a label, the user moves the cursor to the appropriate cell, types the new entry and presses the enter key. This process is repeated until all entries have been made. At this point, the enter key is pressed again and control is passed either back to the main menu if only changes were being made, or to the next input screen if a new run is being performed.

The first items to be input are the values for depreciable and non-depreciable property. Table 11 shows the input screen for the depreciable and non-depreciable property. INVEST assumes that everything will be depreciated according to ACRS (accelerated cost recovery system) therefore the depreciable property must be broken into 3, 5, 10, and 15 year depreciable property according to IRS life tables. The values for the depreciable and non-depreciable property are entered as uniform distributions so a low and high value is entered for each entry.

The next items to be input are the values for equipment replacement. Table 12 shows the input screens for 3 and 5 year equipment replacements. If, during the course of the investment period, any equipment needs to be replaced, the user enters the type of equipment that is being replaced, the value, and the replacement year. All investment

Table 11. Input screen for the depreciable and non-depreciable property from the INVEST program.

Asset Description	Purchase Cost LOW	Purchase Cost HIGH
3-year depr. property	$0	$0
5-year depr. property	$0	$0
10-year depr. property	$0	$0
15-year depr. property	$0	$0
Non-depr. property	$0	$0

Table 12. Input screen for the equipment replacements from the INVEST program.

3 YEAR EQUIPMENT REPLACEMENT	Purchase Cost	Year Replaced
	$0	0
	$0	0

5 YEAR EQUIPMENT REPLACEMENT	Cost	Year Replaced
	$0	0
	$0	0
	$0	0

tax credits and depreciation are handled automatically.

The third items to be input are the initial assumptions. Table 13 shows the input screen for the initial assumptions. These include; whether the model is to be run as a deterministic or probabilistic model; the number of iterations (30-100); the length of the investment period (5-20 years); and the risk free interest rate. In addition, the percent capacity, the initial investment, and the initial working capital are entered as uniform distributions with a high and a low value entered for each entry.

The final items to be input are the cash flows and the annual rates of change. Table 14 shows the input screen for the cash flows and annual rates of change. The flows are separated into revenues, variable expenses, and fixed expenses. Each category may be further broken down by entering labels of specific revenues and expenses. The user enters the labels for the revenues and expenses, a low, mode, and high value for each label, and an annual rate of change for each label. The low, mode, and high values make up the triangular distribution and the annual rates of change provide for one or more of the flows to change at different rates. This rate is not representative of the inflation rate, but is a relative measure. For example, if labor costs were thought to be increasing more rapidly than raw material costs, then labor costs could have an annual rate of change of 2% and raw material costs an annual rate

Table 13. Input screen for the initial assumptions from the INVEST program.

INITIAL ASSUMPTIONS

FIXED VALUES	VALUE	
TYPE (1=prob.,2=deter.)	0	
ITERATIONS (1 if det,30-80 if prob)	0	
PLANNING PERIOD (5-20 yrs)	0	
INTEREST RATE (decimal)	0.0%	
ESTIMATED VALUES	**LOW**	**HIGH**
CAPACITY (decimal)	0%	0%
INITIAL WORKING CAPITAL	$0	$0
INITIAL INVESTMENT ($)	$0	$0

Table 14. Input screen for the cash flows and annual rates of change from the INVEST program.

OPERATING CASH FLOWS	LOW	MOST LIKELY	HIGH	% CHANGE
REVENUES				
	$0	$0	$0	0.00%
VARIABLE EXPENSES				
	$0	$0	$0	0.00%
	$0	$0	$0	0.00%
	$0	$0	$0	0.00%
	$0	$0	$0	0.00%
	$0	$0	$0	0.00%
	$0	$0	$0	0.00%
FIXED EXPENSES				
	$0	$0	$0	0.00%
	$0	$0	$0	0.00%
	$0	$0	$0	0.00%
	$0	$0	$0	0.00%
Net Resale Value (all assets)	$0	$0	$0	

of 0%. The final item to be entered on this input screen is the net resale value of all assets. This is the value for which all the assets could be sold at the end of the investment period.

Upon execution, each flow is sampled from the triangular distribution to provide the first year cash flow. The depreciable property is sampled from the uniform distribution and the depreciation is calculated for each year and the equipment replacements, if any, are calculated. Each year after the first, the flows are incremented by the annual percent change. In the final year, the resale value is sampled and the NPV, IRR, and payback period are calculated. The entire process is repeated for each iteration and the mean NPV, IRR, and payback period are printed. In addition, histograms of the NPV, IRR, and payback period may be printed.

Base Case Description

The plant proposed in this study will produce an OSB panel with a density of 40 pcf. It will be produced mainly from alder with an average specific gravity of 0.41 and have resin and wax contents of 5% and 2%, respectively. These figures were chosen based on previous studies done on the technical aspects of producing OSB from red alder (Zylkowski 1983). Based on a preliminary feasibility study by Murad (1985) and on raw material availability, the base case used in the study is a plant with annual capacity of 75 MMSF (3/8-in. basis) and it is located in a coastal county of western Oregon.

Raw Material and Energy Requirements

The raw material and energy requirements for the base case were computed using a modified version of the Parvcost computer program developed by Harpole (1977). Parvcost is a mathematical model of wood, chemical, and energy flows in a board plant. It calculates the requirements and costs of wood, chemicals, and energy per unit of finished board.

For the purposes of this study, Parvcost was translated from FORTRAN to a menu-driven, LOTUS 1-2-3 based program. This was done to allow for ease of entering data and making changes. In order to run the program initially, the user is required to enter several pieces of data. These data are separated into five categories. These are: COSTS; EVALUE, which consists of estimates of BTU values of different fuels; EDEMAND, which consists of estimates of energy requirements; PHYS, which consists of physical statistics of the wood such as specific gravity, moisture content, etc; and BOARD, which includes board statistics such as weight of the finished panel, panel length, etc. The program then calculates the requirements and costs of the raw material and energy per unit of finished board. A summary of the input values used to run the program is given in appendix A.

Table 15 shows the board statistics for varying thicknesses (3/8, 7/16, and 1/2 in) of OSB using alder as the raw material. Table 16 shows the raw material and energy requirements for various panel thicknesses.

Table 15. Raw material needs for varying thicknesses of OSB.

Specifications	LBS/MSF 3/8"	LBS/MSF 7/16"	LBS/MSF 1/2"
Gross board weight	1325	1544	1767
Weight of water	75	88	100
Ovendry wt. of board	1250	1458	667
Wt. of resin (5% liquid)	63	72	83
Wt. of wax (2% solid)	25	29	33
Wt. of wood	1163	1356	1550

Table 16. Raw material and energy requirements for OSB production.

Raw material and energy	Requirements per MSF 3/8"	Requirements per MSF 7/16"	Requirements per MSF 1/2"
Wood (OD SG=.41)			
OD wood (lb.)	1389	1620	1852
Green wood (lb.)	2500	2917	3334
Solid wood (CuFt)	54	63	72
Resin (lb. liquid)	87	80	91
Wax (lb. solid)	27	32	37
Heat (MCF)	0.46	0.53	0.61
Electric power (KWH)	188	219	250

The figures in table 16 include waste factors and all losses due to production. The waste factors for wood, resin, and wax are 16%, 28%, and 7%, respectively.

