C I N T R A F O R

Working Paper

73

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This material is based upon work supported by the Cooperative State Research Service, US Department of Agriculture, and the State of Washington Department of Community, Trade and Economic Development. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the funding agencies.

EXECUTIVE SUMMARY

The US residential construction industry, traditionally the largest market for softwood lumber, has undergone a period of uncharacteristically rapid change over the past decade. The effects of timber harvest restrictions in federal and state forests on softwood lumber price, price volatility, and product quality, combined with technological advances by producers of substitute materials, have contributed to increased use of material substitutes in residential construction. The objective of this research was to assess the extent of material substitution in residential construction and provide insight into the factors driving these changes. The results offer convincing evidence that softwood lumber has continued to lose market share in the residential construction industry and that builders remain concerned about its quality and price. The study also shows a shift on the part of builders towards a more favorable impression of the environmental impacts of substitute products, including steel and concrete, relative to softwood lumber.

This study is based on a random sample of 2,400 residential construction firms segmented by geographic region and firm size. The survey was also mailed to the 100 largest home builders, as reported in *Builder* magazine. The overall response rate was 12.8% (12.1% of the random sample and 37.1% of the 100 largest firms). The results show that residential builders have steadily increased their use of substitute structural materials since 1995. Respondents reported increased use of all of substitute materials included in the survey. Almost all respondents reported using at least one substitute material (compared to 91% in 1995) and over 80% of the respondents reported using glulam beams, wood I-joists, and laminated veneer lumber (LVL). While use of steel, reinforced concrete and plastic-fiber lumber increased, engineered wood products emerged as the clear winners. On a regional basis, builders in the western US reported higher usage of all substitute products. In addition, the survey data suggest that large firms were more likely than small firms to try new substitute products, particularly finger jointed lumber, structural insulated panels, laminated veneer lumber, as well as newer engineered wood products such as parallel strand lumber and laminated strand lumber.

The survey data were analyzed to assess the extent to which various structural products were used in walls, floors, and roofs, the three end-use applications that consume the greatest volume of structural lumber. The most commonly used products were softwood lumber, steel lumber, finger-jointed lumber, wood trusses, LVL, and wood I-joists. While softwood lumber still dominated wall framing in 1998, with an 83% market share, it has lost market share (down from 93% in 1995), particularly among large firms. Softwood lumber's share of the floor framing market declined from 59% in 1995 to 42% in 1998. While it is still the most widely used product, with a 42% market share, the market share of wood I-joists has increased from 23% in 1995 to 39% in 1998. Softwood lumber used to frame roof rafters is no longer the dominant material used in residential roof systems. Survey data show that wood trusses increased slightly from 46% to 48%, while softwood lumber declined from 51% to 40%.

To assess builders' satisfaction with softwood lumber, respondents were asked to rate the level of the importance, and their corresponding level of satisfaction, with 13 softwood lumber attributes. The importance ratings obtained in 1998 were virtually identical to those reported in 1995. Softwood lumber straightness, strength, availability, and lack of defects were rated as the most important attributes. The survey data suggest that price is much more important to large firms than small firms. Builders reported that, while they were more satisfied with the price and price stability of softwood lumber in 1998 relative to 1995, they remained unhappy with softwood lumber quality, particularly with respect to lumber straightness and overall occurrence of defects.

A gap analysis highlighted the difference between the mean importance ratings (where 7 indicates "extremely important" and 1 indicates "not important at all") and the mean satisfaction ratings for each product attribute (where 7 indicates "extremely satisfied" and 1 indicates "extremely dissatisfied"). Survey findings indicate that while builders are less concerned with price issues than in 1995, they remain very concerned about the perceived decline in softwood lumber quality. The data provide clear evidence that residential home builders are least satisfied with product attributes they rate most important, suggesting that builders are dissatisfied with the value (defined as the ratio of price/quality) of softwood lumber.

To provide a more concise interpretation of the importance and satisfaction of the different softwood lumber attributes, a factor analysis was performed to group together those softwood lumber attributes that are highly

correlated to each other. The results of the factor analysis are almost identical with the results obtained from the 1995 survey and suggest that the 13 product attributes used to describe softwood lumber can be summarized into three factors: quality attributes, economic attributes, and technical attributes.

Finally, the survey assessed builders' perceptions of the environmental impact associated with using substitute products relative to softwood lumber. Although environmental marketing is not prevalent in the US forest products industry, most industry observers believe that it will become more important. While reduced environmental impact had the lowest importance rating of the 13 softwood lumber attributes, survey findings revealed that more builders in 1998 had a favorable perception of the environmental impact of substitute products, including steel and concrete, over softwood lumber than in 1995.

This survey clearly indicates that softwood lumber has continued to be displaced by substitute materials in segments of the residential construction industry that it has traditionally dominated: walls, floors, and roofs. To a large degree, this loss of market share can be attributed to a perception among residential builders that the value of softwood lumber has declined: a direct result of rising prices and a perceived drop in lumber quality. Much of the loss in market share experienced by softwood lumber can be attributed to the increased use of engineered wood products. Many would argue that this is a normal process of product evolution within the forest products industry, attributed to technological advances in manufacturing processes driven by the changing forest resource. However, this study identified two trends that should concern managers in the forest products industry. First, the use of non-wood substitute building materials has increased significantly since 1995. Second, there is a growing perception among home builders that using non-wood building materials (including steel and reinforced concrete) is better for the environment than using softwood lumber. This trend away from wood products is likely to continue unless there is an effective response to the challenge posed by substitute materials.

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INTRODUCTION

Recent changes in global and domestic wood products markets, along with the rapidly rising acceptance of substitute building materials, have put softwood lumber producers in a difficult position. Softwood lumber has traditionally dominated the structural framing of residential housing in the US. A 1988 study reported that more than a third of the annual US lumber consumption went into residential housing, while more than three fourths of that amount was used in single-family construction (McKeever and Anderson 1992).

Over the last decade, three major developments have caused drastic changes in this typically conservative industry. First, in 1989 when the federal government drastically reduced the timber supply from federal lands to protect endangered species, an increasing amount of US lumber demand had to be supplied by Canadian mills and private timberlands in the Southeast. Second, these supply reductions, combined with a sustained increase in US housing starts and changes in the global market (particularly quotas on Canadian imports and the Asian depression of 1997), opened the door for substitute products. Third, the growing importance of the repair and remodeling (R&R) market, particularly through large retail home centers such as Home Depot, has reshaped domestic consumer demand and distribution networks.

A 1995 CINTRAFOR study on material substitution in residential construction found that builders were most dissatisfied with the price, price volatility, and quality of softwood lumber (Eastin, Simon, and Shook 1996). This study was conducted during a period of price volatility caused by federally regulated timber harvest restrictions (Figure 1). Since then, prices have fallen and stabilized because PNW producers have increased lumber yield from the available stumpage, and because reduced demand from Japan has left more and better timber available for PNW mills (Smyth 1998). While some analysts believe that prices have now fallen too low because PNW mills are actually overproducing (Taylor 1998c), the industry will soon face restrictions on private timber harvests as well, due to the need to protect riparian areas for salmon habitat.

