Identifying Opportunities for Engineered Lumber Products in the Modular Housing Industry

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(ABSTRACT)

Modular housing is an important segment of the factory-built housing industry, in the Mid-Atlantic. In 1998, a study was conducted to assess the structural needs and requirements of this industry. This study addressed three questions. (1) What is the current and future state of the industry? (2) What structural material trends are present between 1992 - 2000? (3) What opportunities exist for product substitution and development of new structural materials?

This study found that the modular housing industry in the Mid-Atlantic region is growing. The greatest barrier to market expansion is transportation costs. Expansion is expected in the South and Midwest regions of the US. Most competition comes from site-built and manufactured homebuilders. To stay competitive, respondents plan to increase customization options and home size.

The need for cost effective, quality structural materials is a growing concern. Softwood dimensional lumber has been decreasing since 1992 and is expected continue to decrease through 2000. Decreases are due to design changes and quality concerns. The use of engineered lumber has increased in order to compensate for decreases in dimensional lumber necessary to meet the structural needs of the industry.

Using factor analysis and perceptual mapping techniques, dimensional lumber was not perceived to be as suited for structural building applications as engineered lumber. However, respondents felt that engineered lumber tended to be more expensive. Perceptual mapping also identified gaps between the ideal needs of building applications and the ability of current materials to meet those needs. Opportunities for new product development exist where gaps occurred.

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CHAPTER 1 – INTRODUCTION

Problem Statement

The Appalachian region has an abundant supply of low-grade hardwoods. However, markets for this material, particularly higher value markets, are limited. Higher value markets for Appalachian hardwood resources traditionally included hardwood lumber, dimension products and veneer for traditional uses in the furniture, cabinet and flooring industries. Use of lower quality material has generally been limited to pallet parts, pulp and ties. However, recent advances in technology have improved the designing and engineering of structural materials. These technologies have created new markets, which add value to low-grade hardwoods and use this resource more efficiently. “Engineered lumber products are formed by gluing together veneers, wood wafers, or smaller pieces of solid dimension lumber” (Evans p. 94 1993). By the year 2000, $1.53x10^9$ lineal feet ($4.71x10^8$m) of engineered lumber products, composed of 21 % glulam, 27% parallel chord trusses, 23% laminated veneer lumber (LVL), 19% wooden I-joists, 5% parallel strand lumber (PSL) and 5% other engineered lumber products, are expected to be produced in the United States (Peterson et al. 1993). These engineered products substitute for traditional softwood structural lumber materials used in building construction. This is particularity important since supplies of softwoods from the Pacific Northwest are constrained and the South might be limited due to lack of capacity, opening new substitution opportunities for engineered lumber products.

Modular housing is a new and fast growing segment of the housing industry and offers a market opportunity for engineered lumber products. In the East, modular housing production facilities exist in close proximity to the Appalachian region. This creates an opportunity to expand markets for engineered lumber products, made from Appalachian hardwoods. Engineered lumber products can provide accurate dimension and quality requirements desired in structural applications. The modular housing industry demands high quality structural materials to meet design and structural needs. For example, to overcome design restrictions that limit the use of traditional marriage headers, modular manufacturers utilize engineered marriage headers made from laminated veneer lumber. Marriage headers are used to join adjoining sections together. Laminated veneer lumber is often made from soft pine and yellow poplar. As more substitution and new product opportunities are discovered, new markets will open for low quality Appalachian hardwoods resulting in more efficient use and increased value of this resource.

A study was needed to investigate modular manufacturers in the Appalachian and Mid-Atlantic regions due to their large presence in these regions and proximity to the Appalachian hardwood resource. The current and future structural wood material needs of this housing segment were analyzed to identify opportunities to extend markets for engineered lumber products from the Appalachian region. This study seeks to investigate: (1) the modular housing market and product trends; (2) structural material use; (3) production factors; and (4) structural material performance requirements for the modular housing industry. The study will strive to identify opportunities for engineered lumber products to meet current and future material needs of the modular housing industry. Critical structural performance requirements will also be identified. A performance requirement will be deemed important if it contains a constraint to a step in the manufacturing process or prevents a structural material type from being used in a specific application. By analyzing this information, the study strives to identify two major opportunities for the producers of engineered hardwood products: (1) Identification of substitution opportunities for current engineered products; and (2) identification of current and future performance needs to aid in the development of new engineered lumber products.

This study identified opportunities to add value and offer market alternatives for low-grade Appalachian hardwoods. Results will be useful in providing engineered lumber products producers and designers with information on the modular housing industry's structural material needs and substitution opportunities. This will result in expanded markets for engineered products made from Appalachian hardwoods.

Objectives

In order to address this study's research problem, the following objectives were met:

1. Evaluate and assess the current and future state of the modular housing market, based on:
    a. Market and product trends
    b. Structural material use
    c. Production factors
    d. Wood product performance requirements

2. Determine critical performance requirements for selected structural applications, based on constraints during the manufacturing process as well as requirements for finished products. These structural applications included the following: (1) marriage headers, (2) other headers, (3) wall framing, (4) floor framing, and (5) roof framing.

3. Determine material substitution opportunities for engineered lumber products and identify performance gaps to generate ideas for new product development.

Study Model

The model below is a representation of the study's research design (Figure 1.1). The state of the industry in 1992 was compared to 1997 and projected 2000 industry data. Past data came from Fuchs' (1993) study. This information was used to develop an industry profile. This profile was then used to determine structural material trends over an eight year period. Knowledge of performance requirements was necessary to better understand the industry's structural material needs. Material trends were used along with performance requirements to determined substitution opportunities and performance gaps. Performance gaps were useful to generate ideas for new product development.

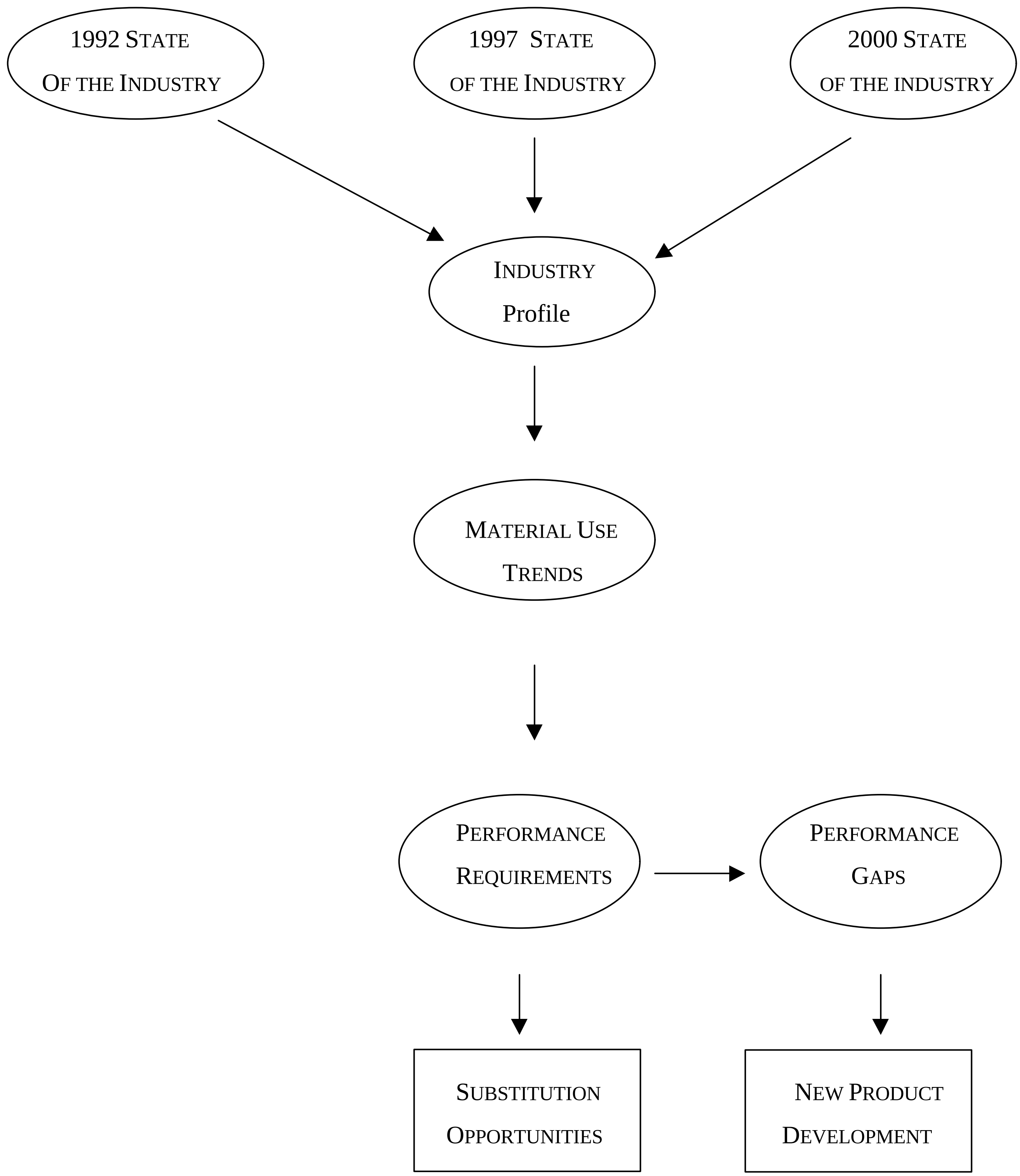


Figure 1.1 Model of Study

The information generated in this study may be used to:

- Aid in the development of new products and enhance current products to increase value and utilization of Appalachian hardwoods.
- Provide information on modular housing structural material use and material needs to assist engineered lumber product producers and developers to expand market opportunities for hardwoods, traditionally of low value

Justification

Producing quality housing efficiently and cost effectively has turned the industrial housing market into the fastest growing segment of the housing industry. Mobile, modular and panelized builders produce 65% of all single-family homes and low-rise apartments (Automated Builders 1996b). The producers of modular houses, one segment of the industrialized housing industry, build their product as a unit and all construction functions are self-contained in a factory. Because of this, they are more willing to find new ways to cut costs and improve designs while maintaining quality. This innovative segment provides a market opportunity for engineered products produced from hardwoods. This market segment offers the engineered lumber products industry an opportunity to emphasize their products' structural reliability and instill confidence in its use (Williamson 1993). With increased communication between the industries, engineered lumber products could provide substitution opportunities for many current softwood applications.

"As environmental concerns escalate worldwide, it will become increasingly important that structures be built to minimize environmental impacts" (Bowyer 1993 p. 11). When designing a structure, the builder should try to choose materials that avoid the generation of waste, is energy efficient and will perform long-term with little maintenance. Because of the high energy cost to process raw materials, steel structural beams are tapered and designed to use as little material as needed to meet the design requirements. The US benefits from abundant wood resources, but as demand for resources grows and wood resources continue to come under more environmental restrictions and public scrutiny, the wood products industry will need to reconsider the ways wood is used and find new ways to use wood more efficiently.

Low quality, small diameter trees are currently being utilized in products such as oriented strand board (OSB) and laminated veneer lumber (LVL). OSB as a substitute for plywood using smaller, lower quality timber, which are chipped, oriented in perpendicular planes, pressed, and bonded together with heat hardening resins. This product has been a huge success and has taken a large share of the market away from plywood. LVL is a promising engineered lumber product that could someday replace dimensional lumber used in structural applications requiring high strength and stability.

Wood provides the builder with the opportunity to build long spans with more strength per mass than an equal span of steel. Use of wood in structural applications is an important issue not only in its strength properties, but also in meeting the ethical responsibility to use raw materials more efficiently (APA 1997). According to Ryan (1993), the National Academy of Sciences states that steel requires 50.32 million BTUs per ton of energy to extract, transport, process, manufacture, and build with, while LVL is estimated to take only 5.75 million BTUs per ton to produce. Therefore it take almost nine times more energy to make steel than it does to make LVL. LVL was first marketed in the United States in the early 1970s under the trade name Micro-Lam and is commonly referred to by this trade name (Vlosky et al. 1994).

Over the past decade, the wood industry has seen an important shift in the way commodity products are marketed, leading to greater product differentiation. Several factors have contributed to these changes: (1) a leveling off of the housing market, (2) a change in the raw material supply for large diameter old growth forests, (3) the use of small diameter logs (many coming from fast growth plantations), and (4) a realization of the potentially large commercial and industrial construction market (Peterson et al. 1993). As people's preferences change, the housing industry has had to change to meet these needs. Today, homeowners demand larger houses, with higher ceilings and larger rooms (NAHB Research Center 1997). Custom features, such as vaulted ceilings and home offices, are often added to floor plans. These factors affect the amount of wood in a home and change the performance requirements of the materials used in the construction process.

Since modular houses often use up to 30% more wood and typically are 20% heavier than traditional stick-built homes (Strong 1998); manufacturers might be more sensitive to changes in lumber prices. Increased wood use is caused by strict design requirements and structural needs. Roof systems, especially, use a high volume of wood since roofs are folded during transportation. More wood is used per square foot to add rigidity to the structures to withstand high stresses caused during shipping. In visiting some factories in Virginia, it was discovered that a major portion of lumber used by the industry was spruce-pine-fir (SPF) this was confirmed by an unpublished study conducted by the Appalachian Hardwood Center at West Virginia University (Fuchs 1993). This softwood lumber must either come from the Pacific Northwest, Northeast, or Canada. Table 1.1 confirms that the entire housing market uses a significant proportion of SPF.

Table 1.1. Percent of lumber used for total new residential construction by species and building application for the US in 1994

	Exterior Walls	Interior Walls	Floors	Roofs	Total
Southern Pine	6%	7%	37%	41%	25%
Douglas Fir/Hem-Fir	46%	35%	34%	26%	35%
Spruce-Pine-Fir	47%	57%	28%	29%	38%
Other	1%	1%	1%	4%	2%

Source. National Association of Home Builders Research Center, 1997
(Complied by: Random Lengths, 1997b)

In 1990, the amount of timber harvested from federal lands in the Pacific Northwest plunged from 10.4 billion board feet to about 3.1 billion in 1995 due to cutting restrictions. Because of these restrictions, home builders have had to look elsewhere for high grade lumber (Colton 1997). In 1993, imported softwood lumber increased 14% over 1992 figures (Western Wood Products Association 1994). Increases in imported softwood lumber suggest that lumber buyers look for other sources to meet their needs if supply is curtailed or lumber quality decreases (Reddy 1994). Increasing demand and softwood supply restrictions, provide Appalachian hardwood, and engineered product producers, substitution opportunities. The modular industry has a significant presence in the Mid-Atlantic region including: New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia, Ohio, Tennessee, Kentucky. The potential to use engineered products from hardwoods is very promising due to consistent performance and quality characteristics, as well as their proximity to hardwood producing regions and markets.