From table 16 we can see that it takes approximately 0.69 ODT of alder to produce 1 MSF (3/8-in basis) of OSB. The current price for alder was obtained by surveying several members of the Northwest Hardwood Association. Through a telephone survey conducted in March 1986, the price for alder pulpwood delivered to mills on the Oregon coast ranged from 16-24 dollars per wet ton. Based on this survey, the triangular distribution for the wood was developed. The low point was 16 dollars, the mode was 19 dollars, and the high point was 24 dollars. If we assume the wet wood has an average moisture content of 80%, then the distribution per ODT of alder would be 29, 34, and 43 dollars, respectively. Using a conversion factor that states there is an average of 7.6 tons/MBF, these prices convert to $122, $144, and $182 per MBF. Based on another conversion factor that 1 ODT of alder equals approximately 78 cubic feet, 1 cubic foot of green alder equals .013 ODT or 1 cunit of green alder equals 1.3 ODT. This converts to a price distribution of $0.38, $0.44, $0.56 per cubic foot, respectively.

Table 17 shows the cost distribution for each of the raw material and energy costs. Based on the cost distributions shown in table 17, tables 18, 19, and 20 show the gross variable cost distribution for varying panel thicknesses. The distribution for total gross variable cost per MSF (3/8-in. basis) is \$49.13, \$56.65, and \$64.67.

Table 17. Cost distribution for variable costs.

Requirement	Low	Mode	High
Wood (\$/ODT)	16.000	19.00	24.00
Resin (\$/lb. liquid)	0.250	0.29	0.30
Wax (\$/lb. solid)	0.180	0.18	0.18
Heat Energy (\$/MCF)	3.000	3.50	4.00
Electricity (\$/KWH)	0.035	0.04	0.05

Table 18. Cost distribution in \$/MSF of variable costs for 3/8" OSB.

Requirement	Low	Mode	High
Wood	20.00	23.75	30.00
Resin	17.14	19.89	20.57
Wax	4.95	4.95	4.95
Heat Energy	0.46	0.54	0.50
Electricity	6.58	7.52	8.65
Total Gross Variable Cost	49.13	56.65	64.67

Table 19. Cost distribution in $/MSF of variable costs for 7/16" OSB.

Requirement	Low	Mode	High
Wood	23.40	27.79	35.10
Resin	20.05	23.27	24.06
Wax	5.79	5.79	5.79
Heat Energy	0.54	0.63	0.59
Electricity	7.70	8.80	10.12
Total Gross Variable Cost	57.48	66.28	75.66

Table 20. Cost distribution in $/MSF of variable costs for 1/2" OSB.

Requirement	Low	Mode	High
Wood	26.60	31.59	39.90
Resin	22.79	26.45	27.36
Wax	6.58	6.58	6.58
Heat Energy	0.61	0.71	0.67
Electricity	8.75	10.00	11.50
Total Gross Variable Cost	65.33	75.33	86.01

Labor Requirements

For the base case plant with an annual capacity of 75 MMSF (3/8-in basis) we assumed four shifts operating 310 days per year with a total of 67 people. Table 21 shows the production schedule.

Table 21. Production schedule for an OSB plant with 75 MMSF annual capacity (3/8" basis).

Net operation hours/day	22
Nonoperating days/year	
2 weeks vacation	14 days
13 holidays	13 days
Less avg. 2 hours/day	28 days
Subtotal	55 days
Net operating days/year	310 days

Table 22 shows the crew requirements for the same plant and Tables 23 and 24 show the distributions for the average wages and salaries of all the personnel in terms of cost/MSF and cost/year. The figures for the wages and salaries were obtained from surveys collected by the Employment Division in Salem, OR. All wages and salaries represent union rates and include a 30% factor for payroll expenses and fringe benefits. The distribution for total wages and salaries per MSF is $45.30, $45.30, and $52.20 and the distribution in terms of cost per year is $3.4 million, $3.4 million, and $3.9 million, respectively. Appendix B contains a listing of the wage and salary

Table 22. Crew requirements for hourly production of OSB for a 75 MMSF annual capacity plant. For each shift, except where stated.

Wood yard crane operator	1 (day only)
Flake operator	2
Knife grinder	1
Hammermilling, screening, air classification, reducing overs	2
Weighing and blending	2
Forming machine operator	2
Caul and stacking station	1
Conditioning chambers, caul separation and cleaning	1
Saw operator and stocking	1
Climatizing chambers	1
QC technician	1
Relief operator	1
Guard and scale operator	1
Shipping area	2 (day only)

Table 23. Cost distribution for wages and salaries for the base case.

Item	Cost ($/MSF 3/8-in. basis) Low	Mode	High
Wages (per 8 hour shift)	36.56	36.56	42.83
Administration salaries			
Office manager (1)	0.40	0.40	0.43
Ass'n accnt. + pur. (2+2)	1.07	1.07	1.17
Clerk/typist/recep. (2)	0.37	0.37	0.40
Janitor (1)	0.19	0.19	0.21
Total	2.03	2.03	2.21
Payroll charges (30%)	0.61	0.61	0.65
Grand total	2.64	2.64	2.86
Superv. + tech. salaries			
General manager (1)	0.93	0.93	0.96
Marketing manager (1)	0.67	0.67	0.69
Plant eng. + tech. dir. (1+1)	.93	.93	1.00
Shift foreman + woodyard shipping sup. (4+1+1)	2.16	2.16	2.40
Total	4.69	4.69	5.05
Payroll charges (30%)	1.41	1.41	1.46
Grand total	6.10	6.10	6.51
Total wages and salaries	45.30	45.30	52.20

Table 24. Cost distribution for wages and salaries for the base case.

Item	Cost ($1,000/year) Low	Mode	High
Wages (per 8 hour shift)	2,742	2,742	3,212
Administration salaries			
Office manager (1)	30	30	32
Ass'n accnt. + pur. (2+2)	80	80	88
Clerk/typist/recep. (2)	28	28	30
Janitor (1)	14	14	15
Total	152	152	165
Payroll charges (30%)	45	45	48
Grand total	197	197	213
Superv. + tech. salaries			
General manager (1)	70	70	72
Marketing manager (1)	50	50	53
Plant eng. + tech. dir. (1+1)	70	70	75
Shift foreman + woodyard shipping sup. (4+1+1)	162	162	180
Total	352	352	380
Payroll charges (30%)	137	137	142
Grand total	489	489	522
Total wages and salaries	3,428	3,428	3,948

figures.

Capital Costs

For the base case 75 MMSF plant, the total capital costs (excluding land) were set to be uniformly distributed between 15 and 28 million dollars. These figures were obtained from estimates by Columbia Engineering. The capital cost includes buildings, machinery, and engineering and contingencies. The engineering and contingencies category includes initial working capital, project management, delays, and unforeseen cost increases. The initial working capital was set equal to three months operating costs.

Production Costs

Table 25 shows the cost of materials on an annual basis and per MSF (3/8-in basis). Table 26 shows the cost of energy and maintenance on an annual basis and per MSF (3/8-in basis). The distribution in terms of low, mode, and high estimates of the total energy and maintenance costs are $17.54, $18.91, and $20.91 per MSF, and $1.3 million, $1.4 million, and $1.6 million per year, respectively.

Sales and advertising expense and the general administration costs are calculated as a percentage of the sales price. The sales and advertising expense is figured to be 7% of the sales price and the general administration cost is figured to be 1% of the sales price.

Table 25. Cost distribution of material costs for the base case.