Softwood lumber producers have resolved price and supply problems for now, but current research indicates that builders remain dissatisfied with softwood lumber quality. Lumber producers and industry advocates have been reluctant to acknowledge quality problems publicly. They generally refer to the “perceived” drop in quality, noting that the grading rules that define lumber grades have not changed. The net result, however, is quite clear. Substitute products, particularly engineered wood products, gained market share when lumber prices were high. The quotas on Canadian imports, which artificially lowered timber supply to an even greater degree, exacerbated this pricing problem. Subsequently, when prices dropped back down, many builders had developed a preference for the engineered wood products to which they had become accustomed.

Many builders have found that, for many structural framing applications, engineered wood products can reliably and affordably suit their framing needs. This trend has been well documented. Countless articles have listed the various wood and non-wood substitutes that are available to builders along with their advantages and disadvantages. This paper will present the most recent information on the available product mix. Descriptions of the different types of structural framing products included in this study can be found in Appendix C. The following literature review will focus specifically on wall, floor, and roof framing, the largest end use applications for framing materials.

To compete well, firms must be familiar with industry trends and the characteristics of key market segments. Thus, it is necessary to examine recent trends in US demographics and the housing market. The sustained strength of the US economy in general, and housing starts in particular, has consistently defied conservative forecasts over the past few years. To date, neither the long-awaited lumber shortage, nor the long-dreaded downturn in the economy has occurred.

Regional differences in the data are examined as well. Population growth, age of housing stock, climate, resource availability, and many other factors have an effect on regional housing markets. With a better understanding of regional demand characteristics, suppliers can better satisfy their customers, recognize organizational weaknesses, and take advantage of growth opportunities.

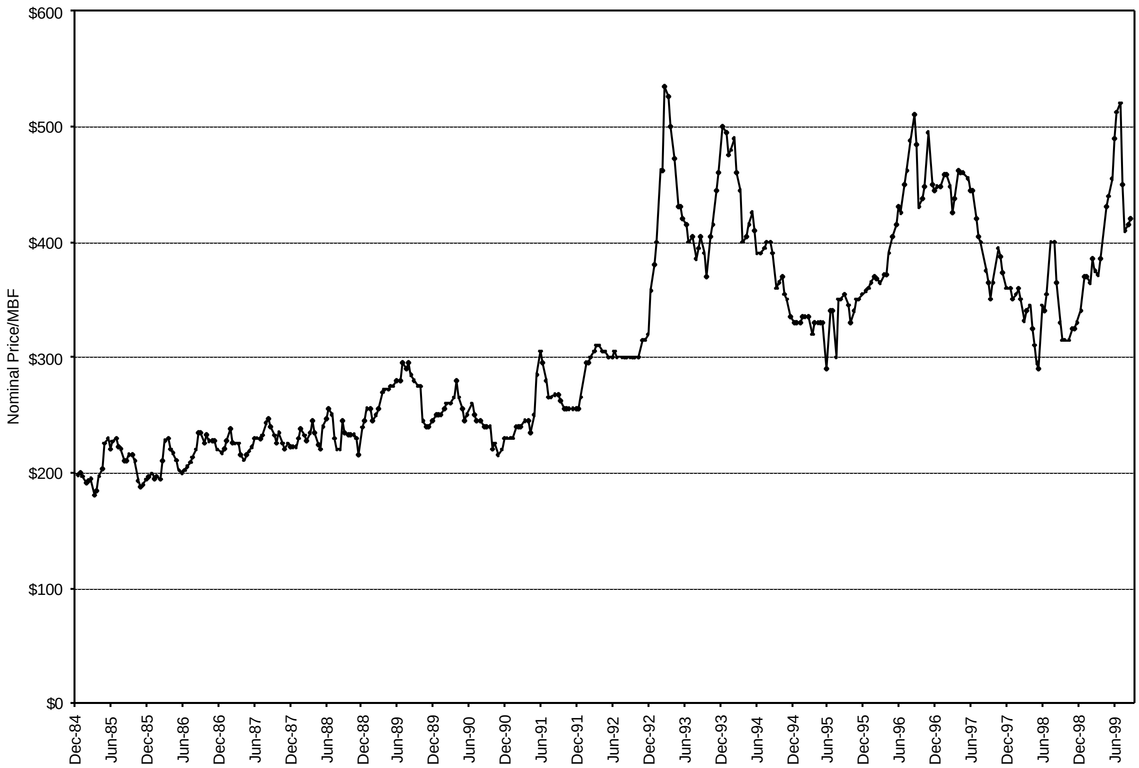

Figure 1. Nominal prices for kiln-dried Douglas fir Standard & Better grade 2 by 4 lumber. (Source: *Random Lengths*, 1999)

The repair and remodel (R&R) market will also be discussed, focusing on the changes its emergence has imposed upon the softwood lumber industry, as well as the different purchasing patterns of small and large builders. This study examines the different perceptions and usage patterns of small and large builders. The most notable difference is that large builders, who focus almost exclusively on single and multi-family residential construction, have different needs than smaller builders, who are generating an increasing proportion of their revenue from the R&R market. At the same time, small builders are purchasing an increasing proportion of their materials through the national building material chains, rather than from smaller local lumber yards.

At this writing, Home Depot, which claims to be the world's single largest lumber retailer, announced that it will no longer sell old-growth wood products after 2002. Forest certification efforts in the US have struggled thus far, as consumers still seem unwilling to pay a significant price premium for environmentally certified products. At the same time, green marketing is very important in parts of Europe and could have an increasing impact upon the US market in the near future. As of now, however, US environmental policy has had a much greater effect upon the forest products industry. Negative perception of the environmental impact of forestry activities was undoubtedly one of the driving forces behind the supply constraints confronting softwood lumber producers, particularly in the PNW. As a result, producers have a strong incentive to project a favorable environmental image. Advertising campaigns promoting substitute building products have made a concerted effort to take advantage of the confusion surrounding this issue by claiming to produce more environmentally-friendly products. Although lumber stands up well in comparison to non-wood products, the wood products industry has been ineffective in communicating the environmental benefits of using wood objectively and unequivocally to the general public. The challenge is to understand public perceptions and misperceptions and identify strategies to more effectively communicate the environmental benefits of using wood as a building material.

The following literature review will explore the history of material substitution in the forest products industry and examine the marketing literature covering the adoption and diffusion of new industrial materials. The former section will put the competition for market share between different materials into an historical perspective. The latter will give the firms competing in structural framing a better picture of the mechanisms of change. The timber management and capital expenditure decisions made now by softwood lumber producers will have a great impact on their long-term success or failure. A better understanding of the factors that drive the trial and adoption of new products, combined with a knowledge of the historical context and current market conditions, should help producers position themselves properly. The market, the available resource, and public perception of the industry have all changed. The "reversability" (ability to regain lost market share) that softwood lumber producers crave may never be possible. That does not mean that their products are no longer viable and valuable; rather it means that they must find a new, more appropriate place in today's market by responding adequately to the needs of the most receptive target markets.