The modular housing segment commands a large proportion of the industrial housing market and tends to be more innovative than stick-built housing, which increases their willingness to try new products. It is hoped that as these builders begin to use more engineered products from hardwoods that these products will spread into the rest of the housing market. Modular housing market share has remained steady at 6 % of the industrialized housing starts since 1995, however, this segment is expected to command a growing portion of the overall housing market as new production facilities are built and new technologies make greater shipping distances possible (Automated Builder 1996b). The modular housing industry offers one possible market alternative for growth to the engineered lumber products industry and hardwood producers throughout the Appalachian region. This industry creates a market opportunity, which can provide wood product producers a larger market for their current products and provide them with ideas to generate new products.

CHAPTER 2 - LITERATURE REVIEW

Background of the Modular Housing Industry

Modular houses are built in the controlled environment of a factory. These homes are built as components, usually designed on computers by architects and licensed engineers. The designs are turned into blue prints and sent to the factory where the home is assembled in as little as six to seven days. In the factory, exterior and interior walls, wiring, plumbing, and other utility fittings are installed. The house is built into three-dimensional sections, called modules or units; a unit is considered one trailer load or section, two or more units make up a house. Modular units are between 12 and 16 feet wide and up to 60 feet long, and can be transported hundreds of miles from the factory to the building site (Mathieu 1987). The modules are shipped to the construction site 75 % to 95 % compete. On site, units are lowered onto a pre-prepared foundation, stacked and joined together. Roof and trim work are connected where sections meet and utilities are connected to outside lines. Decks and garages are often added at this time. Houses can be 100% complete in as little as three days after it arrives on site (Mathieu 1987).

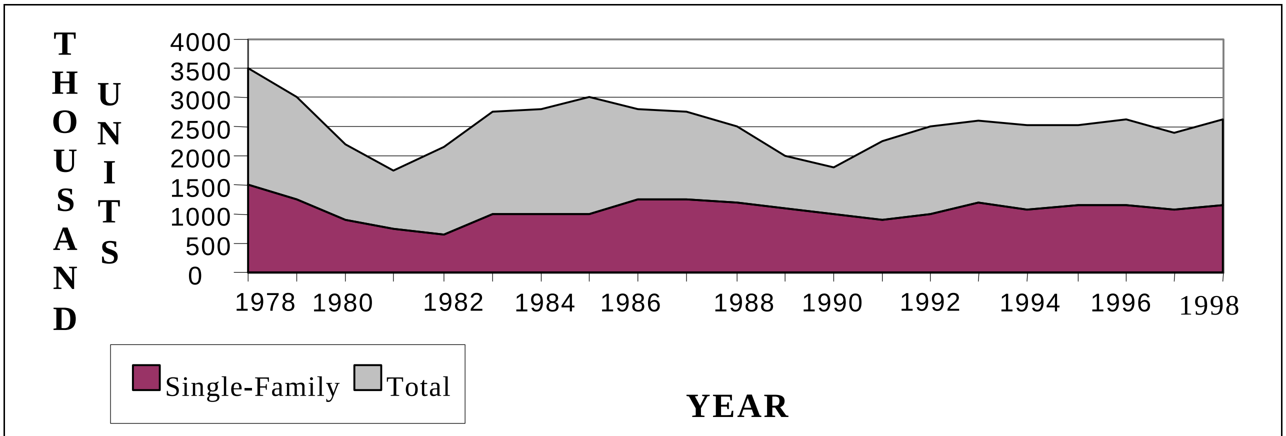
Modular systems developed from the low income housing programs begun in the 1960s. The first modular homes were no more than two units joined together to make small single-family dwellings much like a doublewide mobile home. Mobile homes are constructed based upon the Federal Construction Safety Standards Act or "HUD Code" (US Dept. of Housing and Urban Development 1997). Modular homes began by competing directly with HUD code homes, but stressed higher quality and better construction. However, modular homes could not compete with HUD homes on construction costs since they were built to meet the same national building codes as stick-built homes, which demanded stricter quality standards. Today these homes compete with traditionally constructed home to meet national building codes. Many producers have begun concentrating on medium to high value homes, focusing on faster building times, better construction, lower overall costs, and no hidden costs. Producers have also extended their product lines to include townhouses, duplexes, apartments, and light commercial buildings.

These modular homes or modules resemble box-like structures, which are usually 70-95% complete upon leaving the factory. Producers build primarily single family homes, with a small part of their production focusing on some multi-family homes and commercial buildings.

In order to withstand the high stress put on these structures during transport and installation, they often exceed national building codes in performance and construction requirements. Modular homes are becoming more common and are sold either directly to the customer or through local builders or builder/dealers.

Growth Opportunities in the Modular Housing Market

Growth opportunities for modular housing are directly related to changes in housing starts. In 1996, housing starts of single-family homes reached their highest levels since 1986. Starts reached 1,161,000, a 7.9% increase over 1995 figures of 1,076,000 (Figure 2.1).



Source: US Bureau of the Census, 1998

Figure 2.1. US housing starts 1978 - 1998 (in thousands), 1998 figures forecasted

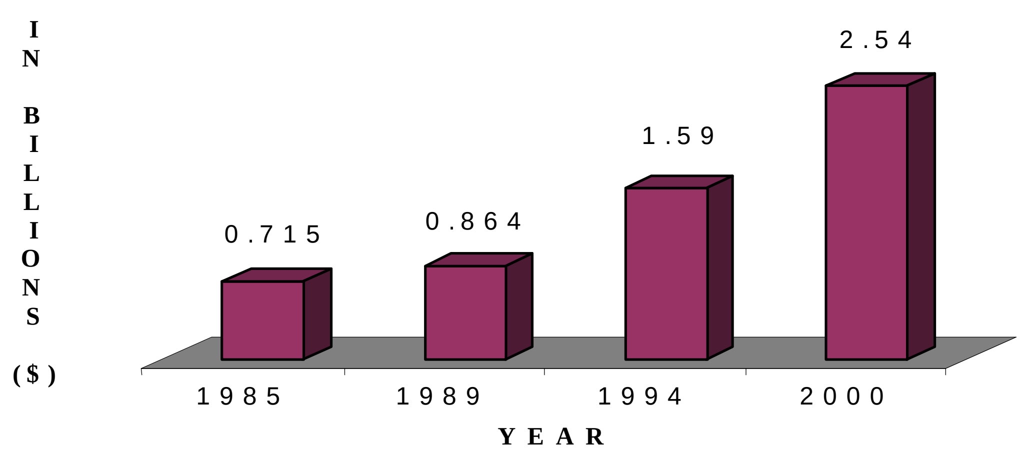
As expected single-family starts follow overall housing starts (Table 2.1). In 1998, housing starts are expected to drop due to higher interest and lumber costs according to the National Association of Home Builders (NAHB 1998b). Starts are expected to increase in 1999 due to lower interest rates. Trends in softwood lumber prices are hard to determine due to wide fluctuations in price. However, softwood lumber consumption is expected to rise to 56 billion board feet by 2040 (USDA Forest Service 1990). While lumber is still a small percentage of the total cost of a home, the U.S. is a net importer of softwoods opening opportunities for new materials from alternate sources.

Table 2.1. US housing starts forecast and interest rate forecast, 1994 - 1999

	1994	1995	1996	1997	1998*	1999*
Total Starts (000)	**1457**	**1354**	**1477**	**1478**	**1341**	**1467**
Annual % change	13.2	-7.1	9.1	0.1	-9.3	9.4
Single-family (000)	***1198***	***1076***	***1161***	***1140***	***1071***	***1156***
Annual % change	6.5	-10.2	7.9	-1.8	-6.1	7.9
Multifamily (000)	***259***	***278***	***316***	***338***	***270***	***311***
Annual % change	59.7	7.5	13.7	7.0	-20.1	15.2
New Home Sales (000)	***670***	***667***	***758***	***807***	***700***	***828***
Annual % change	0.6	-0.4	13.6	6.5	-13.3	18.3
Existing Home Sales (000)	***3946***	***3802***	***4085***	***4206***	***3777***	***4364***
Annual % change	3.8	-3.6	7.4	3.0	10.2	15.5
Interest Rates (Freddie Mac Commitment)						
Fixed-rate	8.4 %	8 %	7.8 %	7.6 %	6.9 %	6.4 %
ARMs	5.3 %	6.1 %	5.7 %	5.6 %	5.6 %	4.9 %
Prime Rate	7.1 %	8.8 %	8.3 %	8.4 %	8.4 %	7.4 %

Source: National Association of Home Builders, 1998a *forecasted

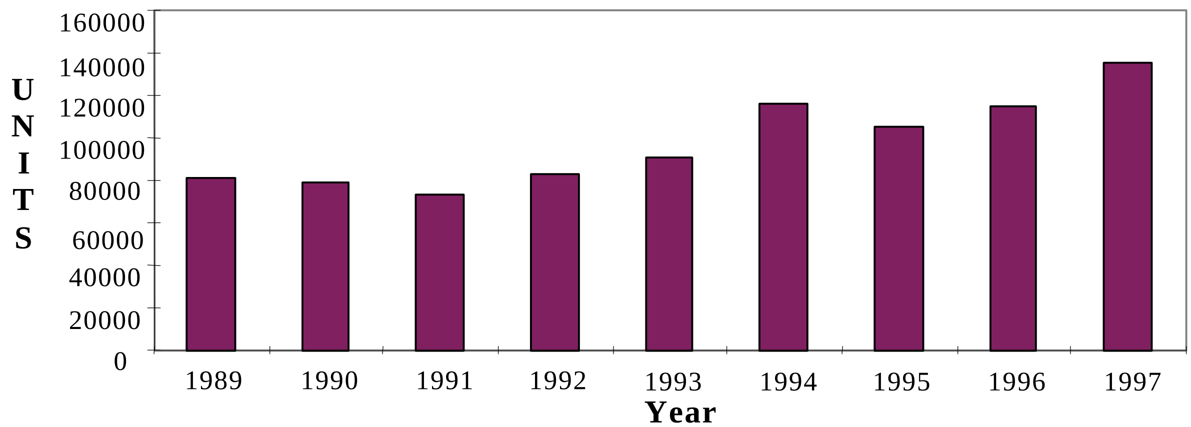
Although the modular housing industry commands only 2% of the total nationwide housing market and 6% of the industrialized housing market, that figure is expected to increase (Bady 1996). The current projected dollar value of modular housing shipments is expected to reach $2.54 billion by the year 2000 (Figure 2.2).



Source: The Freedonia Group, Cleveland (Complied by Bady, 1996)

Figure 2.2. Modular housing shipments in 1985 projected through 2000, by dollar value in billions

Figure 2.3, shows how the number of modular houses has increased between 1989 and 1996, despite decreases in the overall housing market. This is the most significant gain of any of the factory-built housing types (Bady 1996). A study done by the Freedonia Group, a Cleveland-based research firm, predicts that a substantial increase in the average cost of modular homes will boost the industry's dollar-based growth as manufacturers continue to develop more elaborate, sophisticated designs (Bady 1996).



Source: Automated Builder Magazine, 1997

Figure 2.3. Number of units produced by modular housing manufacturers 1989 - 1996

Most modular companies offer a broad range of designs, including starter homes, but recently there has been a trend toward larger more upscale houses. These trends are inline with overall single family home trends. Over the past twenty years the average square footage of single-family homes has slowly increased. In 1975, the average home was only 1,645 sq. ft (Table 2.2), by 1990; the average home was 2,080 sq. ft. Since 1992, the average home has leveled out at approximately 2,100 sq. ft. Increasing overall size of homes presents a challenge to modular manufacturers. Manufacturers and designers must find ways to increase the size of their homes and still remain within the dimensional limitations required for transportation and production facilities.

Table 2.2. Characteristics of new single-family homes built in the US: 1975 – 1997

	1975	**1980**	**1985**	**1987**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Total Completed (000s)	875	957	1073	1123	966	838	964	1039	1160	1066	1129	1116
Central AC Installed	46	63	70	71	76	75	77	78	79	80	81	82
2 1/2 Baths or More	20	25	29	38	45	44	47	48	49	48	49	50
4 Bedrooms or More	21	20	18	23	29	28	29	30	30	30	31	31
1 Fireplace or More	52	56	59	62	66	62	64	63	64	63	62	61
Full or Part. Basement	45	36	35	39	38	40	42	40	39	39	37	NA
Slab	35	45	48	43	40	38	38	40	41	42	44	NA
No Garage or Carport	24	24	25	18	16	17	15	14	13	14	13	NA
2 Car Garage or More	53	56	55	65	72	71	75	77	78	76	78	78
Brick Exterior	32	28	22	18	18	18	19	21	21	20	21	NA
1 Story	65	60	52	49	46	48	48	48	49	49	NA	NA
2 Stories or More	23	31	42	46	49	47	47	48	47	48	47	NA
1,200 sq. ft. or Less	25	21	20	13	11	12	10	9	9	10	NA	NA
2,400 sq. ft. or More	11	15	17	21	29	28	29	29	28	28	30	NA
Average sq. ft.	1645	1740	1785	1905	2080	2075	2095	2095	2100	2095	2120	2150
Median sq. ft	1535	1595	1605	1755	1905	1890	1920	1945	1940	1920	1950	1975
Median Lot Size sq. ft. *	NA	9180	8875	9295	10000	9750	9600	9600	9500	9375	9100	NA
Average Lot Size sq. ft.	NA	NA	17610	17600	14680	14275	14060	13440	13645	13665	13705	NA

Source: US Bureau of the Census. Compiled by: National Association of Home Builders Research Center, 1997. Note: With the exception of total completed, average square ft., median square ft., Median lot size and average lot size, numbers are percentages. NA: Not Available
(*) Denotes number for new homes sold. Not available for homes built on owner's lot.

The number of young adults in the housing market is falling as the smaller population of generation “X” begins to buy their first homes (Deardorff and Montgomery 1995). This is causing a weak demand for starter homes. On the other hand the baby boomers are moving into their second homes or buying vacation homes. This segment wants larger more custom homes. This trend offers an opportunity for modular producers to enhance the quality of their product by adding customized features such as turrets, specialized ceilings, octagon rooms, larger room openings, different shapes and placements of bump-outs, wider ranges of roof designs, gables, garages, split levels, curved walls, archways, and decorative columns. These customized features often call for the use of engineered products to meet structural requirements for the design. This provides a market opportunity for the producers of these products to increase sales and develop new products.

Modular houses offer the opportunity for more cost control, timesaving, and quality consistency, then a traditional stick-built house (Bady1996). A stick-built home usually takes around six months or more to finish. Modular systems on the other hand take less then 3 to 4 weeks to complete. To the builder, this means savings of $10 to $15 per square foot (Bady 1996). Crest Homes a division of Schult Homes Corporation in Indiana produces modular homes and markets them as way of differentiating themselves from the competition. The company sells their homes for 5% to 10% below market price and guarantees a 90-day move-in (Bady1996). The time length before move-in becomes very important to the buyers since interest rates can only be guaranteed for 90-days.