Material Costs	Low	Mode	High
		Cost ($/MSF)	
Wood	20.00	23.75	30.00
Resin	17.14	19.89	20.57
Wax	4.95	4.95	4.95
Total material cost	42.09	48.59	55.52
		Cost ($1,000/year)	
Wood	1,500	1,701	2,250
Resin	1,285	1,491	1,542
Wax	371	371	371
Total material cost	3,156	3,564	4,164

Table 26. Energy and maintenance costs for a 75 MMSF annual capacity OSB plant.

	Low	Mode	High
		Cost ($/MSF)	
Electricity	6.58	7.52	8.65
Thermal energy	0.46	0.54	0.50
Maintenance (parts)	10.50	10.85	11.76
Total energy + main. costs	17.54	18.91	20.91
		Cost ($1,000/year)	
Electricity	494	564	648
Thermal energy	34	40	37
Maintenance (parts)	787	813	882
Total energy + main. costs	1,315	1,417	1,568

Tables 27 and 28 show a summary of the production cost distributions for the proposed OSB plant per MSF (3/8-in. basis) and per year. The distribution in terms of low, mode, and high estimates of the total production cost is $113.42, $121.83, and $138.23 per MSF and $8.5 million, $9.1 million, and $10.4 million per year, respectively.

Table 27. Summary of production costs for the base case.

Items	Cost ($/MSF) Low	Mode	High
Material			
Wood	20.00	23.75	30.00
Wax	4.95	4.95	4.95
Resin	17.14	19.89	20.57
Energy + maintenance			
Electricity	6.58	7.52	8.65
Thermal energy	0.46	0.54	0.50
Maintenance	7.00	7.49	8.00
Wages and salaries			
Wages	36.56	36.56	42.83
Superv. salaries	6.10	6.10	6.33
Admin. salaries	2.63	2.63	2.80
Advert. + sales expense	10.50	10.85	11.90
General adminis. cost	1.50	1.55	1.70
Total production cost	113.42	121.83	138.23

The accelerated cost recovery system was used to calculate all depreciation. Under this system, all assets must be separated into 3 year, 5 year, 10 year, and 15 year property according to IRS life tables. All ACRS property is

Table 28. Summary of production costs for the base case.

Items	Cost ($1,000/year) Low	Mode	High
Material			
Wood	1,500	1,781	2,250
Wax	371	371	371
Resin	1,285	1,491	1,542
Energy + maintenance			
Electricity	494	564	648
Thermal energy	34	40	37
Maintenance	525	562	600
Wages and salaries			
Wages	2,742	2,742	3,212
Superv. salaries	457	457	475
Admin. salaries	197	197	210
Advert. + sales expense	788	814	892
General adminis. cost	113	116	127
Total production cost	8,506	9,135	10,367

eligible for investment tax credits. For the purposes of this study, full investment tax credits were taken on all 3 and 5 year property as provided for in the 1981 Tax Recovery Act. State and Federal taxes were calculated using the tables provided by the State Revenue Office of Oregon and the IRS.

Sales Price

It is difficult to accurately predict the OSB selling price because of market fluctuations. For this study, historical price data for OSB was used to forecast future price. Price data covering the past four years was obtained from Crow's weekly newsletter and these prices were used in conjunction with Box Jenkins Time Series Analysis to predict the selling price of OSB.

A time series is simply a collection of observations made sequentially in time. The weekly price of OSB for the past four years constitutes a time series. The first step in analyzing a time series is to plot the data and to obtain descriptive measures of the main properties of the series. For example, is the general trend increasing, are there cyclic variations, are there seasonal variations, etc? Once the series has been described, a methodology developed by Box and Jenkins can be used to predict future values of the series. The Box-Jenkins methodology is a procedure by which a stochastic model is fit to the series and this model is then used to predict future values of the series. These models are complex mathematical models which are beyond the scope of this paper to describe in detail (Chatfield 1980).

Figure 19 shows the price data for 7/16 in. OSB and 1/2 in. CDX Western plywood over the past four years. From this figure, it is evident that OSB prices follow the same general trend as plywood prices. During 1982 and the first half of 1983, the general trend was for increasing OSB prices. However, the trend was for decreasing OSB prices during the last half of 1983 and the first half of 1984 and OSB prices fell sharply during that period. Since about the middle of 1984, OSB prices have been slowly increasing.

After successfully fitting a model to the prices shown in Figure 19 and performing the forecasting, the low, mode, and high estimates, of selling price were \$155, \$155 and \$170, respectively.

Financial Analysis of the Base Case

The input values used to analyze the base case are summarized in the next several tables. Table 29 shows the inputs for depreciable and non-depreciable property. Table 30 shows the initial assumptions, and table 31 shows the cash flows and rates of change. Tables 29, 30, and 31 are reproductions of the actual input screens used in running the INVEST program.

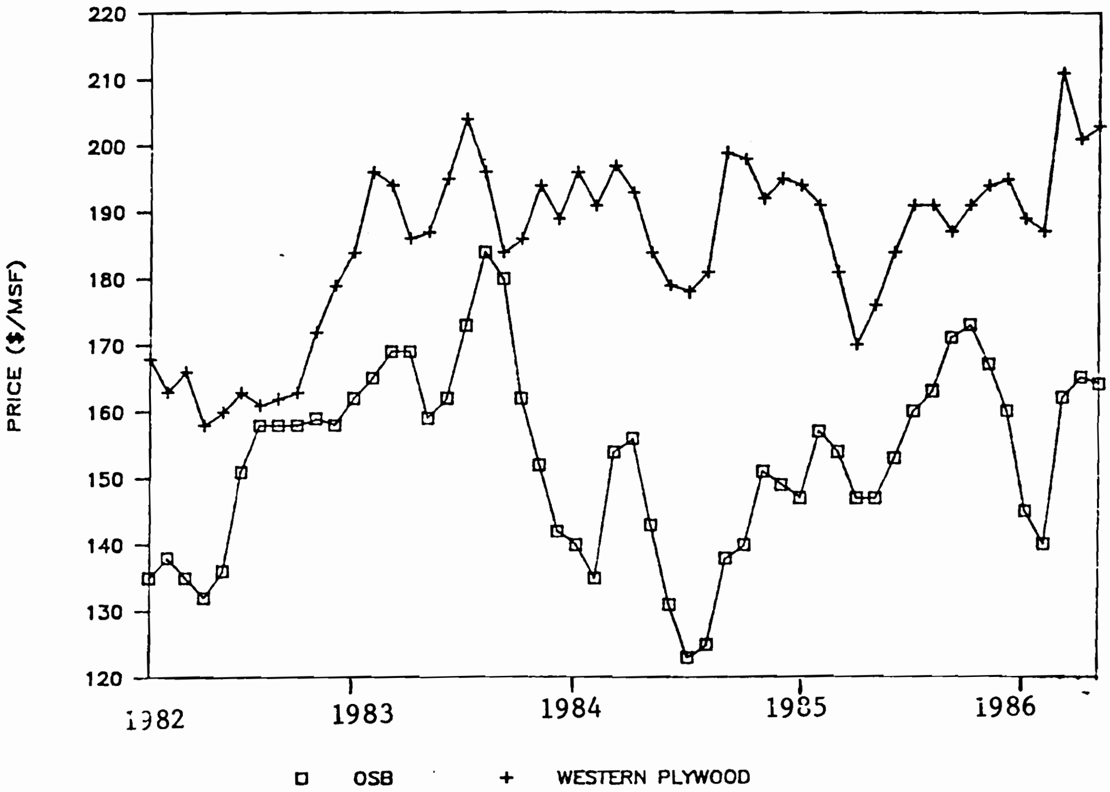

Figure 19. Selling price of 7/16 in. OSB and 1/2 in. CDX Western plywood, 1982-1986.