LITERATURE REVIEW

Recent Changes Affecting the Softwood Lumber Industry

Just before the spotted owl controversy, the Forest Service published "An Analysis of the Timber Situation in the United States: 1989-2040." The section on material substitution in the housing industry reported the growing use of panel products and the existence (not the threat) of steel framing. The term "engineered wood product" is nowhere to be found (USFS 1990). In those simpler days, US and Japanese housing start trends provided a good indication of the health of the US softwood lumber industry. This, then, is a very good baseline from which to study the radical changes that have taken place in the industry over the past decade.

Subsequent timber harvest reductions of 30-40% in federal forests in the PNW resulted in drastic price increases for softwood lumber, increasing price volatility, and many mill closures. The sawmill industry responded by investing in new technology, allowing it to make major improvements in wood recovery (Ehringer 1999). They have improved price stability and maintained supply by producing similar volumes of lumber from fewer and younger logs. Today, when most softwood lumber producers talk about future prospects, they speak solely of increased recovery and efficiency. This is clearly one way to address the lumber quality issue. It may not be enough, however, to satisfy the target market; homebuilders and remodellers. Softwood lumber producers also need to consider the following points seriously:

1. The opportunities to differentiate lumber products in a cost efficient way by incorporating product attributes that end-users value and for which they are willing to pay a price premium.
2. The value of providing better customer service, and gearing production to satisfy the needs of different types of distribution systems.
3. The economic viability of longer, rather than shorter, rotations that would produce higher quality timber.
4. The possibility of a demand shift in some segments of the housing market towards smaller homes built with higher quality, premium-priced materials (Heavens 1999).

The softwood lumber industry has made a commitment to short-term returns, attempting to produce the best quality lumber from shorter rotations. This strategy makes perfect sense to economists, but it is displeasing to customers. It is not very well suited to today's market, and it is even less suited to the market of the future. Douglas-fir lumber is inherently valuable because of its appearance, structural strength, and durability. It is too high quality to be chipped or sliced for engineered wood products. On the other hand, with short rotations, it has serious problems competing with substitute products (e.g., wood I-joists, steel framing or LVL) that offer increased dimensional stability and labor cost savings at competitive prices. There is no simple answer, but producers clearly must look beyond the traditional product mix.

Global trade has played a major role in the recent fate of the softwood lumber industry as well. In the years immediately following the spotted owl harvest restrictions, Pacific Rim export trade kept the industry alive. It was during this time period that Canadian lumber, engineered wood products, and non-wood substitutes made major gains in the US structural framing market. By the time the Asian economies imploded in 1997, PNW mills were better equipped to efficiently produce dimension lumber for the booming domestic market at reasonable prices.

The results of many recent studies, including those by the Center for International Trade in Forest Resources (CINTRAFOR) and the National Association of Home Builders (NAHB) Research Center, show that builders are increasingly dissatisfied with lumber quality. *Builder* magazine, meanwhile, recently ran an article entitled "Straight Talk About Wood Quality," which advised builders on how to minimize the amount of culls in the lumber they purchase. "The wood [that builders] are getting has too much wane, too many knots, and knots that fall out or bleed through finishes. The lumber warps, twists, cups, bows, checks, and shrinks, and it's milled (or dried) to inconsistent dimensions"(Schwolsky 1996).

Schwolsky recommends one of four possible strategies for the builder, depending upon individual cost analyses. First is the no action alternative, "keep picking through the same lumber piles, returning rejects and replacing defects." Second, find a better lumber source. Third, pay a price premium for higher-grade lumber. Fourth, switch to a substitute product. Above all else, he recommends that the builder take more control of the supply issue, demand better lumber, and factor the normal amount of rejects into cost accounting (Schwolsky 1996). In conclusion, he notes that good lumber is still available, it is just harder to find. Whether one agrees or not, builders perceive that the quality of softwood lumber has declined while price increased. This perception has provided builders with the incentive to try substitute products that they might not have considered using ten years ago.

The Emergence Of Substitute Products

Supply and quality problems in the lumber industry left the door wide open for wood and non-wood based substitutes. Aggressive push marketing strategies employed by retailers of engineered wood products have been quite successful (Eastin, Shook, and Simon 1999). As existing substitute products have gained market share and newer products have made their presence felt, an explosion of new building technologies present the possibility of a revolution (or at least major changes) in the US housing industry. Softwood lumber producers have never before faced this level of competition in the framing market. The most common substitute products, grouped into three categories: engineered wood products, non-wood materials, and composite framing substitutes, are described in Appendix C. Tables listing the geographic distribution of the producers of most of the products listed below can be found in Appendix D.

In addition to CINTRAFOR, the Wood Products Promotion Council (WPPC) and the NAHB Research Center have also investigated material substitution in residential construction as part of their ongoing industry research. The WPPC's 1988 study (McKeever and Anderson, 1992) focused on many aspects of lumber consumption in residential construction. In 1993, the NAHB's Home Builder Industry Survey (WPPC 1996) reinvestigated the same issues and added many others. The resulting data on lumber consumption and material substitution has produced studies from the WPPC and the Western Wood Products Association (WWPA), as well as a 1996 American Plywood Association (APA) study comparing the results of the 1988 survey and the 1995 survey with regard to engineered wood products (McKeever and Anderson 1992; APA 1996). This study itself is a follow up to a 1996 CINTRAFOR survey focusing on material substitution in the residential construction industry (Eastin *et al*., 1996).

Table 1. Consumption of lumber in residential construction 1995.

Application	BBF	%
Wall Framing	4.9	31.4
Roof Framing	4.6	29.5
Floor Framing	1.8	11.5
Total Framing	11.8	75.6
Dimensional Softwood Consumption	14.3	91.7
Total Lumber Consumption	15.6	100.0

Source: Wood Products Promotion Council 1996.

All of these studies have focused specifically on wall, roof, and floor framing. It is universally agreed that residential construction is one of the primary market segments for softwood lumber producers, and that wall, roof, and floor framing use more lumber than any other end use application (Table 1). Consequently, each of these studies asked respondents to quantify the product mix used in each application. This section will summarize the findings of those studies.

Wall framing: The WPPC has estimated that residential construction consumed 15.6 billion board feet (BBF) of softwood lumber in 1995. Wall and roof framing both consume roughly 30% of that total. Floor framing, at 11.5%, is the third largest end use application. It is important to note that these totals include the lumber used to manufacture wood trusses.

Both the WPPC and the CINTRAFOR studies from the mid 1990's reported that softwood lumber still dominated wall framing, although substitutes such as steel framing, concrete, and finger-jointed studs showed modest growth. The WWPC reported that 88% of the lumber used in single family unit wall systems and 90% of that used in multi-family construction went into light framing. In addition, concrete block and panelized construction both had less than 10% share of exterior wall framing. Concrete use tends to be more of a reaction to geography and climate, while panelized construction is an emerging construction technology.