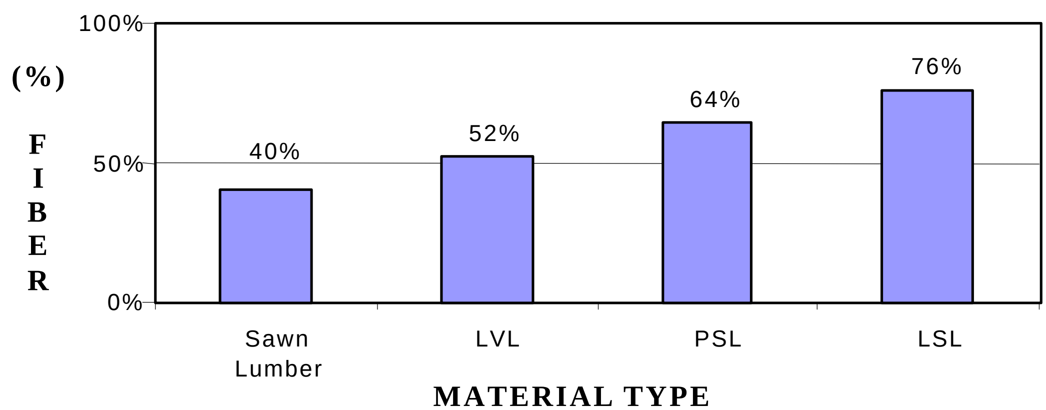
In the past, modular manufacturers have struggled with negative image problems since many consumers confuse modular homes with manufactured homes. Improved construction techniques, quality, appearance, and consumer knowledge about modular homes has lead to increased acceptance of this housing type. As companies move out of cities and more people are working at home, the population has shifted towards more suburban and rural areas, allowing more people than ever before to work at home. These people want space in their homes designated for offices, causing more design changes. Changes in design can lead to different structural material performance needs opening opportunities for engineered lumber products.

Factory built housing will play an increasing role in the housing market since the supply of skilled labor to the home building industry is growing scarce (Crowley et al. 1993). Modular housing factories and other industrialized housing segments can take semi-skilled and even poorly skilled workers and teach them to do one skill and do it well. Craftsmen can also be localized instead of having to contract each one individually and pay for each one to go to the construction site.

Engineered Lumber Products

Our nation’s most renewable resource comes from second and third growth forests managed with sustainable forestry practices and harvested on 30 to 80 year rotations. Trees from these plantations are smaller in diameter when harvested than trees obtained under natural forest management. These logs tend to contain more knots and juvenile wood that affect strength and in-service performance (Smulski 1997). While small dimensional lumber will always be available, the future of the supply of large sized, high quality dimensional lumber is uncertain. At the same time demand for lumber continues to rise. The United States is the world’s largest producer and consumer of wood products, averaging 230 board feet per capita (Smulski 1997).

Engineered lumber products take advantage of lower quality wood fiber by gluing together veneers, wood wafers, or smaller pieces of solid dimension lumber to form a very high quality product (Evans 1993). Figure 2.4 compares the percent of wood fiber used from a log by different structural materials. Laminated veneer lumber (LVL), parallel strand lumber (PSL), and laminated strand lumber (LSL) are the best examples of high utilization of wood. All three of these products are examples of structural composite lumber (SCL). These materials are used for girders, beams, headers, joist, studs and columns and can be treated. The cited advantages these materials have over sawn lumber are higher strength properties, predictable performance, availability of long lengths, dimensional consistency and dimensional stability (Nelson 1997a).



Source: PFS Research Foundation, 1997

Figure 2.4. Percent of wood fiber used from a log by structural material type

LVL is the most commonly used types of SCL. For this study it was considered a separate product. LVL is made from full size veneer sheets, glued together a parallel orientation. This product is than trimmed into specific dimensions to meet the exact requirements requested by the customer. LVL is made from many species and is an ideal use for low quality soft hardwoods. LVL produced from red oak, yellow poplar and red maple is being researched at Pennsylvania State University (Vlosky et al. 1994).

SCL can be produced from fast-growing species, such as poplar and aspen, these species are less expensive than traditional species chosen for structural lumber, such as Douglas fir and Southern yellow pine (Ryan 1993). These products also use material from low-quality trees that traditionally could not be used for structural applications and transforms them into a value-added product. Because engineered products can be specially designed, these products can have consistent quality, high strength properties and consistent performance characteristics, giving them the opportunity to better meet current and future structural and design requirements than solid-sawn lumber.

An example of SCL is TimberStrand ™. TimberStrand ™ is the trade name of Trus Joist MacMillan's new parallel-strand framing lumber. TimberStrand ™ is marketed for trusses, wall studs, and short-span headers (Automated Builder 1996a). TimberStrand ™ uses small diameter trees, usually aspen or poplar to make billets of engineered lumber. Billets are formed from thin strips, aligned parallel and pressed together with heat and adhesives, then smaller pieces are cut to size (Automated Builder 1996a). Parallel-strand lumber (PSL) is used for headers, rim boards, core material in windows, doors, furniture frames and specialty millwork (Ryan 1993). By discovering design limitations of current materials and applications, future opportunities can be discovered which will give engineered lumber product producers the clues they need to create new products.

Glulam beams represent another type of engineered product. Glulam or glue laminated beams are made from individual pieces of small dimensional lumber glued together to form a large single piece, with the grain of each piece running parallel to the grain of each of the other pieces (Evans 1993). Glulam has many advantages when compared to solid dimensional lumber. Glulam beams can be much larger than the trees the material came from. Straight members are often up to 100 ft long, 7 feet deep, and 20 inches wide (Russell 1997). These long spans offer design flexibility and allow for open floor plans, unsupported in the center by columns. Pieces can be strategically placed to take advantage of different grades. Higher grades of lumber are placed in areas where laminations have the highest stress near the top and bottom of the member, while lower grades are used near the center where stress is lowest (Russell 1997). This allows material to be used more effectively. Glulam is most often used in the roof systems of commercial buildings, but it is being used more often in residential roof and floor systems (Russell 1997).

Engineered wooden I-beams or I-Joists are beams with a cross section that resembles the letter "I" (Evans 1993). The top and bottom chords are usually made out of LVL lumber. These chords are connected together by a thin piece of LVL, plywood or oriented strand board. These beams use significantly less lumber than solid lumber of equal dimension. They also are lighter in weight. Wooden I-beams are commonly used for floor joists, headers and roof members. They are available in a wide variety of dimensions. Holes for running utilities can be cut in areas where the shear loads are lowest (Nelson 1997b).

Prefabricated trusses are assembled from individual members of solid dimensional lumber to form a rigid framework and are used to support the roof, floor or wall systems of a building (Evans 1997). These trusses are made using finger-jointed pieces of small dimensional lumber glued together or with metal plating to hold the dimensional lumber members together to form a truss.

Finger-jointing is also used to construct studs. Finger-jointing small sections of boards together allow for optimal use of the lumber. Defects can be removed to increase the grade of the final product. Finger-jointed studs are commonly found in 2x4 and 2x6 dimensions. These studs are used in the wall systems of buildings.

Opportunities in the Industrial Housing Industry

Many modular housing companies have taken an innovative approach in construction techniques, which increases their willingness to try new products (Bobbitt 1997). Industrialized housing has strict material requirements where quality control is very important. Individual components are checked upon receipt as part of a strict quality control system. Engineered lumber products could be used to cut down on the time requirements for guaranteeing quality, since engineered products are designed to be more consistent in quality and properties. The longer span possibilities and lighter weights of some engineered lumber products have the potential to save on installation costs and reduce labor injury to installers (Ryan 1993). Designs and needs in the modular housing industry change over time. Engineered lumber products can be redesigned readily to meet customers' evolving needs.

The industrial housing industry is ideal for new product development, not only because these producers are some of the most innovative in the housing industry, but in this growing market there are a relatively small number of manufacturers producing a large quantity of homes. They also have small supply channels buying most of their structural products in bulk directly from the producer. This means that new products could be targeted to a few industrial customers rather than a large number of diverse customers. This would help hardwood and engineered product producers market their product.

Designs of homes are rapidly changing as peoples' tastes change. Larger homes with high ceilings, home offices and greater amounts of open space, require producers to redesign rooms and find ways to span these areas. Designs also need to be flexible so homes appeal to a wide variety of preferences and can include custom features. Computer-aided design (CAD) software programs are being employed by most builders to offer quick design flexibility. CAD systems allow the builder to check the dimensions to make sure the design can be built before the plans goes to the plant (Professional Builder 1993). Changes in material use (i.e. use of LVL marriage headers versus solid softwood marriage headers) can be easily added to the program's design specifications (Bock 1998). CAD systems allow modular builders to easily add in cathedral ceilings and pre-built dormers, turned gables and porches that were not possible a few years ago (Professional Builder 1993).

Modular manufacturers are faced with a unique set of design and construction problems. Due to highway restrictions, modular manufactures are limited on lengths, widths, and heights of modular sections. Already engineered lumber products are helping manufactures to solve these problems. For example LVL is used as a marriage header to span openings between modular sections redistributing loads to allow for higher ceilings in rooms that cross more than one modular section. Newly designed roof trusses allow modular sections to be wider by folding roof overhangs.

A similar study conducted by Fuchs (1993) found that competitive pricing, accuracy of dimension and lumber straightness were the three most important softwood lumber attributes to modular housing manufacturers in 1992. However, these attributes rated lowest in satisfaction. Due to strict design specification in the modular housing industry, manufacturers could be more sensitive to price or quality than other housing segments (Fuchs 1993).

Warped wood means wasted wood, since lumber must fit very strict dimension requirements. This dissatisfaction provides an opportunity for engineered hardwood products. Engineered lumber products such as parallel strand lumber (PSL), made from yellow poplar, have many advantages. Since PSL is made from strips of pressed veneer, defects are distributed evenly throughout the board reducing the chance of failure. Boards can be made to any size and dimension and are guaranteed to be straight.

The need for substitute products is becoming more apparent as traditional western sources of softwood lumber have been reduced. In 1991, the US Forest Service reported timber harvests were down 29% across all regions of Oregon, California and Washington compared to 1983-1987 levels (Wiedenbeck and Araman 1993). While the South is trying to fill this deficit, it is unlikely that they can continue to make up the growing demand for lumber in the country, especially large high quality dimension lumber such as 2 x 10s. This has opened up opportunities for engineered lumber products produced from Appalachian hardwoods to be used as substitutes for common building materials.

Modular housing facilities in the East are concentrated in or near the Appalachian region, in close proximity to hardwood timber resources. This proximity should help wood product producers develop symbiotic relationships with modular housing manufacturers. This relationship could be used to determine the modular housing industries' structural material needs and to develop new products to meet these needs.

Past Studies of Structural Softwood Lumber Performance Attributes

Fuchs' (1993) study used softwood lumber attributes to rank the importance of supplier and performance based softwood lumber attributes by the industrial housing industry and compared the attribute's importance by the industry's level of satisfaction from current materials on each attribute. This data was used to develop satisfaction discrepancy scores. This study found that lumber straightness, competitive pricing and consistency of grading had the largest gaps between importance and current satisfaction.

In Hansen's (1994) study, an attempt was made to isolate the measurement of quality. Respondents were asked to rate eighty attributes based on its importance to the quality of lumber or service. The results of Hansen's study provided a reduced list of five attributes to describe the principle determinants necessary to assess softwood lumber quality. These variables of quality were grouped into five quality dimensions: (1) Supplier/Salesperson Characteristics; (2) Supplier Services; (3) Supplier Facilities; (4) Lumber Performance and (5) Lumber Characteristics.

Reddy's (1994) study modified the principle determinants from Hansen's study to investigate the price sensitivity of softwood lumber buyers for the U.S. wood treating industry. The perceptions of softwood lumber treaters were analyzed using conjoint analysis to estimate the trade-off treaters made between quality enhancing attributes and price. He determined that since lumber treaters had general agreement on what constituted a high value softwood product, suppliers could manipulate the quality levels of attributes to influences the value perception of treaters. He also found that lumber quality was more important than service, but treaters were willing to pay more to add services.

The results of these three studies were used to determine structural lumber attributes for used in this study. These three studies provide important background information since they relate to how consumers perceive wood products based on quality, performance, importance, and satisfaction. These studies also provided a means of grouping softwood characteristics based upon consumer perception.

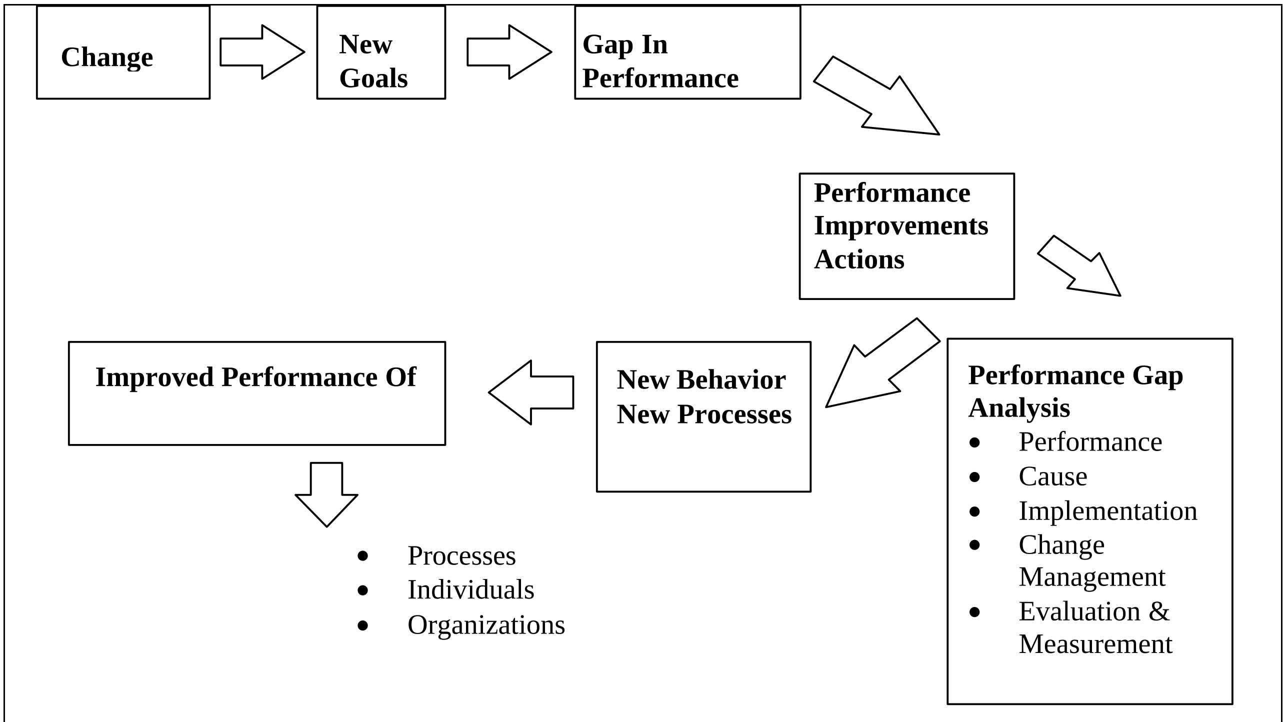
Performance Gaps/New Product Development

One of the goals of this study is to provide engineered lumber producers with opportunities to development new products. One of the ways to learn about new product needs is to look for gaps between the satisfaction of customers and the performance of current products as well as any unmet needs. The initial motivation to innovate is generated by the perception of a problem or opportunity, such as a lack of maximum performance. The need for improved performance may also arise from new technology, fast growth, competitive challenge, process failures, or some other forceful change in the current state of things (ASTD 1996). Performance gaps can also be brought about through changes among consumers, or by loss of market due to new competition (Zaltman, Duncan and Holbek 1973). New technical specifications such as those required by new governmental regulations can also bring about performance gaps (Zaltman, Duncan and Holbek 1973).