Source: Crow's 1982-1986

Table 29. Cost distribution of depreciable and non-depreciable property for the base case.

Item	Cost ($1,000/year) Low	Cost ($1,000/year) High
3 year property	750	1,400
5 year property	7,500	14,000
10 year property	0	0
15 year property	5,250	9,800
Non-depreciable property	1,500	2,800

Table 30. Initial assumptions for the base case.

Item	Value	
Type	1	
Iterations	70	
Planning period	18	
Interest rate	11%	
	Low	High
% capacity	95%	100%
Initial working capital	$2,282,401	$2,638,990
Initial investment	$15,000,000	$28,000,000

Table 31. Cost distribution of cash flows for the base case.

Item	Cost ($1,000/year)			Annual rate of change
	Low	Mode	High	
Revenues	11,250	11,625	12,750	2%
Wood cost	1,500	1,781	2,250	2%
Resin cost	1,285	1,491	1,542	0%
Wax cost	371	371	371	0%
Labor cost	2,742	2,742	3,212	0%
Elec.+energy cost	494	564	648	0%
Other var. cost	787	813	882	0%
Administ. sal.	197	197	210	0%
Superv. sal.	457	457	475	0%
Maintenance cost	525	562	600	0%
Administ. cost	113	116	127	0%
Net resale value	2,000	2,500	3,000	0%

There were several assumptions made during the execution of the program. They were that:

1. The interest rate was taken to equal the prime lending rate plus 2%.
2. Full investment tax credits were taken on all 3 and 5 year depreciable property.
3. The ACRS system was used for all depreciation.
4. Initial working capital was taken to equal 3 months operating costs.

After running the program for the base case, table 32 shows the results.

Table 32. Results of the financial analysis for the average base case.

NPV (net present value)	$1,670,842
IRR (internal rate of return)	12.53%
Payback Period (years)	8.0

The average NPV was $1,670,842, the average IRR was 12.53%, and the average payback period was 8 years. Figure 20 shows the distribution of NPVs, Figure 21 shows the distribution of IRRs, and Figure 22 shows the distribution of payback periods. From these figures it can be determined that there is a 81% chance that the venture will have a positive NPV and a 70% chance that the IRR will exceed the cost of capital. From these results it is evident that the venture cer

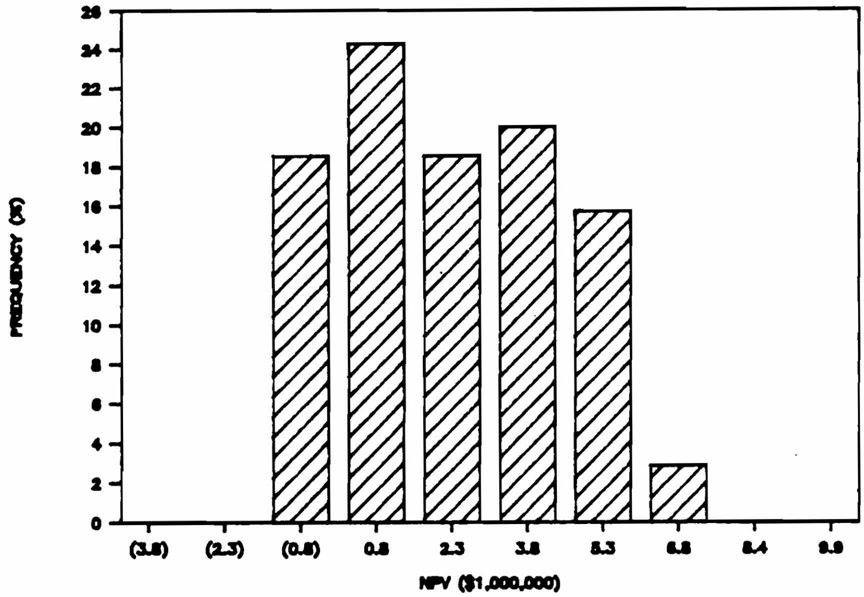

Figure 20. Histogram of NPV's for the base case.

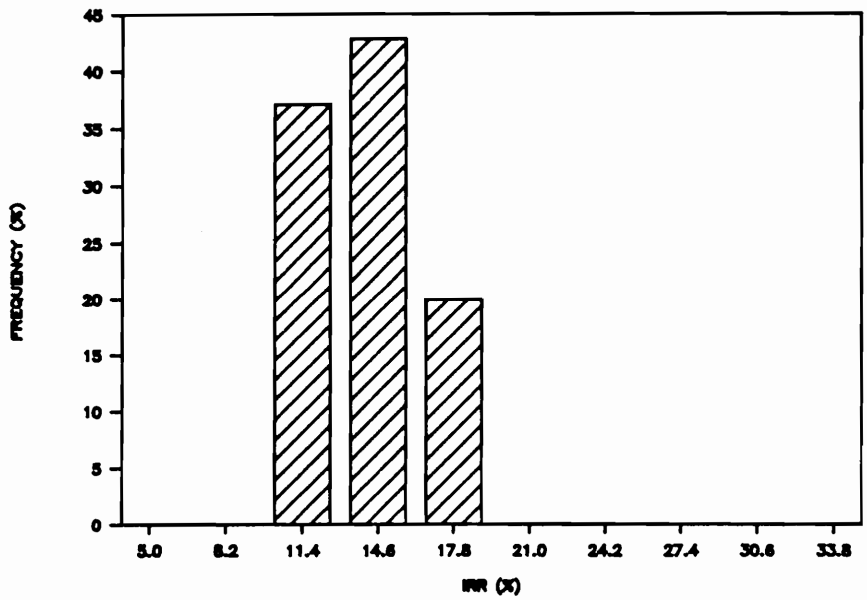

Figure 21. Histogram of the IRR's for the base case.