Roof framing: The two dominant systems for roof framing are wood trusses and stick frame rafters. McKeever and Anderson (1992) found that nearly 90% of the lumber used in single family roof systems went into roof framing. Their data indicated that 62% of the roof systems used trusses, 38% used rafters, and less than 1% used steel or other products. WPPC (1996) found that 51% used trusses, while 44% used rafter systems. The 1996 CINTRAFOR study found that 51% used trusses, while 46% used rafter systems (Eastin, *et al*., 1996).

Floor framing: The product mix in floor systems is more varied. McKeever and Anderson (1992) reported that 70% of the floor systems used solid wood lumber, 9% used wood trusses, and 3% used wood I-joists. The WPPC (1996) study included concrete slab floors used in single story houses. It found that lumber and wood trusses had a 53% share, concrete slabs 33%, and wood I-joists 12%. The CINTRAFOR (1996) study reported that lumber had a 59% share, wood trusses 16%, and wood I-joists 23%.

Identifiable trends: Given the differences in study design and data analysis, it is difficult to make direct comparisons between the three studies discussed above. Each one has distinct strengths and weaknesses. Some general conclusions are possible, however. First, solid wood lumber has maintained its dominance in wall framing. Second, wood truss usage in roof framing is quite significant, although it appears to have decreased in recent years. There are, however, too many inconsistencies between the studies to draw conclusions on this particular point. Third, solid wood lumber is losing market share in floor systems to wood trusses and wood I-joists. Current data now estimates that 25-30% of all new homes use wood I-joist flooring systems.

Housing market trends and segmentation

CINTRAFOR initiated this study with the intention of creating a longitudinal measure of material substitution in the residential construction industry. The design of this study mirrors Eastin, *et al*. (1996), very closely. It was therefore possible to compare many of the results with those from the earlier work. The housing industry has enjoyed the benefits of a strong economy between 1995 and 1998, (Figure 2). The Joint Center for Housing Studies at Harvard University, in "State of the Nation's Housing: 1998" (1999), reported that, "between 1994 and 1997, the net addition of 4 million households to the ranks of homeowners set a three-year record." Nevertheless, industry experts have been justifiably reserved in their outlook. One industry analyst wrongly predicted timber shortages and economic slowdowns three years in a row. Most forecasters have now resigned themselves to a sense of cautious optimism. This section will examine the dominant trends in the housing industry and how they could affect the forest products industry. It will then explore the background of two very important segments within the residential construction industry, firm size and regional markets.

Current trends in US housing

The Joint Center begins "The State of the Nation's Housing: 1998" (1999) with the statement: "Now in its eighth year of sustained growth, the US economy has brought unprecedented strength to housing production and sales. Spurred by strong employment growth, low mortgage interest rates, and new, more flexible financing options, national home ownership rates have reached an all-time high."

Citing a number of different factors, their report also predicts that housing starts should continue the trend of roughly 1.5 million average annual housing starts for at least another decade. The implications for the forest products industry are clear. While demand will remain strong, the residential construction industry will not provide exceptional growth opportunities. Since demand will not grow, producers must be careful not to drive down prices by oversupplying the market. Furthermore, they must focus on beating their competitors in value, service, efficiency, and the identification of specific target markets (Bernhardt 1999).

Figure 2. Annual housing starts in the US, 1946-1998. Source: Joint Center for Housing Studies, 1999.

Population demographics reinforce the validity of forecasts for steady housing demand in the future. The aging of the population and the aging of the housing stock will both help maintain, rather than hinder, national demand for housing. Variation in the age of the housing stock, as well as regional population shifts, will differentiate local markets, however. The differing needs of aging baby boomers and their children will also change the type of housing demanded by consumers.

Undeniably, recent economic prosperity has spurred the construction of many large and expensive suburban homes. At the same time, murmurs of concern regarding the perils of over-development and the need to reestablish a sense of community are rippling through the national consciousness (Heavens 1999).

As baby boomers become "empty-nesters," they are increasingly looking for smaller homes that simplify their life. Smaller homes on smaller lots, with the master suite and the laundry room on the ground floor, satisfy their desire to enjoy more of their free time, and are also more sensitive to their needs as the physical limitations of aging become problematic. The director of communications for the Western Wood Products Association acknowledges this trend (Bernhardt 1999) and architect Susan Susanka recently published a book on the subject, *The Not So Big House: A Blueprint for the Way We Really Live*.

The increasing number of single person households (led by the children who have recently departed from baby boomers' nests) further indicates a trend towards smaller homes, in addition to growth in the multi-family residential and manufactured housing industries. Demand for retirement living will increase as well (Joint Center 1999). The age of the housing stock is a constant, but minor factor in future housing demand. It will also help sustain the steady growth of the R&R market. All of these indicators together point to a future in which single family housing is a cash cow, a market segment that generates high revenue with low growth. Forest products firms must maintain market share in this segment and diligently pursue future growth opportunities elsewhere. Monitoring the changing needs and preferences of the population is essential to identifying those new opportunities.

Regional housing trends

Before discussing differences in regional housing markets, it is important to note that most studies on this topic categorize the regions of the US differently. Thus, data from different studies can only be compared in a general sense or in terms of the trends that become apparent. One very noticeable trend has been the extremely consistent proportions of regional housing starts from 1994-1997 (Figure 3). Housing starts have been highest in the South and the West, especially in the suburbs surrounding metropolitan areas, for several years. The Joint Center (1999) cites local employment and population growth as the primary drivers of regional housing markets. The authors differentiate between three types of regional markets. Markets such as Nevada, Arizona, and Georgia have shown consistent growth. Markets such as Iowa, North Dakota, and West Virginia have consistently ranked at the bottom of annual housing starts. Markets such as Colorado, Utah, and Idaho experienced temporary growth when California's slow economy and high cost of living encouraged migration to the Mountain states. They predict continued decreases in the population growth of the Northeast.

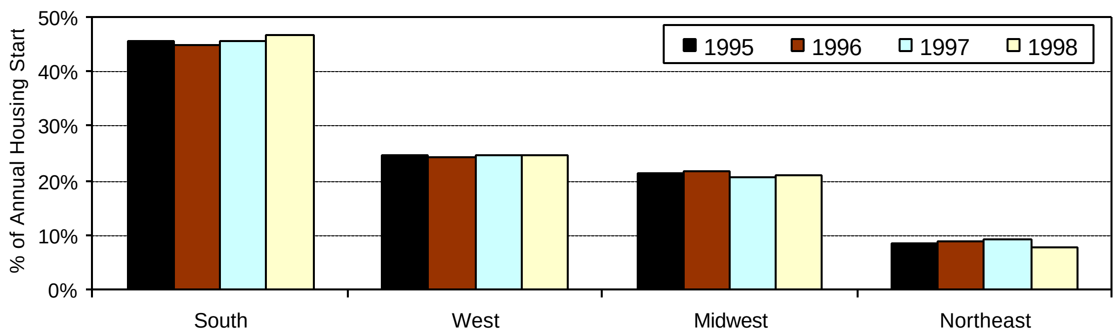

Figure 3. Regional trends in US housing starts. Source: Widman's *Wood Review* 1998.