Rogers (1982) defined a performance gap as the discrepancy between an organization's expectation and its actual performance. This difference between how an organization's members perceive its performance compared to what they feel it should be, can be a strong motivation to search for an innovative product (Rogers 1982). Performance gaps are perceived to have a significant adverse consequence for organizations if the gaps are not narrowed or bridged (Zaltman, Duncan and Holbek 1973). Often organizations are not even aware of a performance gap. However, once the gap is perceived, the need for change creates the conditions necessary to promote change within the company. The organization will alter its structure and functions in order to search for a means to close the performance gap.

The search for the solution to a performance gap can be both internal and external. The internal search involves looking within the organization to determine if the organization already has the answer to the performance gap or the means and resources to develop a solution. The external search involves looking outside the organization for a solution that may already exists and adopt that product or process. The firm can also commission research and development work outside the organization to obtain needed solutions (Zaltman, Duncan, and Holbek 1973).

Figure 2.5 is a model of the chain of events to improve performance. Within the model is a five step system to identify and solve performance gaps. Step 1 analyzes performance to determine if any problems or opportunities exist. A performance gap can apply to current or future work plans. Step 2 analyzes the cause or causes of the performance gap. In step 3, interventions and alternatives are designed, evaluated and selected to determine the best way to solve the performance gap. In step 4, the selected action is implemented. Finally in step 5, the action is measured and evaluated to determine its impact on the performance gap. Upon successful evaluation of the action, new behaviors or processes are adopted. The action becomes become part of the organization’s operating procedure and the performance gap is closed. Identifying and understanding performance gaps is an important step in the development of innovative new products. Critical inputs on how to improve products come not from state-of-the-art technology but from insights about a customer’s needs (Utterback 1979). In this case modular manufacturers are the potential customers. They are the best source of information to the wood industry as to their particular needs.



Source: American Society for Training and Development, 1996

Figure 2.5. Chain of events in used by companies for performance improvements

A clear case in how a performance gap led to the development of an innovative new roofing system was discussed in a paper by Crowley et al. (1993). Their research pointed out the demographic changes taking place in the housing industry. They found that the traditional supply of skilled carpenters had declined. Also timber production trends indicated a reduction in wide dimension and structural grade lumber causing these products to become scarcer and more expensive for the consumer. These changes caused a performance gap due to lack of skilled carpenters and a future lack of raw materials. These factors drove up the cost of housing making a single-family house less affordable.

The solution to the roofing problem was to develop a roof system that would serve the widest possible range of house designs and have a distinct advantage over traditional trusses and stressed-skin panel methods. The product would also need to be responsive to consumer needs, marketable, take advantage of flexible manufacturing systems to ensure market responsiveness, assure consumer confidence through quality control, be compatible with current wood-frame construction technologies and practices, be code compliant and provide perceived cost and value improvements over conventional roofing systems. The MIT Innovative Housing Construction

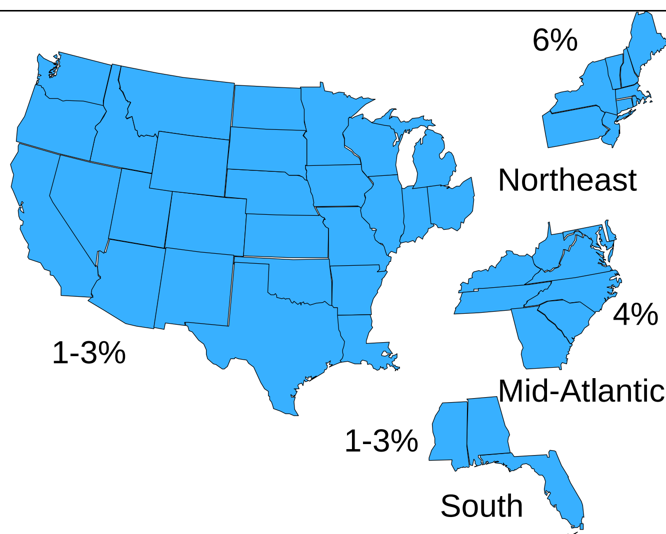
Technology Program (IHCTP) developed the product (Crowley et al. 1993). The final product was a roof system composed of two uniquely designed structural components: the ridge beam and the enclosure components (structural insulation panels). This new system utilized existing and proven technology to develop innovative components and assemblies. They took the benefits of standard wood-frame construction and improved its short falls, so that the product could be understood by the customer and easy to integrate into construction plans. The product is a net-shaped roof component, which is quick to design, manufacture and erect. The study found that a fairly complex roof could be installed on an average-sized two-story house by three to four workers with the aid of a crane in about four hours (Crowley et al. 1993). With further testing and marketing this new roofing systems can solve the gap caused from the lack of skilled carpenters and possible future raw material shortages.

CHAPTER 3 - RESEARCH METHODOLOGY

Population Description

In 1989 there were approximately 200 modular manufacturers in the U.S. By 1994, that figure had dropped to 170 as big companies grew through increased sales, acquisitions, and mergers (Automated Builders 1994). As of May 1996, there were again approximately 200 modular home manufactures in the United States (Automated Builder 1996b). Mid-sized companies in all areas of the industrialized housing industry enjoyed substantial gains in production during 1995 (Automated Builder 1997). During the first quarter of 1996, modular builders experienced a 19 % increase over 1995 figures. This was the greatest gain of all industrial housing manufacturers (Bady 1996). In 1996, modular manufacturers produced approximately 115,000 units. Two or more units make up a house. In 1997, modular housing commanded approximately 6 % of the industrialized housing market.

Traditionally, markets for modular homes have been strongest in the Northeast. Pennsylvania contains approximately 50 % of all manufacturers in the Mid-Atlantic region. However, many manufacturers and builders are strengthening their position in other market areas. Modular housing currently accounts for 6 % of the total housing market in the New England states (Figure 3.1), 4 % in the Mid-Atlantic region and from 1% to 3% throughout the rest of the country (Automated Builder 1997).



Source: Automated Builder Magazine, 1997

Figure 3.1. Modular housing share of total housing starts by region in 1996

Many Northeastern and Mid-Atlantic producers are expanding to high growth areas of the South, reflecting marketing response to 1997 housing starts. In the northeast, starts were 0.7 % under 1996 figures, indicating a slowing of housing starts, but in the South starts were up 5.1% and accounted for nearly 30 % of all housing starts in the United States (Table 3.1). It is interesting to note the strong correlation between modular housing factory location and increases in market share, indicating that as customers accept the product, the distance a home can be shipped becomes a critical constraint to growth.

Table 3.1. Housing starts and building permits in 1997 in thousands of units, rates are adjusted seasonally and annually

	April	March	Percent Change From Previous Month	Percent Change From Year Ago
Total Starts	**1473**	**1435**	**2.6**	**-3.2**
Single Family	1118	1115	-0.3	-8
Multi-Unit	355	320	10.9	15.6
Northeast	137	148	-7.4	-0.7
Midwest	292	290	0.7	-10.2
South	699	628	11.3	5.1
West	345	369	-6.5	-12.4
Total Permits	**1446**	**1457**	**0.8**	**-2.7**

Source: US Bureau of the Census (Complied: by Random Lengths, 1997a)

The population of this study contained all modular manufacturers in the following states: New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia, Ohio, Tennessee, North Carolina, and Kentucky. These states were selected because of their proximity to the Appalachian region and their compatibility with previous research by Fuchs (1993). In 1992, modular home producers in Maryland, New York, Pennsylvania, and Virginia accounted for 50.3% of all stationary buildings shipped in three-dimensional assemblies (SIC 24524), for a total of 371.3 million dollars (USDA Census of Manufacturers 1992). Manufacturers were located using lists generated from: The 1998 Pennsylvania Community Development and Housing Office, Manufactured Housing Division, The 1997 Guide to Building Products, The Modular Building Systems Council, and the Automated Builders Top Manufacturers List (Automated Builder 1996c).

Data Collection Procedures

Table 3.2, provides a timeline of the sequence of events used to collect data for this study. This study was started with a literature review in the summer of 1996. Preliminary data was collected in the summer of 1997. A mailed questionnaire was sent out in the spring of 1998. During the summer of 1998 the mailed questionnaire was followed up with personal interviews and a second questionnaire.

Table 3.2. Timeline of 1997 modular housing study

Event	Dates
Step 1: literature review	July 1996 – July 1997
Step 2: preliminary interviews	Summer 1997
Step 3: questionnaire	Spring 1998
Step 4: interviews	Summer 1998
Step 5: second questionnaire	Summer 1998

Step 1: literature review

An intensive literature review was conducted to identify and utilize previous research on industrial housing, with emphasis on modular housing and applicable industrial marketing literature. This search included industry statistics and product trends in the modular housing sector and background information on current engineered lumber products on the market, such as wooden I-beams, laminated veneer lumber, and prefabricated trusses. Other literature relevant to this study included research on industrial innovation, new product development, product similarity measures and performance gaps.

Selection of structural material attributes

This study assessed modular housing manufacturers' perceptions of structural material performance characteristics. These characteristics were selected based on those shown to be important in past studies (Fuchs 1993; Hansen; 1994 and Reddy 1994). In addition, attributes were included that were most relevant to material performance and other more general characteristics and which might be an important consideration by the modular housing industry when choosing a structural material. These attributes are listed below:

- Lumber Straightness
- Growth Rate (rings/inch)
- Accuracy of Dimensions
- Consistent Moisture Content
- Consistent Grade
- Reliability of Supply
- Competitive Pricing
- Small Orders
- Large Orders
- Just-In-Time Delivery
- Supplier Arrange Credit
- Trademark
- End Coating
- Protective Wrapping
- Overall Product Consistency
- Overall Product Quality
- Service
- Technical Assistance

Step 2: preliminary interviews

Preliminary interviews were conducted with modular housing manufacturers during the summer of 1997. The purpose of these visits was to acquire familiarity with the industry, assess general views and trends within the industry, and to develop criteria for future analysis. These interviews were conducted of a convenience sample of three Virginia producers located within a short distance of Virginia Tech: Nationwide Homes in Martinsville; Mod-U-Kraf in Rocky Mount; and Princeton Homes in Danville.

Step 3: questionnaire

In May 1997, a structured questionnaire was sent to all identified modular housing manufacturers within the population. The questionnaire was useful in collecting demographic information and quantifiable data. Thirty-nine separate companies were identified, with the majority of these companies located in Pennsylvania. Prior to sending the questionnaire, each company was called to identify a contact person. The goal was to find contact people who contributed to the decision making process when choosing structural materials. These people included top executives, plant managers, general managers, purchasing mangers, and quality control managers. The scope and purpose of the study was explained to the contact person and their participation was requested. The types of information collected by this questionnaire included: (1) a demographic description of each company; (2) identification of 1997 markets and future target markets in 2000; (3) identification of 1997 structural material usage; and (4) estimated material usage in 2000. Projection to the year 2000 was used since it was assumed that most companies could estimate accurately about three years into the future. Table 3.3 provides a description of demographic variables that were used to describe the current and estimated future state of the modular housing industry along the mid-Atlantic region. These trends are important since they contribute to changes in material use.

Table 3.3. Demographic and market variables used to describe, measure and analysis the Mid-Atlantic housing industry in 1997 and estimated change by 2000

Variable	**Description**	**Measure**	**Analysis Type**
Company Size			
Sales Volume	Sales in 1997	Dollars	Mean, Standard Deviation
	Sales in 2000	Percent Change	Mean, Standard Deviation
Production	Number of Units in 1997	No. of units	Mean, Standard Deviation
	No. of Units in 2000	Percent Change	Mean, Standard Deviation
Market Area	Market Area in 1997	States	List
	Expected Market area in 2000	States	List
Product Mix			
Building Type	Single Family Homes Produced 1997	No. of Units	Mean, Standard Deviation
	Multi-Family Homes Produced 1997		
	Commercial Units Produced 1997		
	Single Family Homes Produced 2000	Expected Change in percent +, -, No Change	Percent, Frequency
	Multi-Family Homes Produced 2000		
	Commercial Units Produced 2000		
Square Footage	Largest Single Family Home 1997	Square Feet	Mean, Standard Deviation
	Most Popular Single Family Home 1997		
	Smallest Single Family Home 1997		
	Largest Single Family Home 2000	Expected Change in percent +, -, No Change	Percent, Frequency
	Most Popular Single Family Home 2000		
	Smallest Single Family Home 2000		
Price	Largest Single Family Home 1997	Dollars	Mean, Standard Deviation
	Most Popular Single Family Home 1997		
	Smallest Single Family Home 1997		
	Largest Single Family Home 2000	Expected Change in percent +, -, No Change	Percent, Frequency
	Most Popular Single Family Home 2000		
	Smallest Single Family Home 2000		

Material use for 1997 and expected values for 2000 was described, measured and analyzed by the variables found in Table 3.4 (i.e. volume, structural material type, and size). Structural material types were measured for each of the following building applications: (1) marriage headers; (2) other headers; (3) studs; (4) beams; (5) floor framing; and (6) roof framing. These changes were compared with 1992 data (Fuchs 1993). This information was used to develop structural material trends from 1992 through 2000.