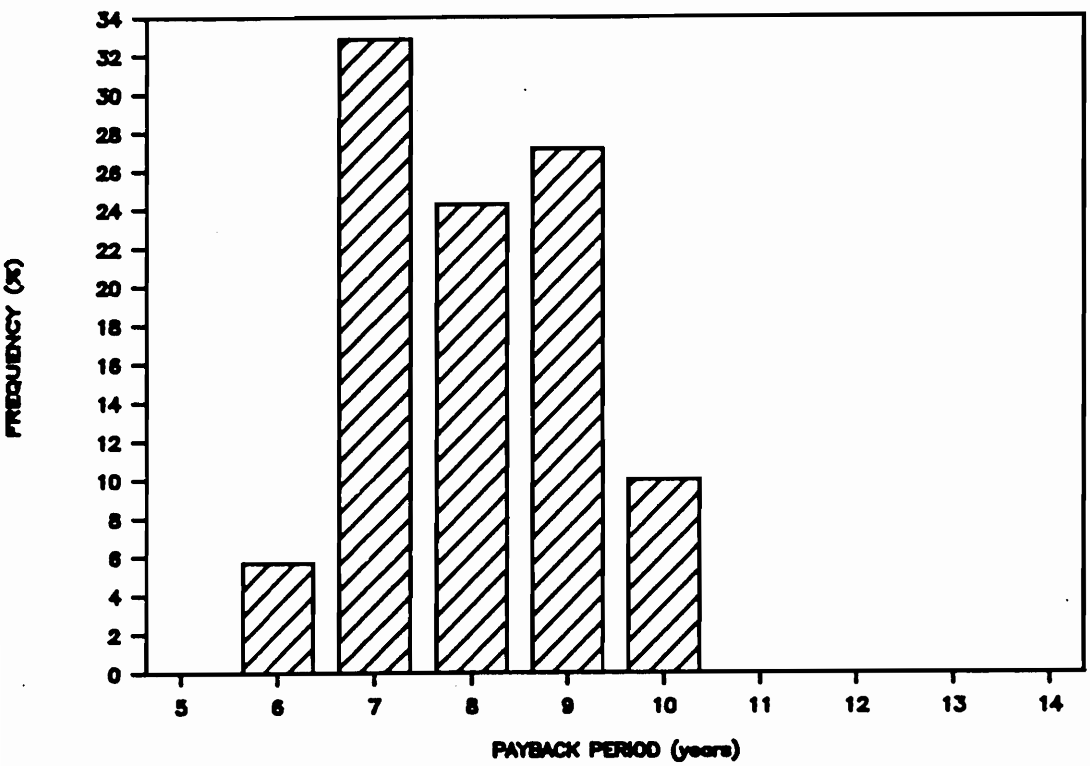

Figure 22. Histogram of the payback periods for the base case.

tainly is feasible, however, the return is probably not large enough to attract many investors.

Sensitivity Analysis

A sensitivity analysis was performed on each of the important variables to determine the effect on the profitability of the venture. The variables considered in this analysis were: wood cost, labor cost, capital cost, interest rate, and selling price. Table 33 shows the effects of these variables at values 10% and 20% above and below the base case.

Figure 23 summarizes the effects of changes in the selected variables on NPV. Within the range examined, sales price had the greatest effect on NPV. Next in decreasing order of importance were capital cost, interest rate, labor cost, and wood cost.

Figure 24 shows the comparison of the NPV's obtained as a function of the selling price for OSB and wood cost at values 10% and 20% above and below the base case. Figure 25 shows the comparison of NPV's obtained with selling price of OSB and labor cost varying over the same values. These two figures show that NPV is relatively insensitive to wood cost and labor cost over the range of values examined. It takes a large change in the wood cost or labor cost to cause a change in the NPV. However, NPV is highly sensitive to changes in OSB selling price. By means of comparison, a

Table 33. Sensitivity of NPV, IRR, and payback period to selected variables.

% of Base Case	80%	90%	100%	110%	120%
			NPV ($1,000,000)		
Wood cost	3.5	2.5	1.6	1.00	.49
Labor cost	3.8	2.8	1.6	.69	-.27
Capital cost	5.7	3.7	1.6	.16	-2.36
Interest cost	5.5	3.8	1.6	.11	-1.07
Sales price	-10.3	-3.4	1.6	6.55	11.71
			IRR (%)		
Wood cost	13.99	13.14	12.53	12.08	11.69
Labor cost	14.06	13.40	12.53	11.32	11.11
Capital cost	16.63	14.47	12.53	11.42	9.41
Interest rate	12.73	12.92	12.53	12.45	12.33
Sales price	3.19	8.54	12.53	16.14	19.79
			Payback Period (years)		
Wood cost	7.3	7.7	8.0	8.3	8.6
Labor cost	7.2	7.6	8.0	8.5	9.0
Capital cost	6.1	7.0	8.0	8.1	8.9
Interest rate	8.0	7.9	8.0	8.1	8.0
Sales price	16.6	10.9	8.0	8.3	8.6

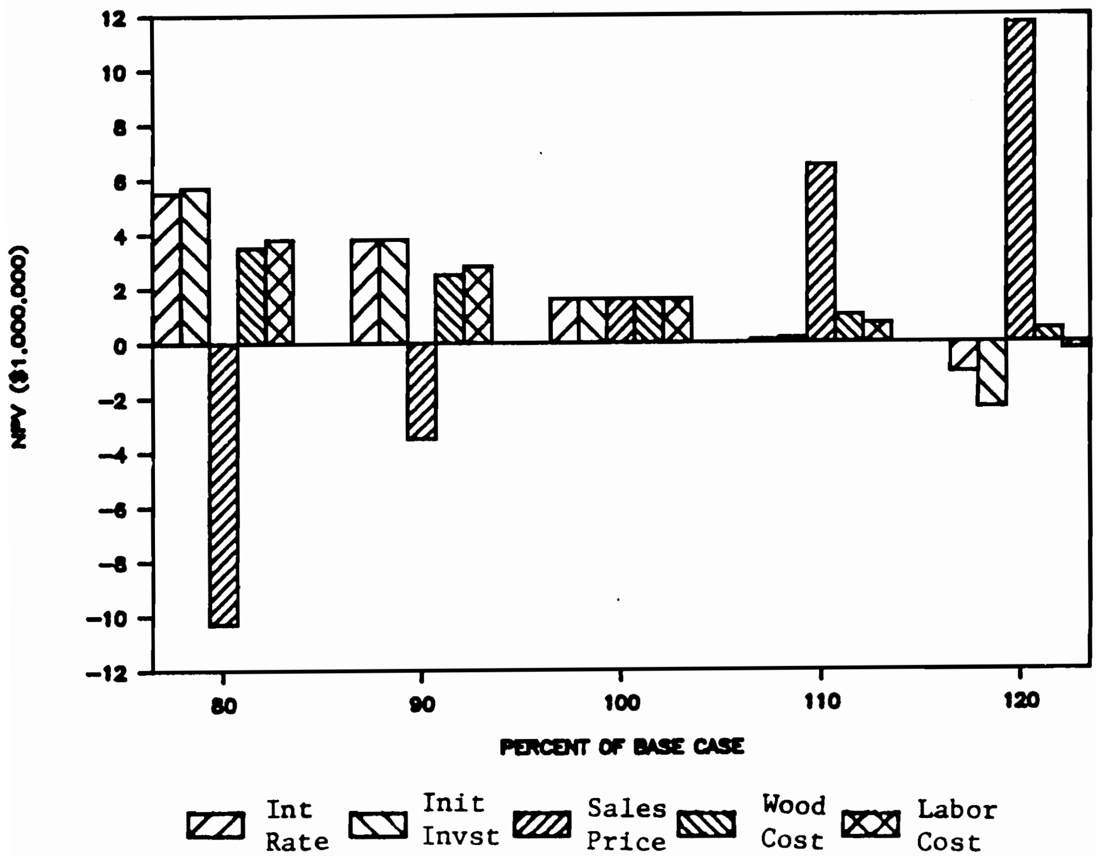

Figure 23. Sensitivity of NPV to selected variables.

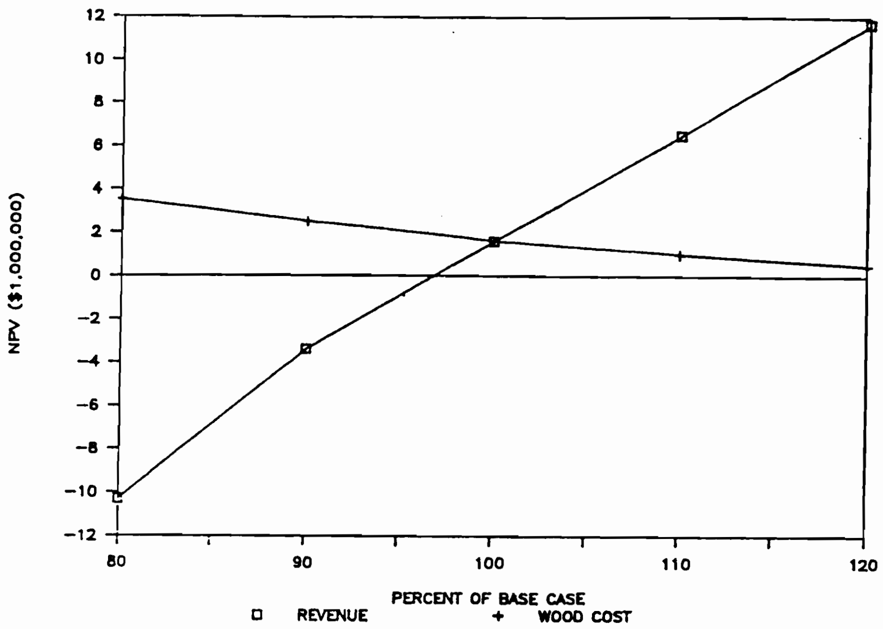

Figure 24. Sensitivity of NPV as a function of selling price of OSB and wood cost.