Builder magazine's Gerry Donohue (1998) agrees that housing starts will continue to be higher in the South and West and that growth will be slow in the Midwest. His forecasts of regional growth rates differ somewhat, however. Donohue asserts that the markets with the highest per capita growth rates in housing starts will be those that have had lower growth rates in recent years. In other words, the slowpokes in the booming economy will catch up. He predicts high per capita growth rates in the Northeast, where the age of the housing stock is an important factor. He also predicts and cites recent evidence of high growth in California now that the economy is healthy and outward migration has slowed considerably.

Regional market segmentation also requires some knowledge of the general material preferences in each region. Regional product preferences can be attributed to local supply issues as well as local constraints, such as climate or pest control problems. In the former case, Bernhardt (1999) states that Western timber supply constraints, along with an increased supply of Canadian lumber in the Northeast and Southern yellow pine in the South, have reduced the ability of PNW producers to influence other regions. "Basically, the three regions are distinct and have very little ability to affect markets outside of their region."

In general , the literature suggests that the average Western builder uses a wider variety of lumber substitutes and is more willing to try newer products. In the Northwest, this may be attributed to the rising price and declining quality of local timber. In the Southwest, both the lack of local timber and the unique demands of the climate may help explain the differences. Finger-jointed lumber, for example, is extraordinarily popular among builders in the Dallas area and across the Southwest. This can be attributed to the more reliable local supply of the product (its production is concentrated in Louisiana and Texas), as well as the increased importance of lumber that will not warp or twist in hot, dry climates (Jones 1993). Thus, forest products firms should concentrate on developing products that suit the specific needs of their customers.

Differences Between Small And Large Builders

Profile of NAHB builder members: This study provides a better definition of the material requirements of key segments within the residential construction industry. Firm size is one obvious distinction. Approximately 85% of the NAHB's members built at least one single family home in 1997. The NAHB classifies firm size by the number of annual housing starts. It classifies small builders as those starting fewer than 25 houses per year, medium builders as those starting 25-99 houses per year, and large builders as those starting 100 or more houses per year. In 1997, the proportion of small builders rose to 82% and it has been climbing dramatically since 1969. The proportion of medium sized builders dropped to 12%, while the proportion of large builders fell to 6%. Gopal Ahluwalia, commenting on these findings in *Housing Economics* (1998), states that the rising representation of small builders is due to NAHB's increasing efforts to include them in its membership, rather than a shift in industry demographics.

Changes affecting small builders: Upon review of housing industry statistics, the difference in the sources of revenue for small and large firms is immediately obvious. The smallest firms generated over 40% of their revenue from the R&R market, while the average large builder generated almost all (95%) of its revenue from single and multi-family residential construction. The increasing importance of the R&R market has had two major effects upon the residential construction market. First, as a result of R&R demand combined with high housing starts, the availability of labor has become one of the most pressing issues in residential construction. Second, distribution networks have shifted and become more specialized.

Increasingly, small builders, contractors, and do-it-yourselfers are purchasing building materials from the national home center chains, while large builders use service-oriented wholesale distributors. The R&R market has grown significantly large, continues to consume an increasing share of lumber production, and should, according to the Joint Center for Housing Studies at Harvard University (1999), grow 2% annually through 2010. The NAHB Research Center (1999) reports that 23% of all US lumber consumption is used for R&R. This, in turn, has changed the face of retailing. It is estimated that small conventional lumber yards, which controlled over 80% of the market through the 1980's, will most likely lose half of that share by the end of the 1990's. Those same forecasts predict that the large home center chains will double their market share to 20% over the decade, while large wholesale distributors serving professional contractors and builders will rise from 5% market share in 1991 to capture 40% by 2000 (Taylor 1998).

Changes affecting large builders: In dealing with the buying co-ops that service smaller hardware chains and lumber yards as well as the large wholesale distributors that offer builders just-in-time (JIT) services, producers are faced with a different set of requirements.

> (T)he importance of the North American wholesale building materials distributor may be increasing for a number of reasons. As the volume demands of home centres drive more commodity manufacturing strategies at the mills, service-related gaps are occurring when trying to meet JIT delivery schedules; there are also the headaches of supplying a multitude of smaller-volume specialty products.... With their ability to buy and inventory products during weak markets, offer value-added services, and provide highly mixed shipments....the strategically focused building material distributors will remain a key factor in the North American market. (Taylor 1998c)

Data from previous studies indicate that large firms tend to drive innovation in the residential construction industry. They are more likely to try newer products and they are more likely to use a broader mix of substitutes. Large builders also appear more likely to try and use products that encourage a more systematic approach to homebuilding. The literature supports this finding. *Builder* magazine reports, "small builders will continue to have the edge in land and entitlements, and large builders will have marketing and production efficiencies. In fact, more big companies are moving toward a more modular approach." (Maynard and DePietropaolo 1999) Another reason for this might be related to the type of developments in which small and large builders operate. For example, small builders, who work on a small number of custom homes at any one time, are less likely to bring in the crane necessary for a product such as wood trusses.

The Top 100 Builders: In recent years, *Builder* magazine has compiled an annual list of the 100 largest residential construction firms based on the number of homes built. In addition to providing background on this particular segment of the residential construction industry, information on the largest builders provides valuable insight into industry trends. This section will analyze *Builder*'s reports on the Top 100 construction firms from 1996-1999.

Few industries with such a large impact upon the US economy are as fragmented as the residential construction industry. Despite a pronounced tendency towards market expansion and consolidation through acquisition, the Top 100 builders of 1998 still held less than a 20% share of total residential housing starts (Maynard and DePietropaolo 1999). The 1997 report (Shuroff) points out that only one builder was able to crack the Fortune 500 (which is based on annual revenue). This indicates that, while the special needs of large builders are extremely important, small builders still comprise a powerful market force.

The Top 100 reached a different milestone in 1998, however. The largest firm, Pulte Home Corporation, broke the barrier of 20,000 housing starts in one year, which was once thought unattainable (Maynard and Dietropaolo 1999). Furthermore, although the Top 100 have not yet collectively breached 20% in market share, their share has grown consistently since it bottomed out in 1992 (Ahluwalia 1998). This recent trend towards industry consolidation can be attributed to a variety of factors. Much has to do with the individuality of housing designs and styles as well as the nature of local housing markets. It can also be attributed to macroeconomic changes and shifts in banking policy and finance. Gerry Donohue's 1996 report on the Top 100 tells this story quite well. The federal regulation of thrifts prior to 1980 tied local interest rates to the national housing cycle. During the post-deregulation real estate boom of the 1980's, "housing cycles became local (and) geographic diversification gave big-volume builders a huge edge. They could offset poorly performing markets with strong ones and thus even out their income stream. They could even play the cycles, selling units in markets with strong demand and using that cash flow to buy cheap land in slumping markets" (Donohue 1996).