Table 3.4. Variables used to describe, measure and analysis structural material usage for the Mid-Atlantic region's modular housing industry, for 1997 and forecasted for 2000

Variable	**Description**	**Measure**		**Analysis Type**	
		1997	**2000**	**1997**	**2000**
Softwood Lumber	Spruce-pine-fir Southern pine	Board Feet	NA	Mean, SD Frequency	NA
Material Type	Spruce-pine-fir Southern pine Wooden I-beam Glulam LVL SCL Prefab. Trusses Steel Other	% of Total use	Expected % Change +, -, no change	SD Median Range	Percent Frequency
Size	2x4 2x6 2x8 2x10 2x12 Other	% of Total use	Expected % Change +, -, no change	SD Median Range	Percent Frequency
Building Component	Material Type				
Marriage Headers Other Headers Wall Framing Floor Framing Roof Framing	Spruce-pine-fir Southern pine Wooden I-beam Glulam LVL SCL Steel Other	% of Total use	Expected % Change +, -, no change	SD Median Range	Percent Frequency

In a further attempt to assess the needs of the industry, companies were asked to evaluate the importance and current satisfaction level of structural softwood lumber attributes. Respondents were asked to rate the importance and satisfaction of softwood lumber for the following eighteen variables:

- Lumber Straightness
- Accuracy of Dimensions
- Consistent Grade
- Competitive Pricing
- Large Orders
- Credit
- End Coating
- Overall Product Consistency
- Service
- Growth Rate (rings/inch)
- Consistent Moisture Content
- Reliability of Supply
- Small Orders
- Just-In-Time Delivery
- Trademark
- Protective Wrapping
- Overall Product Quality
- Technical Assistance

The importance and satisfaction of softwood lumber was evaluated using a five point Likert scale. Importance was measured with 1 = not important and 5 = very important and satisfaction was measured with 1 = not satisfied and 5 = very satisfied. A five-point scale was chosen so that data would be comparable to Fuch's (1993) study. Data was analyzed using the following statistics: mean, standard deviation, rank and frequency of five. These scores were used to produce weighted satisfaction discrepancy scores, which measure the difference between importance and satisfaction. Results were compared with Fuchs' data, to evaluate how the importance level and satisfaction rating for each of these attributes of solid-sawn lumber might have changed over five years. Changes could occur due to lack of suppliers, lower quality, lower availability, etc. This relates to objective 3, to determine substitution opportunities for existing engineered lumber products. Since attributes, which have a high importance rating but a low satisfaction rating, are not currently meeting the industry's needs, a substitute product might be used to better meet these needs. A performance gap would occur if no existing product can fill these needs, providing an opportunity for new product development.

Analysis of questionnaire response

Raw data was coded from returned questionnaires and the results entered into a spreedsheet using the SPSS statistical program (SPSS 1996). Data was tabulated, counted and analyzed. Preliminary data analysis was developed for descriptive statistics, designed to describe the industry. Means and standard deviations were gathered for all descriptive variables. Means, standard deviations, rank, and frequency data were collected for scaled descriptive variables. Cross-tabulations were used to measure structural materials by application.

This data was compared to Fuchs' 1992 data to measure how the industry has changed since 1992 (Fuchs 1993). Specific data to be compared included: (1) the number of units produced per year by category, (2) softwood framing lumber usage (board feet) and size, and (3) satisfaction discrepancy scores. The questionnaire also collected exploratory research on choosing a structural building material and perceptions of engineered lumber products. This data provided a general view of how the industry has changed over five years in the Mid-Atlantic region. Additional data measuring these same variables as an estimated percent change by 2000 provided a prediction of future trends and industry needs.

Step 4: personal interviews

Following the mailing and collection of the questionnaire, approximately fifty percent of companies were contacted to set up a facility visit, during the summer of 1998. The percentage of companies interviewed was based on distant to facility, location in relation to other modular companies and willingness of the company. Nineteen semi-structured individual and small group interviews were conducted. Each company was asked the same questions, but interviewees were asked to expand upon their answers, in order get a better understanding of the company's needs and concerns. Immediately following the interview, a second questionnaire was distributed on-site to all the participants of the interview. This questionnaire dealt with the importance of structural material attributes by application and perceived performance ratings of structural material types. This second questionnaire was to be mailed back at a later time. Persons interviewed included: (1) plant managers; (2) design engineers; (3) heads of quality control; (4) purchasing agents; and (5) top executives. These were the individuals who assisted in the decision making process of choosing materials. Ideally at least two or three persons were present at each interview at each site. Multiple interviewees increased the variability of responses and also increased the number of respondents for the second questionnaire. The next four sections describe the four areas of the interview.

Material use

The purpose of these interviews was to gain an in-depth look into material use trends and perceptions of different structural material types by the industry. The interviews explored the reasons why a material type was chosen and how these materials might change over the next three to five years. The interviews investigated the industry's views of possible availability and quality problems in the foreseeable future, especially for large dimension, high grade, structural softwood lumber, which is a high value product in higher grades.

Markets and products

During the interview, companies were asked to describe their product and customization options. To grasp changes in the marketplace and company strategy, interviewees were asked how they saw these products and customization options changing over the next three to five years. This information was used to position companies by differences in product lines and market strategies.

Production factors

The interview technique was used to determine the production problems companies are currently having. This might include production factors that limit the use of some products or cause product failures to occur. Companies were asked how quality was ensured and where bottle-necks relating to material use occurred within the production process. Future production needs were ascertained through questions addressing changes in production methods and technologies needed to accommodate the marketplace or to ensure quality. Companies were asked if these changes place new performance or quality requirements on materials or, alternatively, if these changes would reduce these requirements.

Wood material performance requirements

The interviews explored the factors that have caused companies to switch from solid lumber to engineered lumber products by asking: (1) where switching has already occurred; (2) why it occurred; (3) how satisfied companies have been with each switch; and (4) what anticipated other engineered lumbered products have they considered using. The reasons behind the decisions were also requested. Another purpose of the interview was to determine future performance requirements that might result. These interviews found (1) product design changes that were necessary to meet future market demands, (2) how these changes might relate back to material use, and (3) anticipated changes in production systems.

Analysis of results of interviews

Information gathered from the interviews both qualitative and quantitative. Qualitative research was useful in understanding how companies view their industry, learning their terminology and judgments, and capturing the complexities of their individual perceptions and experiences (Patton 1980). The interviews were flexible enough to explore information that appeared pertinent to the study. Questions covered the following topics/subjects:

- Goals and objectives of the company
- Main competitors
- Availability of high grade, large dimension lumber trends
- Discovery of new structural materials
- Evaluation of new structural materials
- Cause of product failures in certain structural materials
- Limitations of design with certain structural materials (i.e. different types of roof framing)
- Problems in the production process relating to material use
- Assurance of quality
- Production process bottle-necks
- Solution of production bottle-necks
- Limitations of choices of structural material types
- Changes in production methods and technologies in the foreseeable future
- Effect of these changes on performance or quality requirements
- Current use of structural engineered products
- Reasons for switching to these products
- Anticipated use of other engineered lumber products
- Designs for the future
- Effect of new designs on structural material use

The information from the qualitative questions was transcribed. Main themes that answer the above questions were tied together into a descriptive statement. This procedure reduced large amounts of text into a readily useable format (Kvale 1996). Quantitative data was collected by asking interviewees to fill out an additional questionnaire designed to measure (1) the individual's importance rating of a structural material in a specific application and (2) their perceived performance rating of different structural materials. These measures were used to design a perceptual map to assist in determining substitution opportunities.

Step 5: second questionnaire

After the group interview, a second questionnaire was administered on site, to the interviewees. This questionnaire explored the important performance requirements of building applications and to determine if building applications have different structural material needs that are critical to the performance of the application. The building applications included in this study were (1) marriage headers, (2) other headers, (3) wall framing, (4) floor framing, and (5) roof framing. The performance of eight types of structural materials was also sought. These materials were: (1) Southern yellow pine, (2) spruce-pine-fir, (3) laminated veneer lumber, (4) structural composite lumber, (5) engineered wooden I-beams, (6) glue laminated beams (glulam), (7) prefabricated trusses, and (8) steel. In order to discover which material types could be substituted for solid lumber in specific application these materials were evaluated by the variables listed below:

- Straightness
- Accuracy and Consistency of Grading
- Hardness (ease of nailing)
- Bending Strength (f)
- Price
- Overall Product Consistency
- Warranty
- Overall Appearance
- Absence of End Splits
- Service
- Accuracy and Consistency of Moisture Content
- Availability
- Stiffness (MOE)
- Accuracy of Dimensions
- Availability of Long Length 16+ ft.
- Overall Product Quality
- Technical Assistance
- Weight
- Fastener Retention

Results were measured using a seven point Likert scale to increase range of responses. Building applications were measured with 1 = not important and 7 = very important. Structural materials were measured with 1 = very poor and 7 = very good. This data was analysis using a factor analysis and perceptual mapping.

Factor analysis

Factor analysis is a common marketing technique that has been found to be an excellent method reducing the number of variables and interpreting dimensions. It is easy to use and has a high predictive validity when compared to other perceptual mapping approaches (Steenkamp, Trip, and Berge 1996). Hansen, Bush, and Fern (1996) used exploratory factor analysis to develop a five dimensional model of total product quality in softwood dimension lumber. This technique identified the important attributes a consumer uses to evaluate a product and then collects data from a sample of consumers concerning their rating of each product on all attributes (Boyd, Walker and Larreche 1995). Factor analysis is based on both perceived differences between objects and differences between peoples' perceptions of objects (Aaker, Kumar, and Day 1998). In a cross-national investigation of softwood sawmill marketing strategies, factor analysis was used to discover five underlying dimensions of market strategy, which could then be compared and contrasted (Niemela and Smith 1996).

The main purpose and function of factor analysis is to reduce the number of variables into a more manageable set using principal component analysis (Aaker, Kumar, Day 1998). This method transforms the original set of variables into new non-related group of variables called factors. Variance is used to measure the amount of information conveyed by each factor. Factor analysis provides three outputs: (1) factor loading, used to interpret the correlation between factors and variables, (2) factor score, used as a variable in subsequent data analysis and (3) the percent-of-variance explained, which determines the number of factors to include and how well the factors represent the original variables (Aaker, Kumar, Day 1998). Factor analysis makes two important assumptions: (1) that factors underlying the variables exist and (2) that variables completely and adequately represent these factors (Aaker, Kumar, and Day 1998). These factors become the dimensions for the perceptual map.

Perceptual mapping

One of the objectives of this study is to identify substitution opportunities for existing structural materials. To help position these materials a modeling technique called perceptual mapping was used. This technique has been used to assist in the development of product positioning strategies and as a tool to generate new product designs, promotional strategy decisions and to predict which products customers will regard as substitutes (Sinclair 1992).

Perceptual mapping has been used in the forest products industry to position wood products in the residential siding market (Stalling 1988). This technique is used to determine consumer's perceptions of products by reducing a large number a variable to a few factors that are easier to interpret. These factors can be used as dimensions to identify the relative positions of products with respect to other types of products (Steenkamp and Trijp 1996). To develop a perceptual map one must: (1) evaluate the important attributes for a product, (2) judge existing products by these attributes, and (3) rate existing products by an "ideal" product (Berkowitz et al. 1994). This map becomes a "picture" of relationships between attributes and competitive position. Perceptual mapping is also useful at identifying strengths of various attributes (Rahill and Rahill 1990). This becomes important when knowledge of product similarities and differences are desired. Map dimensions must be identified and quantified. When many potential product characteristics and attributes exist, factor analysis becomes an important tool to collapse them into single dimensions.

Industry Outlook Model

An industry outlook model was created. This model consisted of two parts. First, a two dimensional "picture" of the industry to position individual companies within the industry based upon their product line (i.e. home size) and market strategy. Secondly, a two-dimensional graph was used to positioned companies based upon the percent of units customized and the of each company's market areas (i.e. number of states).

This model will help to identify current and future market strategies, product lines, customization, and how companies expect their product to change over the next three years. Evaluating how each company expects to change over the next three years helps in understanding the industry's future structural material needs. The assumption this graph makes is that the more customization offered by a company, the more open the company might be to trying new materials in order to offer more design possibilities and/or overcome production constraints. These customization features might have specific performance requirements that might best be met by an engineered lumber product.

Structural Material Substitution Model

Data collected during the interviews on importance ratings of structural applications and perceived performance ratings of structural materials, was used to develop a perceptual map. Because of the large number of structural attributes, factor analysis was used to identify underlying perceptions that could be used to group attributes that were viewed as similar by the industry. These underlying perceptions are called factors. Factors that had the greatest explained variance were used in order to ensure the maximum amount of information would be represented from the original attributes. These factors became the dimensions for the perceptual map and were labeled at that time to ease interpretation. This map was used to help visually interpret possible substitution opportunities by placing each structural material application (i.e. roof framing) on the map and then placing each structural material type (i.e. LVL) on the map using the same dimensions. Structural materials that were equal to or exceeded ideal points/needs of building applications were considered as possible substitutes. If no structural materials met or exceeded the ideal needs of the building applications, a potential product gap/need was indicated.

CHAPTER 4 – RESULTS

Response Rate

Thirty-nine modular housing producers were identified in the Mid-Atlantic region. Twenty-nine companies returned useable questionnaires (74.3 %). Two companies refused to participate in this study. Respondents were called to participate in a follow up interview. Twenty-four companies agreed and nineteen were selected. Three companies were interviewed who did not complete a questionnaire. The response rate for this study is 82.1 % (Table 4.1). The response rate is a combination of the questionnaire response rate plus interviewed companies who did not complete a questionnaire. Companies were considered eligible if the majority of their production was modular construction.

Table 4.1. Response rate report for the Mid-Atlantic region's modular housing industry, 1997

Initial Population	39
Eligible Questionnaire Sample	39
Non-Response	10
Usable Responses	29
Questionnaire Response Rate	74.3 %
Total Interviews	19
Interviewed Companies Without Questionnaires	3
Total Responding Companies	*32*
Total Response Rate	82.1 %

Total production capacity for the thirty-nine companies from the Mid-Atlantic modular industry was approximately twenty-five thousand units in 1997. The twenty-nine modular companies responding to the questionnaire account for 71.0 % of the Mid-Atlantic modular industry production in 1997. Combined responses from questionnaires and interviews represent 86.0 % of the Mid-Atlantic region modular production, non-respondents represent 14.0 % of the region.

Much of this study is compared to a 1992 study of the structural wood product usage and requirements of the factory-build housing industry in the Mid-Atlantic and Appalachian regions of the United States (Fuchs 1993). This study included modular, panelized, precut and stresskin factory-built housing producers. This study's response rates are found in Table 4.2.

Table 4.2. Distribution of Fuch's 1992 factory built housing study, by builder type classifications

Builder Type	Number of Plants	Percent of Total (%)
Modular	46	61.3
Panelized	26	34.7
Precut	2	2.7
Stresskin*	1	1.3
Total	75	100.0

* Known exclusive stresskin manufacturers were purposely omitted from the sampling frame

Responses by State

Summarized below (Table 4.3) is the geographic dispersion of companies, their response rate and location of follow-up interviews. There were no active modular manufacturers in New Jersey, Tennessee or Kentucky. Over half the companies were located in Pennsylvania.