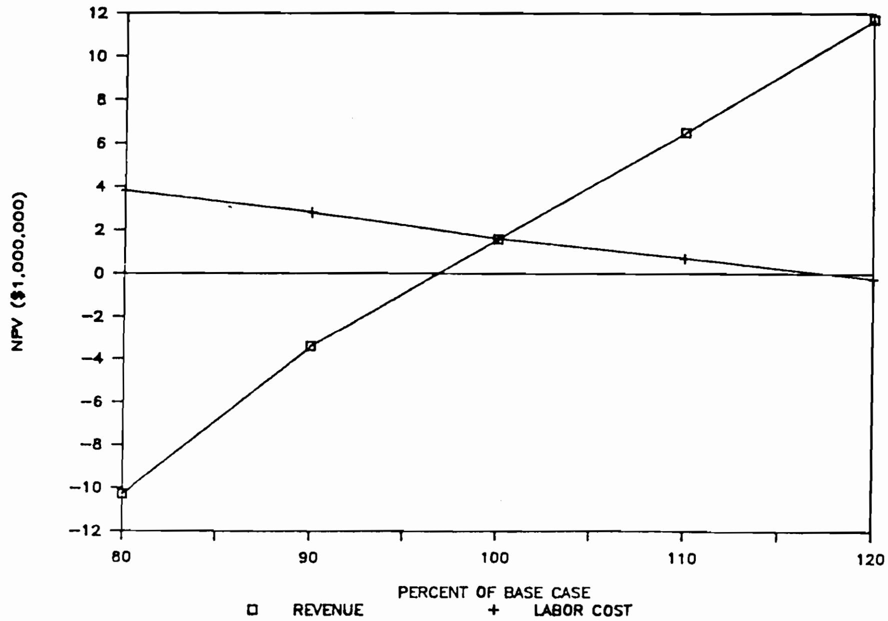

Figure 25. Sensitivity of NPV as a function of selling price of OSB and labor cost.

a 20% decrease in wood or labor cost causes a 2 million dollar increase in NPV, while a 20% increase in the selling price of OSB causes a 10 million dollar increase in NPV. OSB selling price has about a five-times greater effect on NPV than does wood cost or labor cost.

The NPV is slightly more sensitive to the interest rate and initial investment than to wood or labor cost. Figure 26 shows the comparison of NPV's obtained as a function of wood cost and interest rate at values 10% and 20% above and below the base case. Figure 27 shows the comparison of the NPV's obtained as a function of wood cost and initial investment over the same range of values. These figures show that the slopes of the two lines are similar and almost identical relationships hold for labor cost versus interest rate and labor cost versus initial investment.

Figures 28 and 29 summarize the effects of changes in the selected variables on IRR and payback period, respectively.

From this analysis, it is evident that, although wood and labor costs comprise the largest portion of production cost, the selling price has a much greater impact on the overall feasibility of the project. In addition, the interest rate and capital cost also have a slightly greater impact on the overall feasibility than do any of the actual production costs. Since selling price and interest rate

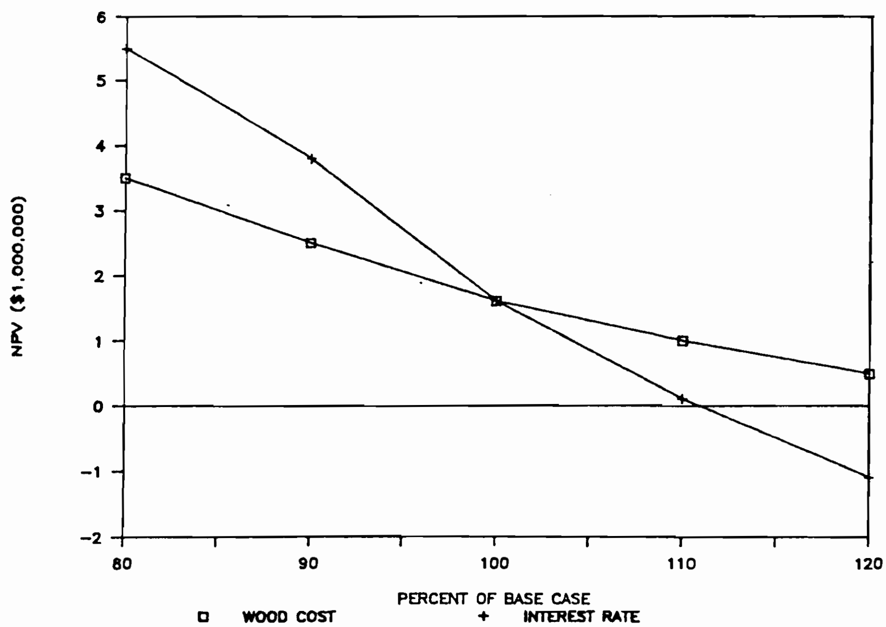

Figure 26. Sensitivity of NPV as a function of interest rate and wood cost.

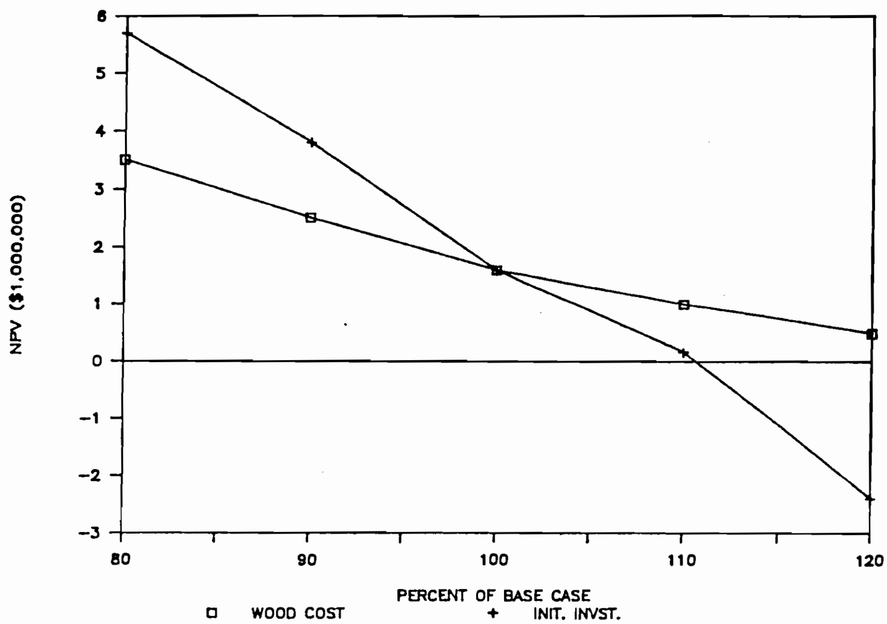

Figure 27. Sensitivity of NPV as a function of initial investment and wood cost.