After the rubble was cleared from the S&L scandal in 1989, regulation of the banking sector increased once more. In order to maintain their advantages in low cost capital, many of the largest builders issued public stock offerings. This allowed them to continue entering new primary markets and even some secondary markets. Public firms, which face continuous pressure to meet stockholders' expectations for growth, are typically more expansion-oriented. Most large builders focus on establishing a medium sized market share in diverse markets. Private builders are more opportunistic in their expansion.

It should not be surprising that the largest firms are now solidifying their advantages through heavy investment in computer technology. Computerization helps large builders increase the customization of their homes, infringing upon the traditional territory of smaller builders. With the ability to do a better job tracking and distributing increasingly specialized items, large firms can now offer more individualized designs. This ability is quite valuable, but requires substantial investment. This is just one more factor that supports the contention that the most vulnerable builders in today's market are not only medium sized builders. Rather, the firms most vulnerable to acquisition or failure have problems with accessing low cost capital. Donohue (1996) offers small builders five strategies by which to compete more effectively against large builders: 1) get access to low cost capital; 2) find a niche in the market ; 3) stay nimble; 4) computerize; and 5) sell service.

Marketing and the perception of environmental impact

Public policy concerns versus "green" marketing: As discussed earlier, environmental policy has a direct impact upon the cost of doing business and the supply of lumber. Environmental, or "green" marketing still has less impact in the US market than it does in Europe. Although they may have strong feelings about the environment, typical US consumers are still reluctant to pay a substantial premium for environmentally certified products. Thus, the environmental policies that negatively impacted price, quality, and availability have had a much greater effect upon the market than has green marketing. Nevertheless, a shift towards green marketing is occurring and forest products firms are becoming increasingly aware of the need to stay ahead of the curve.

The acquisition of raw materials, production, use, and disposal of any building material consumes some natural resources, generates some amount of pollution and waste, has the potential to adversely affect human safety and health, and has some impact on carbon cycling and biodiversity. At the same time, the renewability, recycled content, energy efficiency, and decreased manufacturing or raw material requirements of some products may mitigate negative environmental impacts to some extent.

Life Cycle Analysis (LCA): Claiming moral high ground on environmental issues has been a key component of the competition among substitute building materials over the past decade. Life Cycle Analysis (LCA) is the most widely used tool in comparing the overall environmental impact of different building materials. These "cradle-to-grave" analyses were developed, and are being used effectively, in the UK. Scientific Certification Systems (SCS), an independent laboratory, leads the way in adapting these techniques to the needs of the North American market. Forest industry advocates are quick to point out that these impartial, scientifically-sound studies, usually recommend wood and wood products for many, but not all, end use applications.

Many experts predict that LCA will become a valuable marketing tool. Prospective homebuyers could sit at a computer terminal, weigh the costs and benefits of various materials, and make informed decisions. The cost-effectiveness of such a system remains to be seen, and LCA still has (and will always have) some scientific limitations. Measuring the "cradle-to-grave" environmental impact of any manufactured product will never be an exact science. Such studies are necessary, however, to provide data on which to base public policy decisions and to provide architects, engineers, and designers with good technical information (Bowyer, Lippke, and Wilson 1998).

Fighting the public image battle: Energy efficiency, a major issue in the 1970's, is now a minor concern. Industrial pollution has been extensively regulated by the Clean Air Act and the Clean Water Act. Recycling is on the rise. Most of the remaining old growth timber has been preserved. The forest products industry now generates most of its revenue from fast-growing plantations that are tremendously productive carbon sinks. Over the last three decades, the environmental movement has won many battles and the environment has become noticeably cleaner. Why, then, are the environmentalists still so antagonistic towards the forest products industry?

Opponents of the forest products industry generally have three major concerns. First, they find it upsetting to see clearcuts in areas that used to be lush forests. The 1998 WPPC "National Consumer Opinion Research Study indicates that the term "clearcutting" itself holds negative connotations, particularly for those respondents categorized as environmentalists, who were most likely to agree with the statement, "we are running out of trees." Second, they object to the loss, degradation, and fragmentation of wildlife habitat. Third, the industry has still failed to shake off the negative image attached to the "monopolistic, rapacious timber barons" who fell into disfavor before World War I, when the conservationist and antitrust movements were strong (Yoho 1967). WPPC found that these emotions and attitudes are most likely to be based upon "what they (respondents) have read," rather than "personal experience" or "information from the wood industry."

The WPPC study also indicated that most environmentalists still appreciate the appearance and "natural feel" of wood. In the Pacific Northwest, it is not unlikely that one could find young professional couples who vehemently support federal timber harvest restrictions, but use cedar shake siding on the new additions to their homes. US consumers appreciate the natural aesthetic beauty of wood, but a large proportion of them do not like or trust forest products companies. In order to redefine their public image, forest products companies must change their corporate culture in two fundamental ways. First, throughout the organization, there must be a long-term commitment to follow both the spirit and the letter of the law when it comes to environmental compliance. This may be a bitter pill for some to swallow, but is the only way to regain lost public trust. WPPC results indicated that "changes in opinion are gradual and based upon personal experience to a much greater degree than on communicated messages." Second, firms must switch from a reactive to a proactive stance in developing products that satisfy changing consumer attitudes.

A senior executive of a major forest products company recently commented that "environmentalists have given up working with industry. Instead, they have found an easier way to get what they want, and that's through our customers" (CC Crow 1999). He further states that, even though he expects more timber harvest restrictions in the future, increased efficiency and imported timber will take up the slack in supply. He believes that the solution to environmental concerns lies in thinking of future issues, rather than reacting to current controversies, and in producing products that not only address the issue of environmental sustainability, but also provide customers with the price, service, and quality they demand. "There are signs all around," he states, "telling us that tomorrow's consumers are going to want environmentally friendly wood products. We need to take the leadership to produce those products, rather than wait for the government and consumers to force us to change our way of doing business."

Material substitution in the forest products industry throughout history

Material substitution in the forest products industry is anything but a new phenomenon. John Perlin, in *A Forest Journey* (1989), documents evidence of a similar process taking place in the city of Knossis on the island of Crete during the Bronze Age, about 2,500 years ago. The growing scarcity of local timber prompted a period of great technological innovation and promoted the recycling of materials. The rapid technological progress of the Industrial Revolution at the turn of the last century, coupled with the birth of the conservation movement, changed the market for forest products rapidly and thoroughly as well. A 1917 USDA study on substitution shows just how little has changed over the years.