Table 4.3. Number of responses and initial population by state for the Mid-Atlantic region's modular housing industry, 1997

State	*Initial Population*	*Questionnaire Response*	*Questionnaire Response rate by state (%)*	*Interviews per State*
New York	5	1	20	0
New Jersey	0	0	0	0
Pennsylvania	25	22	88	12
Delaware	1	1	100	1
Maryland	0	1	0	1
Virginia	5	5	100	5
West Virginia	0	1	0	0
Ohio	2	2	100	0
Tennessee	0	0	0	0
North Carolina	2	2	100	0
Kentucky	0	0	0	0
Total	39	29	74.3	19

Out of the thirty-nine companies within the population all but seven of the companies participated in the study in some manner either through a mail questionnaire, personal interview or both. Because of the high response rate reported, figures can be considered to accurately represent the Mid-Atlantic modular housing industry. However, to remove any potential for non-response bias, companies that did not return a questionnaire were compared to responding companies with regard to production based upon the number of units completed in 1997. Five of the non-responding companies provided information by telephone. Automated Builder (1998) magazine was used to gather data for the remaining companies. Sources of non-respondent data for the non-response bias testing procedures are presented in Table 4.4.

Table 4.4. Sources of information used for conducting non-response bias testing procedures for responding modular manufactures in the Mid-Atlantic region vs. non-responding manufacturers, 1997

Total Non-Respondent Sample Size	7
Provided information through personal interview	3
Provided information by telephone	5
Secondary data available[1]	2

[1] Automated Builder 1998

Non-Response Error

Non-response error in evaluating questionnaires occurs as a result of failure to obtain information from some elements of the population that were selected and designated for the sample (Churchill 1996). Non-response must be accounted for since it raises the possibility that those who did not respond are in some way different from those who did. To test for non-response bias, the number of units produced per year by a company was compared using a non-parametric statistical test called the Mann-Whitney U. The number of units produced per year by a company was selected because this measure was easily obtainable and because it is a representative measure of the relative size of a company. Therefore, this procedure can be used in an effort to detect potential bias that may exist based on size. The advantage to this test is that it does not rely on any restrictive assumptions concerning the shape of the sampled population, but that the samples are drawn at random from identical populations (Howell 1997). The Mann-Whitney U test was used to test the following hypothesis:

Ho: There is no difference between the central tendencies of units produced by responding companies versus non-responding companies.

Ha: There is a difference between the central tendencies of units produced by responding companies versus non-responding companies.

Table 4.5 presents the results of the Mann-Whitney U test. This test showed that the twenty-nine respondents had a median of 466.0 units and the ten non-respondents had a median of 590.0 units. The point estimate for respondents minus non-respondents was –134.0. The confidence interval for respondents minus non-respondents (-449.9, 161.9) was 95.2 %. The critical value (W) for this test is 553.0. The probability of respondents equaling non-respondents versus respondents not equaling non-respondents is significant at 0.3940. This test was significant at 0.3939. Therefore, at an alpha level of 0.05 the null hypothesis could not be rejected, thus there is no evidence of any difference between the central tendencies of units produced by responding companies versus non-responding companies.

Table 4.5. Summary of Mann-Whitney U test for comparison of the central tendencies between the number of units produced by respondents versus non-respondents

Single-Family Units Produced In 1997		
	Number	Median
Respondents	29	466.0
Non-Respondents	10	590.0

Point estimate for respondents minus non-respondents	-134.0
Confidence interval for respondents minus non-respondents (-449.9, 161.9)	95.2 %
W	553.0
Test of respondents equals non-respondents versus respondents not equal to non-respondents is significant at	0.3940
Test is significant at	0.3939
Cannot reject alpha at	0.05

Item Non-Response

Item non-response for individual questions within the questionnaire can cause significant problems in questionnaire results. However, questionnaires for this study were very complete with little missing information. When the non-response item was concerning financial information and sales volume, the assumption was made that companies did not wish to share this information and the item was left blank and reported as a separate category. For all other missing items an attempt was made to obtain the information at interviews or by telephone, if the information could still not be obtained the item’s mean, median or mode was substituted. Substitution of values makes the maximum use of data, since only reasonably good values were used (Churchill 1996). However, this technique does increase the potential for bias.

4-1 – DEMOGRAPHICS AND PRODUCT POSITIONING

Demographics on respondents were compiled in four general marketing areas: (1) distribution channel, (2) competition, (3) company sales volume, and (4) market area. A description of respondents' product mix consists of the following: (1) building type, (2) square footage, and (3) price. This section also includes information on interviewed companies' production facilities and how changes in product design affect production.

Mid-Atlantic Marketplace

Channels of distribution

This study found that the majority of producers sold their homes through a builder/dealer network. Of the nineteen companies interviewed, thirteen sold their product this way. Five companies sold homes through builders, but also sold directly to individuals within a limited geographic range. One company only sold directly to the individual. Companies that had more contact with the end user were more likely to lay their own foundations and provide their own set crews. Having their own crews gave the company more control over their product. None of the companies planned on changing their distribution channel over the next three years.

Competition

With the current strong housing market and most plants running at maximum production to fill orders, most companies did not feel that they had competition problems. Only one company planned to close a plant, due to a decrease in sales. Approximately half of the companies interviewed, felt that site-builders were their main competitor. The major competitive disadvantage they felt they must overcome was a negative image problem over site builders, where the potential customer failed to understand the difference between modular homes and manufactured homes. Only those companies, which produced a significant number of small, low customized homes, felt that manufactured homes were a competitive threat. Because of code differences, modular producers cannot compete with manufactured housing based on price alone. Some companies have changed their marketing approach to educate customers about quality related differences between a modular house and a manufactured house. Other companies have chosen to move away from producing low-end homes to larger more customized homes with which manufactured homes cannot compete. As companies move away from low-end homes they feel competition will change to mainly site-built homes and other modular manufactures.

Sales volume

Sales volumes of respondents are presented in Table 4-1.1. Companies within the study had sales volumes ranging from $1,500,000 to $64,000,000 in 1997. Individual company projections of future sales volume ranged from +5 % to +100 % over the next three years.

Table 4-1.1. Sales volume for Mid-Atlantic modular home producers in 1997 and expected change in 2000 (in thousands of dollars), n = 24

	Mean	Standard Deviation	Median	Range
Current sales volume	22,392	15,294	20,000	1,500 - 64,000
Future sales volume*	+34.8 %	+32.3 %	+22.5 %	5.0 % - 100.0 %

* Projected year 2000 sales

Market area

Companies within the study area distribute their product throughout the Mid-Atlantic, South, Northeast and Midwest. The typical market area for an individual firm was ten to eleven states. Market areas for individual companies ranged from 4 to 26 states. Six of 28 companies reported plans to expand into the Southern and Mid-western regions, increasing the average market area to 12.2 states. Reasons given for expansion were to increase sales by taking advantage of high housing starts in these areas and little to no existing modular competition in the South and Midwest regions.

Product Mix

Building type

Modular housing producers build single-family homes, multi-family homes and light commercial structures. Most modular producers focused production on single-family homes. Two companies, however, were in the process by changing over from a producing mostly single-family homes to 100% light commercial structures. Table 4-1.2 shows how the number of units per building type has changed since 1992 and is expected to change over the next three years. In

1992, thirty modular companies produced 8,260 units. In 1997, 29 companies produced 17,936 units, an increase of over 200 %. By 2000, production is expected to increase to 21,102 units.

Table 4-1.2. Total number of modular units produced in 1992, 1997 and estimated change in 2000

BUILDING TYPE	1992[1] (n = 30)	1997 (n = 29)	2000* (n = 29)
	No. of Units	No. of Units	No. of Units
Single-Family	NA	15046	17754
Multi-Family	NA	1503	1713
Commercial	NA	1378	1626
Other	NA	9	9
Total	8260	17936	21102

[1] Fuchs (1992)
* Estimated year 2000 figures

Industry outlook model

The industry outlook model was composed of two parts. (1) A two dimensional "picture" of the industry was used to position individual companies within the industry based upon their product line (i.e. home size) and market strategy. (2) A two dimensional graph that positioned companies based upon the percent of units customized and the size of their market area (i.e. number of states).

Company positioning

Companies that were interviewed tended to have one of four types of product strategies (Figure 4-1.1). (A) Three companies (15.8 %) produced only small homes for the first time buyer or second time buyer who desired a smaller home. Modular companies producing a majority of small homes were most impacted from competition from manufactured housing (i.e. mobile or HUD code homes). In order to compete, these companies planed on either increasing the size and amount of customization for their products or finding a market niche by building homes for the elderly, including units for assisted living complexes. (B) Eleven companies (57.9 %) marketed to a wide range of individuals and builders. Three of these companies (27.3 %) were planning on up-scaling their homes due to competition from manufactured housing and to meet market demands. Many of these companies started out as manufactured home companies. These companies have integrated their product by moving into a mix of manufactured and modular homes or by changing over to 100% modular. Companies currently producing both housing types were planning to increase the number of modulars in their product mix. (C) One company that has always been modular has taken the opposite approach and has started a new facility producing HUD code homes in order to expand their product mix and target every buyer except for extremely customized homes. (D) Five companies (26.3 %) produced mainly mid-end to high-end modular homes, which are highly customized. They stated that their only competitors were site-builders. They had no plans on changing their product mix.

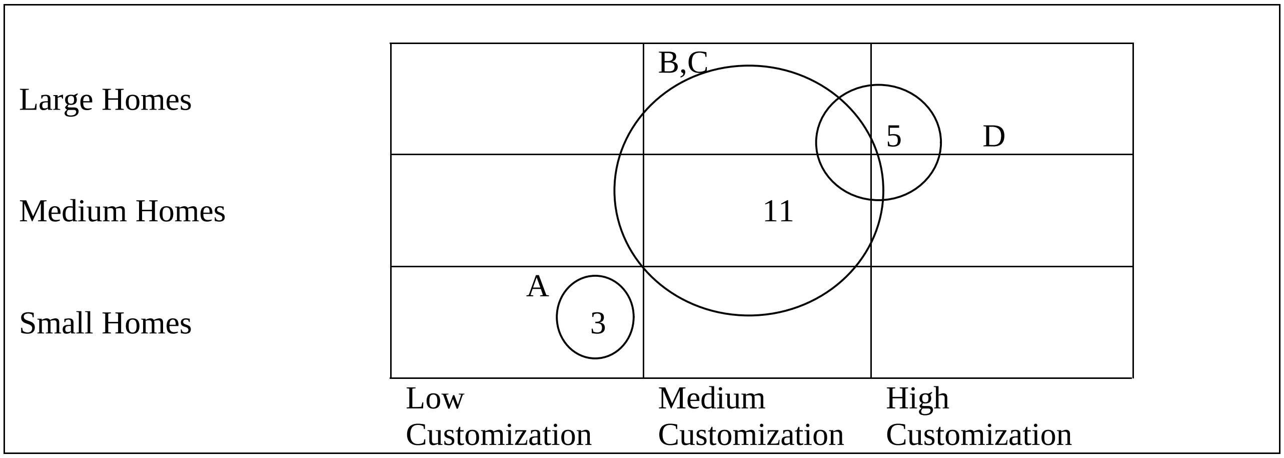


Figure 4-1.1. Company positioning of modular manufacturers, based on product strategies in 1997

Over the next three years modular companies expected that while the basic designs of homes would not change, the materials used to construct these homes would change. Companies expected to use more engineered lumber products (63.2 %) and a few companies expected to use more steel (15.8 %). The majority of companies (89.5 %) expected the frequency of customization to increase. These companies were found in all product groups. Some of these customized features include: turrets, cathedral ceilings, vaulted ceilings, tray ceilings, octagon rooms, pentagon rooms, larger room openings, different shapes and placements of bump-outs, wider ranges of roof pitches, gables, garages, split levels, curved walls, archways, decorative columns, handicapped and elderly friendly baths and kitchens. Two companies (10.5 %) plan on taking more upon themselves to decrease site work for their builders (i.e. finished dormers, porches, garages, and decking kits). These companies overlap groups B and D. Two companies from group D are taking the opposite approach to reduce their production costs and increase their customization options (especially roof pitches), by relying more on builders to finish the house on site.

Customization

Customization was defined on the questionnaire by the percentage of single-family units produced by the company that were custom-built as opposed to built from standard plans with only minor alterations. The mean customization level for companies was 71.6 %, with a standard deviation of 30.7 %. The average median was 90.0 %. Customization levels ranged from 0 % to 100 %. Companies were asked how they felt the level of customization in their product line would change over the next three years. Sixty-nine percent of respondents felt that customization would increase, 27.6 % of respondents felt that there would be no change and 3.4 % of respondents felt that the amount of customization would decrease.

Companies were positioned based on amount of customization and the size of their market area. Size of the market area was based upon the number of states in which companies distributed their product. Figure 4-1.2, shows the current position of companies based on their percentage of customization versus the size of their total market area. Although companies that sell within a small market area can be successful by offering a wide range of customizations, it is apparent that companies that market their product in a broader geographic region offer more customization options. This figure also shows the expected movement of these companies over the next three years and is represented by arrows. Most companies planned to increase the amount of customization offered. Six companies planned to increase both their market area and amount of customization. Expanding companies planned to market in the South and Midwest. Only one company was planning on decreasing the amount of customization, due to production costs. They hoped to lower production cost by increasing standardization.