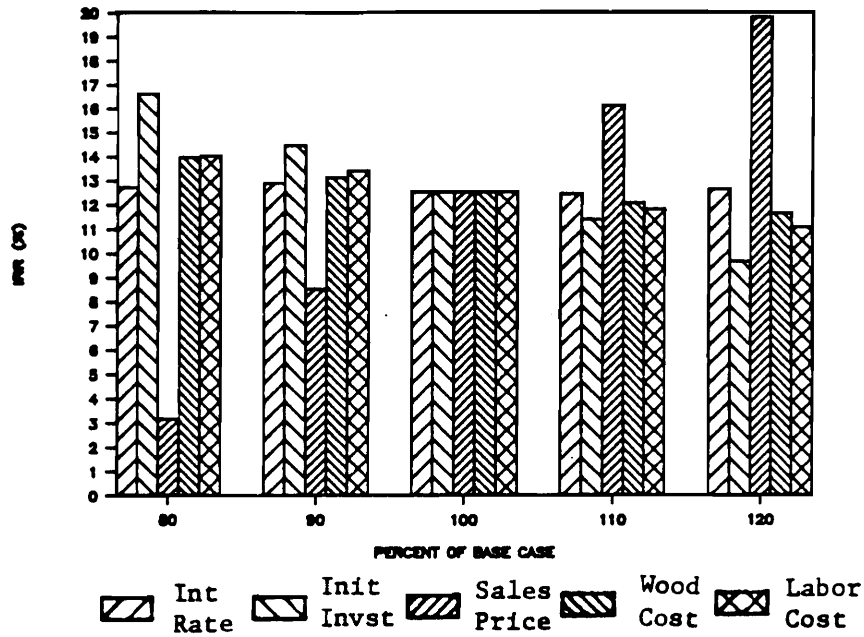

Figure 28. Sensitivity of IRR to selected variables.

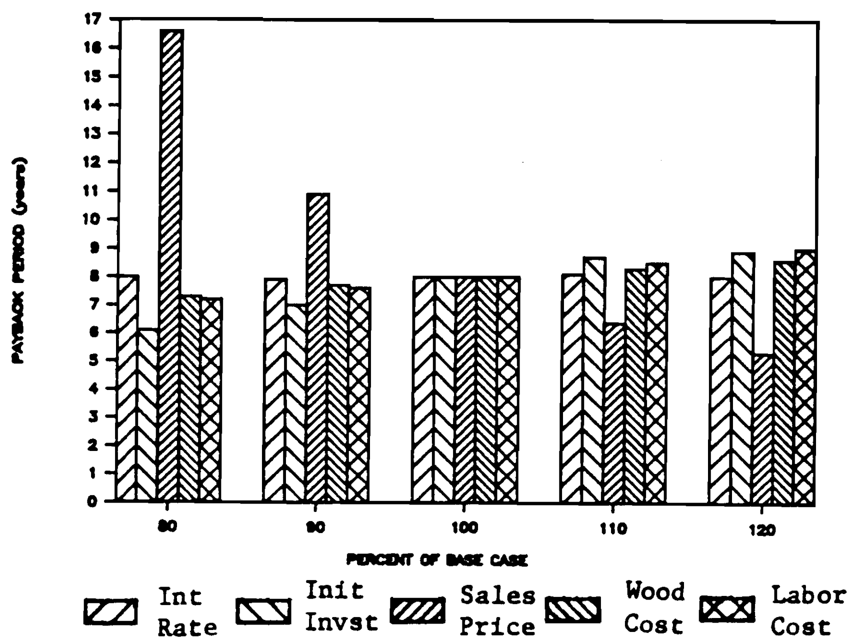

Figure 29. Sensitivity of payback period to selected variables.

cannot be controlled by the producer, production cost variables should be closely controlled. However, as the sensitivity analysis shows, if all other factors are equal, a modest reduction in production costs cannot produce much of a change in overall profitability.

With the economy improving and inflation continuing to decrease, the interest rates are continuing to drop and the housing market is improving. Both of these factors will improve the attractiveness of this venture by lowering the cost of capital and providing a stronger market for structural panels which will increase the possibilities of higher selling prices.

VI. CONCLUSIONS

There were three main objectives in this study that had to be met before the feasibility of locating an OSB plant in Western Oregon could be determined. These were as follows:

> Is there sufficient raw material supply to meet the requirements of a 75 MMSF annual capacity (3/8-in. basis) OSB plant?

The outlook for alder supply in Oregon is very good. Growth exceeds removal and the supply exceeds the current utilization. There are approximately 2.7 million acres of hardwood stands in Oregon with about 4.8 billion cubic feet of volume growing in those stands and alder comprises about 50% of this acreage and volume. This means there are about 1.3 million acres of alder with about 2.4 billion cubic feet of volume. Most of this volume is located along the coast. In terms of availability, alder growth is about 53 MMCF annually while the requirements of a 75 MMSF plant are only about 5 MMCF annually. Even though each of the three regions along the Western Oregon coast could supply a 75 MMSF plant, region I (consisting of Clatsop, Columbia, and Tillamook counties) is the most desirable because of the large timber resource and the fact that the majority of the resource is located on slopes under 35%. Although a high percentage of the alder resource in region I is privately owned, it is very possible that a company could negotiate long term raw material contracts with one or more of the owners or enter some type of joint venture in order to secure sufficient raw material. In fact, this may provide a more stable raw material supply than depending on public sales.

Is there sufficient market availability for the OSB panel in the Western region?

The market analysis shows that a market is developing in the Western region. The analysis of markets in the Northeast and the South show that OSB panels gained acceptance relatively soon after their introduction into the market (Random Lengths 1984). OSB production is expected to increase during 1986 and by the end of this year, OSB is expected to have a 20% share of the total structural panel market (Random Length 1985). OSB has already almost reached this level of penetration in the Northeast and the South. Using these estimates, a 500 MMSF market share is potentially available for OSB in the Western region. This figure represents 20% of the plywood shipments to the top five destinations in the West which are: Los Angeles, Portland, San Francisco, Seattle, and Phoenix.

An OSB plant with an annual capacity of 75 MMSF (3/8-in. basis) would have no problem in finding a market for its line. The market analysis also shows that, although

OSB would initially be used only as a substitute for plywood, as acceptance grows, it will be able to develop and penetrate new markets.

Will the profit justify the investment?

The financial analysis of the base case 75 MMSF plant shows an average NPV of 1.6 million dollars, and an average IRR of 12.5%, and a 81% chance of producing a positive NPV. Although this is not a spectacular return, the venture does have a very good chance of making money.

Since the NPV is positive, the venture is economically feasible. Sensitivity analyses showed that the NPV and IRR realized by the venture were highly sensitive to the selling price of OSB, moderately sensitive to the interest rate and the initial investment, and only slightly sensitive to wood cost and labor cost.

If the economy continues improving as it has been the past several years, causing the interest rates to fall and housing starts to increase, the venture will become more attractive. For example, a one point decrease in the interest rate causes the average NPV to increase by 5 million dollars and a 10% increase in the selling price of OSB causes a 7 million dollar increase in the NPV.

The study shows that if an OSB plant were located in Western Oregon, there would be sufficient raw material available, sufficient demand for the product, and a high probability that the venture would be profitable.