> One of the most important … forces (encouraging substitution of iron, steel, cement and other materials) centers around costs and the utility of the competing materials and the products into which they go. Lumber prices have increased more rapidly during the past 25 years than prices for most of its competitors. For instance, a more or less regularly rising lumber price curve contrasted with a steadily falling cement price curve, covering the period of the development of manufacturing processes and the growth of the cement industry, is indicative of the conditions which have to a large extent made possible the very active competition of cement and its products with wood. The increase in wood prices, while due in part to the gradually decreasing purchasing power of money, which affects timberland values and lumber manufacture and distribution in all their phases, is due very largely also to the exhaustion of local supplies of timber. Higher transportation costs on lumber have resulted logically from the gradual exhaustion of forest resources in the regions near the center of population and lumber consumption, and the gradual shifting of lumber production in turn from the Northeast to the Lake States, to the South, and now, in its initial stages, to the Pacific Northwest. (Thelen 1917)

As American culture became more urbanized, the steel and cement industries were ideally positioned to make a strong entrance into the construction market. Taller buildings required stronger frames, and more densely populated cities required fire resistant materials. Thelen estimated that lumber's share of the construction market dropped 13% in the years preceding World War I. Paul Sharp published a paper in 1949 discussing the industry's response to this crisis. It is interesting to note both the positive changes that came out of the struggle as well as some of the counter-productive responses that can still be found in the industry today.

On the positive side, industry trade associations became stronger and more resources were devoted to technical research projects in wood science. On the negative side, many producers denied the reality and urgency of the changes in the market until it was too late. Some then blamed outside forces for their own failure to respond to shifting consumer demands and successful new technologies. In the 1910's, a bitter advertising war between lumber and substitute products consistently backfired against the timber industry. The industry only recovered when it developed better products to suit new market demands (by increasing efficiency and quality) and when external events (two world wars) again put lumber in high demand (Sharp 1949).

The primary lesson to be learned from this short history is that "reversability" rarely happens in these situations. History marches forward with blatant disregard for the welfare of rural logging communities. Neither, on the other hand, does the forest products industry simply lay down and die. The cycles of timber availability and product quality do not always coincide with economic, political, and technological change. Producers who become complacent often fall victim to these conflicts. Those who anticipate and prepare for change are typically much more successful in competitive markets.

Diffusion and adoption of product innovation

While the general marketing principles of the diffusion and adoption of product innovation are an integral part of introductory marketing courses, literature that specifically defines the unique challenges specific to the forest products or residential construction industries is rare and incomplete. Several observations can be made, however, which could help wood products firms better understand the constraints and opportunities they will encounter when trying to properly address the changing needs of their target markets.

Citing the lack of useful information specific to the construction industry, the NAHB Research Center conducted an extensive literature review and an exploratory study on the adoption of nine relatively new products. The results were published in 1999. They found that the relationship between the structure of the industry and factors known to influence the diffusion of innovation produced a slower rate of technological change than in most other industries of comparable size and importance.

The cyclicality of the industry was the most noticeable constraint, leading to "variable sales, lower rate of profit, smaller firms, sparse management, low investment in capital equipment and specialized labor, and horizontal and vertical fragmentation." The fragmentation of the industry is the other main constraint. Home building is dominated by smaller firms that rely heavily upon raw material producers, manufacturers, suppliers, and subcontractors. This produces discordant priorities and discourages R&D on the part of builders. The NAHB found that the cyclicality and fragmentation of the building industry "tend to increase the costs and risks of conducting and implementing formal research and development, reduce its benefits, lower the amount of feedback from the housing industry's work force and markets, limit the range of search for new ideas and products, and lower the prospects for sale of innovation."

After studying the diffusion of nine specific products, the NAHB reported that innovative technologies often require 15 to 20 years before they are adopted by most builders, economic advantage and simplicity are the characteristics most desired in new substitutes, new building products often face resistance from regulatory institutions, and the costs and benefits of new innovations are often difficult to quantify. They also found many limitations in the available literature on the subject. Very few studies focused on long-term product diffusion, applied traditional diffusion theory by identifying the characteristics of early adopters, or focused on the functional (as well as economic) advantages of innovation.

When innovation does occur in the building industry, it shows the following characteristics:

? Most changes are practical line extensions of existing problems.
? New innovations rarely alter the basic appearance of the home.
? Changes often result from technical or practical problems encountered in the field, especially with small builders.
? Over the long-term, innovative builders will generate some competitive advantage over those who are reluctant to change.

The authors of the study developed a multiple regression model to help identify the characteristics of builders who would be most likely to adopt innovative building products. They reported that large builders who use the smallest number of subcontractors and are more involved in industrialized construction or multi-family housing are the most likely to adopt new products or processes. They also developed a list of questions likely to be asked by builders involved in the process of deciding to use a new product. These questions, listed in order of importance, are:

? Will the consumer accept the new innovation?
? Will the product perform as indicated and be readily available?
? Is the product acceptable under current building codes and licenses?
? Is the builder certain of the decision?
? Will the lender accept it?
? Will the subcontractor unions accept it?

A 1998 study by T. Michael Toole attempts to fill one of the major information gaps identified by the NAHB Research Center: namely, the characteristics of early adopters in the construction industry. Focusing on builders who start 200 or fewer homes per year, Toole developed a regression model and tested each of nine hypotheses twice. Each hypothesis, a factor that could possibly drive the adoption of a non-diffused product, was tested with regard to both high-uncertainty innovations and low-uncertainty innovations. The results are two significant findings. First, early adopters tend, as in other industries, to take advantage of more information sources regarding new products. Second, high uncertainty regarding the cost, acceptance, or long-term performance of a new product will most likely hinder its adoption.

According to classic diffusion theory, a firm will adopt an innovation only if it confers some relative advantage. Relative advantage is broken into two components, improvement of the process of the task at hand and aid to the organization as a whole in reaching its goals. Toole asserts that the high degree of uncertainty within the building industry hinders innovation on both counts. On the former count, builders are wary of the performance of unproven technologies. On the latter, they fear resistance from many sides of the market: homebuyers, building codes, real estate agents, and banks. Based on his findings, Toole recommends that firms with new products provide as much information as possible to potential early adopters in order to reduce the uncertainty associated with using the new product. These efforts should go beyond product literature and advertisements to include more visual and tactile demonstrations of the product's performance.

All of this information reinforces the notion that the building industry is generally less willing to adopt innovations than other industries of comparable scope. Given the fact that builders have indeed been adopted many new products over the last decade, this indicates that their concerns with solid wood lumber's price and quality have been quite significant. David Cawood and Ian de la Roche, in "Dying or Flying? Strategies for Riding the Curve of Change," (1999) attribute this to the "instantaneous information exchange and high consumer awareness" of today's high tech economy, in addition to other obvious changes in the market.

Forest products executives who "may recognize the feeling of working just as hard and watching (their) effectiveness slip," have reached a plateau, according to the authors. They assert that these executives can no longer simply perceive themselves to be part of the "wood business." They are part of the building products business, and should develop new products that address the changing dynamics of the market. They cannot abandon the commodity lumber market, and they should not discontinue efforts to improve efficiency, but they must launch new value-added products in order to grow in today's market.