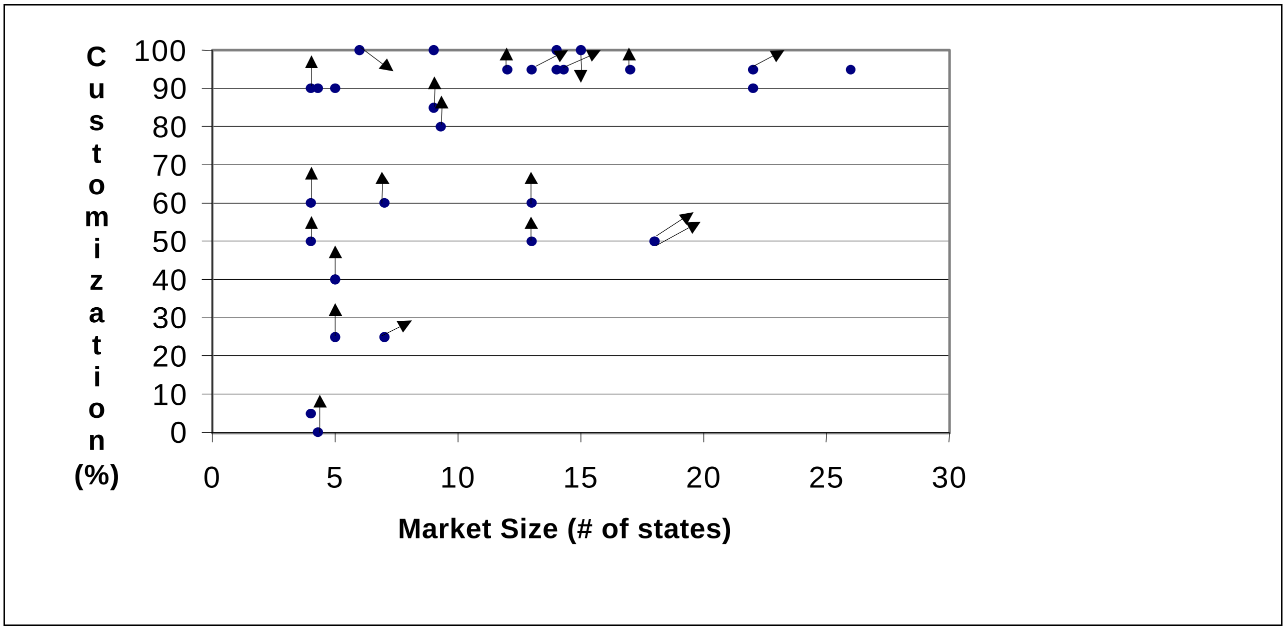


Figure 4-1.2. Industry outlook model, 1997 and projected trends in 2000 for modular manufacturers (The percent of custom built units compared to market area of each company)

Square footage

Square footage of single-family homes was broken down into three categories: (1) a company's largest single-family home, (2) a company's smallest single-family home, and (3) a company's best selling single-family home. Table 4-1.3 summarizes the descriptive statistics of square footage for single-family homes. The largest single-family home companies produced averaged 4338.0 sq. ft. These homes also had the greatest variation in size, ranging from 2200 sq. ft. to 10,000 sq. ft. and the largest standard deviation of 2072 sq. ft. In three years, 50.0 % of the respondents felt that the average square footage of the largest single-family home built by their company would increase; 46.7 % felt that there would be no change. The average size of the smallest home built by respondents was 856.8 sq. ft. Small homes had the smallest variability with a standard deviation of 163 sq. ft. with homes only ranging from 460 sq. ft. to 1200 sq. ft. Sixty-three percent of respondents felt that the square footage of these homes would not increase over the next three years, while 30.0 % felt it would increase. The average size of best selling homes reported by respondents was 1659.0 sq. ft. These homes ranged from 1200 sq. ft. to 3120 sq. ft. and had a standard deviation of 431 sq. ft. In three years, 53.3 % of respondents felt that the average size of a company's best selling home would increase, while 43.3 % of respondents felt that there would be no change.

Table 4-1.3. Square footage of single-family homes built by modular manufacturers, 1997

Home Size	n	Mean	Standard Deviation	Range	Median
Largest	27	4338	2072	2200 - 10000	3600
Smallest	29	857	163	460 - 1200	850
Best Selling	25	1659	431	1200 - 3120	1500

Price

The advertised base price of the largest single-family homes manufactured by individual companies in 1997 was $156,507; the average price was $155,644. Ninety percent of respondents expected the average price to rise in the next three years, while 10% expected no change in price. The base and average prices of large homes have a high standard deviation and a wide range due to customization options. This causes a high variability in price. The base price of the smallest homes manufactured by companies averaged $34,461, while the overall average price was $40,371. In three years, 86.7 % of respondents expected the average price of these homes to increase. All other respondents felt that price would not change. The most popular selling homes produced by respondents had an average base price of $50,076 and an average overall price of $53,579. Eighty-seven percent of respondents felt the average price would increase on these homes and thirteen percent felt that there would be no change. These values are listed in Table 4-1.4.

Table 4-1.4. Base prices and average prices of single-family homes built by modular manufacturers, 1997 (in thousand of dollars)

Home Size	Base Price					Average Price				
	n	Mean	SD	Range	Median	n	Mean	SD	Range	Median
Largest	19	157.5	85.7	70 - 340	125.0	19	155.6	85.7	58 - 325	115.0
Smallest	21	34.5	17.0	20 - 100	30.0	21	40.4	17.0	20 - 100	40.0
Best Selling	19	50.1	16.9	32.5 - 84	43.0	19	53.6	16.9	32.5 - 85	46.0

Production

Production productivity

The average production rate across companies was 21.4 units per week. Two companies however were excluded due to their small size, producing less than 5 units per week. One of the two companies excluded started operations in 1997 and the other company was going through a product re-organization. Over the next three years all but one company was planning on increasing their production. Four companies were considering building new plants to expand their market area and production output capability. One company had just built a plant within their current market area in order to increase their production capacity.

All Thirty-nine companies within the population were contacted about their 1997 production. Thirty-seven companies responded and two were estimated from secondary sources. The average production rate for the Mid-Atlantic modular housing industry was 638.7 units per year, with a standard deviation of 509.3. The median production rate was 500.0. Production rate ranged from a minimum of 40.0 units per year to 2250.0 units per year.

Bottlenecks

The most common bottlenecks in the production process, were caused by complicated assemblies such as: specialized roof designs, laying hardwood floors or tiles, and installing special roofing and siding materials. The second most common bottleneck that slowed production was drywall taping drying time. Other bottlenecks in the production line were caused by materials not arriving on time and poor employee attendance on a particular day.

Most bottlenecks were controlled through pre-planning. This was done by distributing people and resources so that units move smoothly through the line. Units were also staggered so that complicated, more time consuming procedures were spread out. Materials were purchased so that they arrived prior to assembly. Many companies also cross-train their employees so that employees can work in other areas as needed.

Changes to production line

As the design of a home becomes more complicated it negatively effects the efficiency of the production line. To increase production rates, companies scheduled units so that time consuming tasks were evenly distributed between less complicated units. Companies also worked at balancing people and resources to increase production. Some companies had separate areas designated for building add-ons, such as dormers, separate from the main production line.

Designs can be affected by width restrictions during shipping and dimensional restrictions on the production line. Shipping regulations previously limited unit width to 14 feet.

New regulations now allow companies to ship units up to 16 feet wide. This has caused companies to revamp their production lines to accommodate wider units. Some companies who had limited space were unable to redesign their product line without a large capital investment and instead elected to limit their designs to the 14 foot limit.

Quality control

As units move down the production line, quality is ensured by a line item traveler that is checked by the company, an independent third party agency, and a state inspector. Eleven out of the nineteen companies had a separate quality control department. All modular companies used a third party inspector, in order to reduce risk and liability to the company. Third party inspectors also help to ensure quality and to guarantee code compliance.

4-2–MATERIAL USE TRENDS AND FUTURE PREDICTIONS: 1992-2000

Dimensional Lumber

It is important to track the changes in building material usage because it helps to provide an understanding and comparison for potential substitution of other types of structural building materials and the development of new materials. In order to track material usage, current dimensional lumber use was compared with Fuchs' 1992 data, since it was the only known study which measured the modular housing industry's, structural material usage. Fuchs (1993) reports that in 1992, the average responding manufacturer purchased approximately 3.3 million board feet of dimensional lumber per year. By 1997, this figure had increased to 3.8 million board feet. However it is important to note that only 56.5 % of Fuchs' data included modular construction, and some differences maybe due to differences in populations. However, this increase in lumber purchased is consistent with the increase in production found in Table 4-1.2.

In 1992, 59 % of dimension lumber purchased was Spruce-Pine-Fir and 41 % was Southern yellow pine (Fuch's 1993). By 1997, these percentages had changed to 79 % spruce-pine-fir and 21 % Southern pine. This shift indicates a preference to use spruce-pine-fir over Southern yellow pine. During follow-up interviews, modular companies indicated that they have started using more spruce-pine-fir because it was easier to work with, straighter, had less cull and was sufficient to meet most strength requirements. The change in average usage of dimensional lumber used per unit produced is presented in Table 4-2.1. Units include single-family, multi-family, commercial and other. While only 56.5 % of the 1992 data included modular producers, it is still clear that the proportion of Southern yellow pine used per unit has decreased while the amount of spruce-pine-fir has increased.

Table 4-2.1. Average quantity of dimensional lumber used per unit by responding manufacturers in the US in 1992 and 1997 (in board feet)

	1992[1] (n = 44)				1997[2] (n = 29)			
	Mean	SD	Median	Range	Mean	SD	Median	Range
Spruce-Pine-Fir	5763	5067	4667	68 - 32258	4868	4106	4042	81- 15290
Southern Pine	3947	6629	2352	0 - 34247	1293	2148	323	0 - 8280

[1] Fuchs (1993), study included 30 modular, 16 panelized and 2 pre-cut manufacturers
[2] 1997 study included 29 modular manufacturers

Size

Companies were asked the percentage of softwood lumber by quantity that was purchased in 1997 for each of the following size classes: 2x4, 2x6, 2x8, 2x10, 2x12 and other sizes. Companies were also asked to predict their future size needs over the next three years. The average percentages of their responses are found in Table 4-2.2. Respondents reported that the most commonly purchased lumber size was 2x4s (34.2 %). Respondents also purchased large quantities of 2x6 (26.0 %) and 2x10 (23.7 %). All other sizes were used in small quantities. Over the next three years, respondents did not predict any significant changes in any size class. The most common other type of dimension lumber size reported by respondents was 2x3s, which was typically used by respondents as framing material in non-load-bearing walls.

Table 4-2.2. Average percent by volume of dimensional lumber by size for responding modular manufacturers in 1997 and estimated 2000 figures

	1997 (n = 29)				2000* (n = 29)			
Size	Mean	SD	Median	Range	Mean	SD	Median	Range
2x4	34.2	15.9	35.0	12-80	34.2	15.1	35.0	12-75
2x6	26.0	11.1	26.0	5-50	26.5	10.7	25.0	5-50
2x8	10.2	6.8	10.0	0-30	10.3	6.7	10.0	0-30
2x10	23.7	10.5	21.0	5-50	22.8	10.8	21.0	5-50
2x12	4.7	4.7	5.0	0-20	4.7	4.7	5.0	0-20
Other	1.2	2.9	0.0	0-10	1.5	2.3	0.0	0-10

* Estimated year 2000 size distribution

The average size of dimensional lumber used by responding manufacturers was tracked from 1992 through 1997. Figure 4-2.1, indicates that the major size classes purchased by respondents were 2x4s, 2x6s, and 2x10s. The distribution of lumber sizes indicates the amount of 2x4 being used decreased 10.8 percentage points between 1992 and 1997, but the amount of 2x6s increased by 9.5 percentage points for the same time period. All other sizes had only minor changes. The most significant increases were found in 2x6s in 1997 and 2000. The most significant decreases were found for 2x4s from 1992.

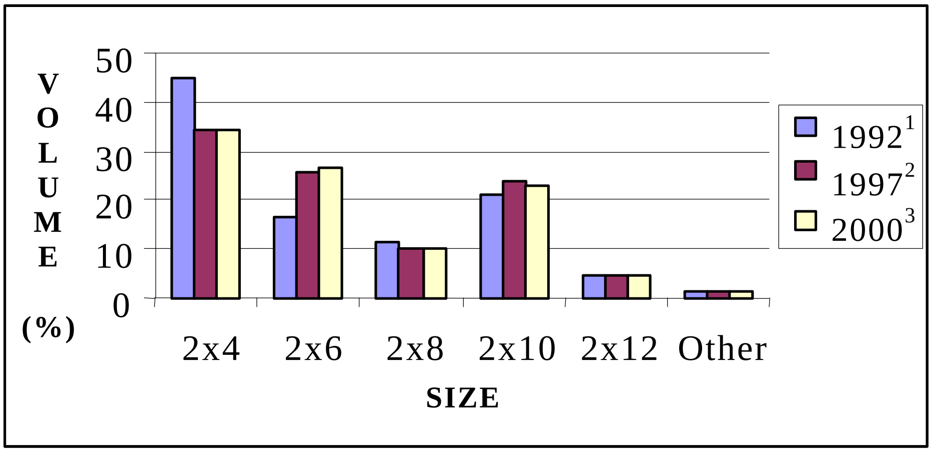


Figure 4-2.1. The percent of dimensional lumber by quantity that was purchased in 1992, 1997 and forecasted for 2000, for each size class

[1] Fuchs (1993), study included 30 modular, 16 panelized and 2 pre-cut manufacturers
[2] 1997 study included 29 modular manufacturers
[3] 2000 estimated percent by 29 modular manufacturers

Grade

The most common grade of lumber purchased by interviewed companies was No. 2 and better. Thirteen companies (68.4 %) reported that the majority of lumber purchased was No. 2 & better. Northern companies tended to use primarily spruce-pine-fir and Southern companies used more Southern yellow pine. Two companies (10.5 %) indicated that they purchased mainly Western spruce-pine-fir in lower grades, because in their opinion Western spruce-pine-fir was higher in quality (i.e. straighter, less cull) than Northern spruce-pine-fir. Only three companies (15.9 %) purchased No. 3 and stud grade lumber. Eight companies (42.1 %) were using some machine stress rated lumber (MSR) as part of some trusses. The major reasons given for not using more MSR lumber were a lack of knowledge and poor availability from suppliers to deliver small orders.

Availability and Quality

During the nineteen follow-up interviews, companies were asked their opinion concerning the availability and quality of softwood lumber. Fifteen companies (78.9 %) felt the availability was the same as five years ago. Two of these companies felt politics was the major factor affecting availability. Three companies (15.8 %) felt that availability was lower than five years ago. One company representative was unsure. Fifteen companies (78.9 %), felt quality of softwood lumber had decreased over the last five years. One company representative felt quality had improved. However, it is also noted that his company now buys a higher grade of lumber than two years ago. One company felt it was the same and one company was unsure. The reasons given for lower quality were (1) that less old growth trees are being harvested. (2) The amount of cull has increased as lumber comes from smaller and smaller trees. (3) Boards from fast grown trees are not as strong or as straight. (4) There is an increased demand for lumber and (5) grading quality has decreased.

Two companies also stated that building codes were revised in 1995, lowering the load a board is allowed to carry. This has caused companies to increase the size and/or grade of the lumber they were using. In three years, fourteen companies (73.7 %) felt that the quality of softwood lumber would continue to decrease and two companies thought it would remain the same. These companies planned on compensating for losses in quality by increasing the use and variety of engineered lumber, using alternative materials, such as steel, buying higher grades of lumber, and using less Southern yellow pine and more spruce-pine-fir. Two companies did not know how they would compensate for decreases in quality.

Material Quality Control

As materials are delivered, over half the companies interviewed checked moisture content. Ten companies checked to ensure the order was correct. Many companies also inspected for damage and overall quality. Two companies were about to change their check-in procedures as part of becoming ISO9000 certified. ISO9000 certification is desired by these companies to improve internal performance (i.e. through more complete and regulated quality inspections) and as a marketing tool.