VII. BIBLIOGRAPHY

American Plywood Association 1986. Regional production and distribution pattern of the structural panel industry. Economic Reports E41. American Plywood Association, Tacoma, WA.

American Plywood Association. 1986. End-use profiles for structural panels 1985-1987. Economics Report E40. American Plywood Association, Tacoma, WA.

American Plywood Association. 1984. Regional production and distribution pattern of the structural panel industry. Economics Report E37. American Plywood Association, Tacoma, WA.

Atterbury 1978. Alder characteristics as they affect utilization. In: Utilization and Management of Red Alder. USDA For. Serv. Gen. Tech. Rep. PNW-70: 71-81.

Bucking, H.G., B. Greten, and J.R. Stillinger 1980. The present status and future developments of oriented structural products. Proceeding: 14th Washington State University International Symposium on Particleboard, Pullman, WA. pp.243-260.

Canada, John R., and John A. White Jr. 1980. Capital investment decision analysis for management and engineering. Prentice-hall Inc., Englewood Cliffs, NJ.

Chatfield, C. 1980. The analysis of time series: an introduction. Chapman and hall, New York, NY.

Columbia Engineering. 1984. Capital cost of OSB. Answer to questionnaire. Columbia Engineering International Inc., Eugene, OR.

Crow's. 1982-1986. Weekly report. Crow's publications, Portland, OR.

Degarmo, E. Paul, William Sullivan, and John Canada. 1984. Engineering economy. MacMillian Publishing Co. New York, NY.

Fabrycky, W. J. and G.J. Thueson. 1984. Engineering economy. Prentice-hall, Inc. Englewood Cliffs, NJ.

Farrenkoph, T. 1984. Timber inventory and growth information for individual counties and owners in Oregon. Unpublished data. Pacific Northwest For. and Range Exp. Sta., Portland, OR.

Fleischer, G.A. 1984. Engineering economy: capital allocation theory. Wadworth, Inc. Belmont, CA.

Gedney, D.R. 1982. The timber resources of Western Oregon: highlights and statistics. Res. Bull. PNW-97. USDA For. Ser. PNW For. and Range Exp. Sta., Portland, OR.

Guss, L.M. 1980. Waferboard:'new' panel invades US industry. Forest Industries, 107(11): 13-15.

Harpole, G.B. and P.I. Ince. 1977. Parvcost: a particleboard variable cost program. USDA For. Ser. Gen. Tech. Rep. FPL-14. U.S. dept. of Ag. For. Ser., Forest Products Lab., Madison, WI.

Helfert, Erich A. 1982. Techniques of financial analysis. Richard D. Irwin Inc., Homewood, IL.

Higgins, Robert C. 1983. Analysis for financial management. Dow Jones-Irwin, Homewood, IL.

Irland, L.C. 1982. Continued expansion for New England waferboard. Forest Industries. 109(12): 18-19.

Johnson, Robert W. and Ronald W. Melicher. 1982. Financial management. Allyn and Bacon Inc., Boston, MA.

Koenigshof, G.A. 1977. Economic feasibility of producing composite panels. Peoceeding: 11th Washington State University International Symposium on Particleboard, Pullman, WA. pp. 269-292.

Lewis, B. 1981. Product standards are vital to future of panel industry. Plywood and Panel. 21(9): 8-9.

Maloney, T.M. 1978. Alder: one of tomorrow's important structural raw materials? Proceeding: Utilization and Management of Alder. USDA For. Ser., PNW For. and Range Exp. Sta., Portland, Or. PNW-70, pp.9-24.

Murad, I. 1985. The feasibility of producing oriented strand board(OSB) from alder in Western Oregon. Master Thesis, Oregon State University, Corvallis, OR.

O'Halloran, M.R. 1979. Development of performance specifications for structural panels in residential markets. Forest Products Journal 29(12): 21-26.

Plank, M.E. 1971. Red alder. USDA For. Ser. American woods. FS-215.

Random Lengths. 1985. 1985 yearbook. Volume XXI. Random Lengths Publications, Inc., Eugene, OR.

Random Lengths. 1985. July 26 weekly report. pp1-2. Random Lengths Publications, Inc., Eugene, OR.

Random Lengths. 1985. August 2 weekly report. pp.1-2. Random Lengths Publications, Inc., Eugene, OR.

Random Lengths. 1985. August 16 weekly report. pp.1-2 Random Lengths Publications, Inc., Eugene, OR.

Random Lengths. 1986. January 17 weekly report. pp.1-2 Random Lengths Publications, Inc., Eugene, OR.

Random Lengths. 1986. March 7 weekly report. pp.1-2 Random Lengths Publications, Inc., Eugene, OR.

Random Lengths. 1986. April 4 weekly report. pp.1-2 Random Lengths Publications, Inc., Eugene, OR.

Random Lengths. 1986. May 16 weekly report. pp.1-2 Random Lengths Publications, Inc., Eugene, OR.

Resch, H. 1980. Utilization of red alder in the Pacific Northwest. Forest Products Journal 30(9): 21-26.

Vajda, P. 1980. Waferboard vs. oriented strand board (OSB). Proceeding: 14th Washington State University International Symposium on Particleboard, Pullman, WA.

Youngquist, John A. 1981. Developing a family of flakeboard products. Proceeding: 15th Washington State University International Symposium on Particleboard, Pullman, WA.

Zylkowski, S.C. 1983. Properties of waferboard manufactued from alder and cottonwood. Master Thesis, Oregon State University, Corvallis, OR.

APPENDICES

APPENDIX A

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
WBMB = 1.00

O.D. specific gravity of the bark
SGBK = 0.7000

Cost of resin per pound
CRES = 0.29

Percent resin required in face
PRRF = 0.05

Percent resin required in core
PRRC = 0.05

Cost of wax per pound
CWAX = 0.20

Percent of wax required in face
PWRF = 0.02

Percent of wax required in core
PWRC = 0.02

Moisture content of wood out of dryer
ODMC = 0.04

The recoverable percent of fines loss
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
PWSR = 0.05

Value for mill process generated wood and bark residues
CODR = 0.00

Cost of electricity per KWH
CKWH = 0.04

BTU in wood fines and residues
BTUF = 0.0085

BTU in bark
BTUB = 0.0095

Dryer BTU demand at boiler
BTRD = 0.0017

Process steam press BTU demand at boiler
BTRP = 0.0192

Thaw pond stram BTU demand at boiler
BTRT = 0.0020

Heating steam BTU demand at boiler
BTRH = 0.0032

Miscellaneous steam BTU demand at boiler
BTRM = 0.0032

Electric usage
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 price of natural gas per MCF
PGAS = 3.00

MMBTUs available per MCF natural gas
BTUG = 1.00

APPENDIX B

List of wage and salary data

Wages (semi-skilled per 8 hour shift) not including 30% payroll charges	$10.50
Wages (maintenance per 8 hour shift) not including 30% payroll charges	$12.50
Administrative salaries (per year) not including 30% payroll charges	
Office manager	$30,000
Assistant accountant	$22,500
Purchasing and receiving	$22,500
Clerk/typist	$14,000
Receptionist	$14,500
Janitor	$14,000
Supervisory and technical salaries (per year) not including 30% payroll charges	
General manager	$70,000
Marketing manager	$50,000
Plant engineer	$35,000
Technical director	$35,000
Shift foreman	$27,000
Woodyard superintendent	$27,000
Shipping superintendent	$27,000