Materials Used for Building Components

To understand the potential for substitute building materials and new product development, it is important to know what materials are currently being used and in what application. This study focused on the eight structural building materials and the five building applications, listed below:

Structural Material
- Spruce-Pine-Fir (SPF)
- Southern Yellow Pine (SYP)
- Engineered Wooden I-beam (WIB)
- Laminated Veneer Lumber (LVL)
- Glue Laminated Beams (Glulam)
- Structural Composite Lumber (SCL)
- Prefabricated Trusses and Studs (Prefab)
- Steel

Building Application
- Marriage Headers
- Other Headers
- Wall Framing
- Floor Framing
- Roof Framing

Table 4-2.3 is a layout of the average distribution of structural materials purchased by companies in dollars for 1997 and the projected changes over the next three years. Dimensional lumber made up 76.8 % of the purchased material in 1997. Prefabricated trusses also make up a large portion (13.8 %) of a company's structural materials needs. Over the next three years, respondents generally expect to purchase less dimensional lumber (-4.6 %) than in 1997 and more engineered lumber and steel products. All companies indicated an expected increase in engineered product use over the next three years.

Table 4-2.3. Mean percent of use for structural materials by dollar value purchased in 1997 and estimated purchase volumes by modular manufacturers, 2000

Structural Material	**1997** (n = 29)				**2000*** (n = 29)			
	% of Use	SD	Median	Range	% of Use	SD	Median	Range
SPF	59.6	18.4	60.0	20-98	55.6	19.0	56.0	20-93
SYP	17.2	18.9	10.0	0-70	16.6	18.5	10.0	0-70
WIB	2.0	4.6	0.0	0-17	3.6	6.6	0.0	0-20
LVL	6.2	5.5	5.0	0-20	7.1	6.7	5.0	0-30
Glulam	0.3	1.9	0.0	0-10	0.7	2.7	0.0	0-10
SCL	0.6	2.8	0.0	0-10	0.8	2.7	0.0	0-10
Prefab	13.8	12.2	15.0	0-46	14.4	12.6	15.0	0-46
Steel	0.2	1.0	0.0	0-5	1.2	4.7	0.0	0-5

* Estimated dollar value of purchased materials in the year 2000

Table 4-2.4 compares the mean percent of material use by structural material type to the weighted mean percent of material use for 1997 and 2000. These means were compared to see if larger companies had a greater affected on the reported material use data than other modular producers. The un-weighted means found in Table 20 indicate that in 1997, larger companies used a higher percent of softwood lumber than other companies, resulting in higher reported means. When each company was given equal representation based the relative size of the company (i.e. the number of units they produce per year), the percentage of softwood lumber use decreased and the percent of LVL and prefabricated trusses increased. In 2000, larger companies will use a higher percentage of softwood lumber and steel and less prefabricated trusses than other modular companies.

Table 4-2.4. Weighted mean percent of use vs. mean percent of use for structural materials by dollar value purchased in 1997 and estimated purchase volumes by modular manufacturers, 2000

Structural Material	**1997** (n = 29)		**2000*** (n = 29)	
	Mean	Weighted Mean	Mean	Weighted Mean
SPF	59.6	56.5	55.6	54.3
SYP	17.2	15.7	16.6	15.2
WIB	2.0	1.6	3.6	2.3
LVL	6.2	6.7	7.1	7.0
Glulam	0.3	0.3	0.7	0.4
SCL	0.6	1.2	0.8	1.1
Prefab	13.8	17.9	14.4	19.5
Steel	0.2	0.1	1.2	0.2

* Estimated dollar value of purchased materials in the year 2000

Tables 4-2.5 through 4-2.7 show the distribution of structural materials by building applications as a percent of total use. Table 4-2.5 describes material used in marriage headers and other types of headers. Half of all marriage headers were made out of spruce-pine-fir, with Southern yellow pine (24.6 %) and laminated veneer (23.4%) making up the other half. Other types of headers were usually made out of spruce-pine-fir (59.1 %), followed by Southern yellow pine (27.7 %) and laminated veneer lumber (9.4 %).

Table 4-2.5. Mean percent of total structural building materials used for marriage headers and other types of headers by respondents, 1997

Structural Material	**Marriage Header** (n = 29)				**Other Header** (n = 29)			
	Mean %	SD	Median	Range	Mean %	SD	Median	Range
SPF	48.5	36.2	50.0	0-100	59.1	40.9	80.0	0-100
SYP	24.6	32.7	5.0	0-100	27.7	38.5	2.0	0-100
WIB	0.0	0.0	0.0	0	0.0	0.0	0.0	0
LVL	23.4	24.2	10.0	0-95	9.4	14.4	0.0	0-50
Glulam	0.0	0.0	0.0	0	0.0	0.0	0.0	0
SCL	0.2	0.9	0.0	0-5	0.3	1.9	0.0	0-10
Prefab	3.1	16.7	0.0	0-90	3.4	18.6	0.0	0-100
Steel	0.2	0.9	0.0	0-5	0.1	0.02	0.0	0-1
Other	0.0	0.0	0.0	0	0.0	0.0	0.0	0

Table 4-2.6 describes the distribution of structural materials used for wall framing and floor framing as indicated by respondents. Almost all wall framing was made out of spruce-pine-fir (95.5 %), although many companies were experimenting or starting to use prefabricated studs. Currently prefabricated studs make up 2.7 % of total use. Seventy-five percent of all floor framing material was made from dimensional lumber, 52.3 % of that being spruce-pine-fir. The next most common framing material used was a prefabricated truss (11.6 %), followed by engineered wooden I-beams (8.5 %) and laminated veneer lumber (4.0 %). Some steel (0.7 %) was also used for floor framing.

Table 4-2.6. Mean percent of total structural building materials used for wall framing and floor framing used by respondents, 1997

Structural Material	**Wall Framing** (n = 29)				**Floor Framing** (n = 29)			
	Mean %	SD	Median	Range	Mean %	SD	Median	Range
SPF	95.5	15.0	100.0	0-80	52.3	37.6	60.0	0-100
SYP	1.0	3.1	0.0	0-10	22.7	34.4	3.0	0-100
WIB	0.0	0.0	0.0	0	8.5	24.6	0.0	0-98
LVL	0.7	2.8	0.0	0-10	4.0	6.6	0.0	0-20
Glulam	0.0	0.0	0.0	0	0.0	0.0	0.0	0
SCL	0.0	0.0	0.0	0	0.0	0.0	0.0	0
Prefab.	2.7	14.9	0.0	0-80	11.6	27.7	0.0	0-90
Steel	0.0	0.0	0.0	0	0.7	3.9	0.0	0-15
Other	0.0	0.0	0.0	0	0.0	0.0	0.0	0

Table 4-2.7 gives the distribution of structural materials for roof framing. The majority of roof framing was made from prefabricated trusses (45.4 %), followed by spruce-pine-fir (30.9 %) and Southern yellow pine (20.0 %). However the majority of this lumber is converted into trusses on site. In 1997, only one company was building with rafters and they were converting to trusses by 1998. The nine companies interviewed, who used prefabricated trusses, in roof systems, stated that they were mainly used for standard roof designs. Many companies prefer to build their own trusses to reduce inventory costs, increase cost effectiveness and quality assurance. Of those companies building their own trusses, only one company plans on switching to prefabricated ones.

Table 4-2.7. Mean percent of total structural building materials used for roof framing by respondents in 1997 (n = 29)

Structural Material	Mean %	Standard Deviation	Median	Range
SPF	30.9	38.2	10.0	0-100
SYP	20.0	34.7	0.0	0-100
WIB	0.0	0.0	0.0	0
LVL	1.8	3.6	0.0	0-10
Glulam	0.0	0.0	0.0	0
SCL	0.0	0.2	0.0	0-1
Prefab.	45.4	44.5	50.0	0-100
Steel	0.0	0.0	0.0	0
Other	1.9	0.9	0.0	0-5

Table 4-2.8 represents how respondents felt structural materials would change over the next three years by building application (i.e. marriage headers, other headers, wall framing, floor framing and roof framing). Approximately one third of responding companies expected the amount of spruce-pine-fir and Southern yellow pine used in all applications to decrease by the year 2000.

Of the material used for marriage headers, 34.5 % of respondents felt that the use of spruce-pine-fir would decrease and 24.1 % of respondents felt that the amount of Southern yellow pine used would decrease over the next three years. Forty-one percent of respondents felt that the use of laminated veneer lumber would increase. Approximately seven percent of respondents felt the amount of wooden I-beams, glulam beams and structural composite lumber used to increase and 3.4 % of respondents felt that the use of prefabricated trusses would increase.

For other types of headers, three companies (10.3 %) planned on increasing the amount of spruce-pine-fir, possibly substituting for decreased use of Southern yellow pine. Thirty-one percent of respondents planned on using more laminated veneer lumber, 6.9 % planned to use more pre-fabricated trusses, 6.9 % plan to use more wooden I-beams and 3.4 % planned on using more structural composite lumber in other types of headers. These increases in the use of engineered lumber occur as over 20 % of respondents expect dimensional lumber use to decrease.

Thirty-four and half percent of all respondents and 10.3 % of respondents felt that the amount of Southern pine and spruce-pine-fir respectively, would decrease over the next three years for wall framing. Almost fourteen percent of respondents felt that the amount of prefabricated studs used in wall framing would increase. Seven percent of respondents felt the amount of wooden I-beams and steel would increase and 3.4 % of respondents felt that the use of laminated veneer lumber, glulam, and structural composite lumber would increase.

Thirty-eight percent of respondents felt that the use of spruce-pine-fir would decrease over the next three years and 20.7 % of respondents also felt the amount of Southern yellow pine would decrease. Twenty-four percent of respondents felt that the amount of wooden I-beams used in floor framing would increase, 17.2 % of respondents felt the amount of prefabricated trusses would increase, and 13.8 % of respondents planned on using more laminated veneer lumber. Only 3.4 % of respondents felt that the use of glulam, structural composite lumber and steel would increase.

Seventeen percent of respondents felt that the amount of spruce-pine-fir used in roof framing would decrease of the next three years. Ten percent of respondents also felt that the amount of Southern pine would decrease. Seventeen percent of respondents felt that the amount of prefabricated trusses would increase over the next three years. Almost fourteen percent of respondents felt that the use of laminated veneer lumber would increase.

Table 4-2.8 Expected percent change for structural building material used by respondents per building application in 2000 (n = 29)

STRUCTURAL BUILDING MATERIAL		Marriage Header		Other Header		Wall Framing		Floor Framing		Roof Framing	
		%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.
Spruce Pine Fir	Decrease	34.5	10	24.1	7	10.3	3	37.9	11	17.2	5
	No Change	62.1	18	65.5	19	86.2	25	55.2	16	79.3	23
	Increase	3.4	1	10.3	3	3.4	1	6.9	2	3.4	1
South. Yellow Pine	Decrease	24.1	7	20.7	6	34.5	10	20.7	6	10.3	3
	No Change	72.4	21	75.9	22	65.5	19	75.9	22	86.2	25
	Increase	3.4	1	3.4	1	0	0	3.4	1	3.4	1
Wood. I-Beam	Decrease	0	0	0	0	0	0	0	0	0	0
	No Change	93.1	27	96.6	28	93.1	27	75.9	22	93.1	27
	Increase	6.9	2	3.4	1	6.9	2	24.1	7	6.9	2
LVL	Decrease	0	0	0	0	0	0	3.4	1	3.4	1
	No Change	58.6	17	69.0	20	96.6	28	82.8	24	82.8	24
	Increase	41.4	12	31.0	9	3.4	1	13.8	4	13.8	4
Glulam	Decrease	0	0	0	0	0	0	0	0	0	0
	No Change	93.1	27	100	29	96.6	28	96.6	28	100	29
	Increase	6.9	2	0	0	3.4	1	3.4	1	0	0
SCL	Decrease	0	0	0	0	0	0	0	0	0	0
	No Change	93.1	27	96.6	28	96.6	28	96.6	28	96.6	28
	Increase	6.9	2	3.4	1	3.4	1	3.4	1	3.4	1
Prefab	Decrease	0	0	0	0	0	0	0	0	6.9	2
	No Change	96.6	28	93.1	27	86.2	25	82.8	24	75.9	22
	Increase	3.4	1	6.9	2	13.8	4	17.2	5	17.2	5
Steel	Decrease	0	0	0	0	0	0	0	0	0	0
	No Change	100	29	100	29	93.1	27	96.6	28	100	29
	Increase	0	0	0	0	6.9	2	3.4	1	0	0
Other	Decrease	0	0	0	0	0	0	0	0	0	0
	No Change	100	29	100.	29	100	29	100	29	96.6	28
	Increase	0	0	0	0	0	0	0	0	3.4	1

Engineered Lumber Use

During interviews, company representatives were asked if the company had increased the amount of engineered lumber used over the last five years. Thirteen companies had substantial increases in engineered lumber use ranging from 100 % to 300 %. Three companies had only minimal increases. Only one company had no increases and increases were unavailable for two companies. The most common reason expressed by respondents for using engineered lumber was for design flexibility. Other reasons included longer spans, better quality, industry acceptance, price competitiveness and protection from unstable lumber prices. Companies learned about new products through sales representatives, trade journals, seminars, third party inspection agencies and trade shows.

Production Line Effects

Eight of the interviewed companies' felt that changes in structural materials could effect the set-up of the production line. These changes usually involved new equipment needs, such as floor jigs, cranes, new storage areas and new rigging assemblies. Due to pre-assembly planning most companies did not find that the production line adjustments limited the introduction of new materials. Three companies did state that sometimes the production line did limit new materials when materials exceeded the allowable length and width restrictions on the production line or there was no available inventory space.

Training

Most companies trained their employees to use new materials through informal in-house training. Often a product representative will be on hand for questions and to demonstrate how to use the product. Many companies used product manuals and product exchange bulletins to inform their employees about new products. Other training included: cross-training to maintain productivity during an absence or turn over, management seminars, videos, staff meetings and other outside training.

Supply Systems

Eleven companies (57.9 %) currently use a just in time (JIT) supplier system. Companies who use JIT did so to reduce inventory and tended to use local suppliers. For the most part, these companies use JIT to delivery everything except wood products and special orders. Of those companies who do use JIT, only one company buys their lumber this way. Respondents stated that it is the volatility price of lumber, which prevents them from buying lumber JIT. Most companies found it more cost effective to buy according to market rates and stockpile lumber when prices were low. One company not currently using JIT was exploring it as an option.

Changes in Technology

During the interview company representatives were asked if they foresaw any changes in technology or production methods which might affect the choice of building material. Most representatives could not think of any changes, but six did foresee some sort of new product that would bridge the gap between the cost effectiveness of dimensional lumber and the quality and strength of engineered lumber. Other changes included: equipment changes as a result of a company converting to steel and changes in construction methods for walls and floors, such as new table walls and jigs. This new equipment would save time and decrease the potential for error.