RESEARCH OBJECTIVES

This study began with three primary objectives. The first objective was to create a longitudinal study of material substitution in the US residential construction industry. This was accomplished by basing the study on a 1995 CINTRAFOR study on the same topic. While the study was updated and improved in several ways, it generated a large amount of comparable results. It is hoped that future studies will require only minor design changes. The second goal was to generate data that complements current research (by CINTRAFOR, the NAHB Research Center, the APA, and others) and fills in some of the information gaps that still exist. The third goal was to examine the differences between key market segments in the US residential construction industry. These goals were accomplished by addressing the following research questions:

1. What are the trends in material substitution over time, between geographic regions, and between large and small construction firms?
2. To what extent do US residential construction firms use substitutes for softwood lumber, especially in wall, floor, and roof framing?
3. How important are different product attributes to builders and how satisfied are they with the performance of softwood lumber with regard to those attributes?
4. Can the product attributes be grouped into factors that explain material substitution trends more concisely?
5. How do builders perceive the environmental impact of specific substitute products relative to softwood lumber?

SURVEY DESIGN AND METHODOLOGY

Sample selection

The population examined in this study is residential construction firms located in the United States. Several factors dictate the sample size: the expected response rate to the mail survey, the data analysis methods utilized in the study, and the number of independent variables employed in the analyses.

The residential construction industry is highly fragmented. Firms operating within the industry can be classified into various segments, such as prefabricated builders, manufactured housing builders, tract builders, speculation builders, and custom builders. Furthermore, very distinct differences exist among firms within each industry segment (e.g., number of units built per year, financing arrangements, material acquisition methods). In order to capture the inherent variance between residential builder segments, the sample used in this study was drawn from an industry database utilizing a stratified random sampling technique.

Cahners Direct Marketing Services, located in Des Plaines, Illinois, provided the database used to generate the sample for this study. Specifically, the source of the sample was the controlled circulation database of the trade magazine *Professional Builder*, which contains slightly over 100,000 single family and multi-family construction firms operating within the United States. The sample was stratified by the state each firm reported as its base of operation. Additionally, the United States was segmented into four distinct regions (northeast, southeast, northwest, and southwest) in such a way that each region received equal representation in the survey sample (Table 2).

A secondary sample was also included in the study. This group consisted of the largest 100 residential construction firms (herein referred to as the Top 100) located in the United States in 1997, where "largest" is defined by the firm's annual housing starts. A list of the Top 100 builders in the United States was obtained from the annual Top 100 list published by *Builder Magazine*. Collectively, the Top 100 residential construction firms built a total of 263,668 homes in 1997 and had total revenues of $43.219 billion.

Survey sample size

The calculation of the survey sample size involved several implicit assumptions. First, it was assumed that the residential construction industry in the United States is normally distributed and consists of approximately 200,000 firms, based on US Commerce statistics. Second, the error of estimation for the data analyses was bounded at 5%. Third, a 95%confidence interval was utilized in the data analyses, which is standard practice in survey research. Finally, the proportion, *p*, of residential home builders familiar with substitute structural building materials was conservatively estimated to be at least 75%.

Given the assumptions described above, the following equation was used to calculate the survey sample size (Cochran 1977):

$$n = \left[\frac{NPQ}{(N-1)\left(\frac{?^2}{4}\right) + PQ} \right]$$

where,

- n = sample size
- N = United States single family and multi-family residential home builder population size
- p = proportion of residential home builders familiar with substitute structural building materials
- q = $(1-p)$
- $?$ = error bound on estimation

Using the equation above, the minimum number of returned surveys required to meet the error estimation bound at the 95% confidence level was calculated to be 300. Assuming a survey response rate of approximately 15% and a undeliverable rate of 15%, a total of 2,400 surveys were mailed for this study. The inclusion of the Top 100 builders in this study increased the total number of surveys mailed to 2,500. Table 2 provides a summary of the 2,500 sample firms by state and region of operation.

Table 2. Summary of survey sample by state and region of operation.

	Number Sampled		Number Sampled
Northeast Region		**Northwest Region**	
Connecticut	22	Alaska	14
Delaware	5	Northern California	139
District of Columbia	2	Idaho	31
Illinois	68	Iowa	60
Indiana	34	Minnesota	85
Kentucky	15	Montana	26
Maine	5	Nebraska	33
Maryland	31	North Dakota	8
Massachusetts	30	Oregon	70
Michigan	63	South Dakota	14
New Hampshire	8	Washington	109
New Jersey	44	Wyoming	11
New York	67	***Regional Subtotal*:**	**600**
Ohio	58		
Pennsylvania	66	**Southwest Region**	
Rhode Island	5	Arizona	41
Vermont	4	Southern California	212
Virginia	37	Colorado	58
West Virginia	5	Hawaii	9
Wisconsin	31	Kansas	23
***Regional Subtotal*:**	**600**	Missouri	45
		Nevada	18
Southeast		New Mexico	16
Alabama	37	Oklahoma	22
Arkansas	22	Texas	134
Florida	207	Utah	22
Georgia	85	***Regional Subtotal*:**	**600**
Louisiana	28		
Mississippi	15		
North Carolina	110	**Top 100 Builders**	**100**
South Carolina	44		
Tennessee	52	**Grand Total**	**2,500**
***Regional Subtotal*:**	**600**		

Survey Development and Execution

A mail survey was used to collect data regarding residential construction firm use of, and perceptions of, substitute structural materials, as well as their use and perceptions of various deck products. Mail surveys typically provide the most efficient means of gathering data from a large population that is geographically dispersed (Dillman 1978). Mail surveys also tend to avoid bias which results from the use of personal interviewers and they allow the respondent to exercise greater care and take more time in completing the survey (Brown 1937; Malhotra 1993; Mangione 1995).

Dillman's (1978) *Total Design Methodology* was used to design and execute the survey. Each survey participant was mailed an eight-page survey instrument and a self-addressed, postage paid, business reply envelope. A cover letter described the purpose of the survey and ensured confidentiality. As an incentive to reply to the survey, participants were offered a summary report of the research findings. Two follow-up mailings containing a cover letter were mailed out, the first approximately two weeks following the initial mailing date and the second one month later. In order to maximize responses from the Top 100, a third letter, which included a $1 bill as an incentive, was mailed out one month after the second follow-up letter. Copies of the cover letters and survey instrument are presented in the appendices.

The survey instrument was pretested by two groups of individuals. The first pretest group, used to determine the comprehensiveness of the survey instrument, consisted of industry experts in forest products and residential construction. The second pretest group consisted of individuals who were generally unfamiliar with both the residential construction market and substitute structural building materials. This second group examined the survey instrument for clarity and ease of use. The survey instrument was then revised based on the comments and suggestions obtained from the pretest participants.

In some cases, differences between early respondents and late respondents can bias the results of a study. In order to assure that nonresponse bias did not significantly affect this study's results, independent sample t-tests comparing the mean responses of early respondents (those who responded in less than 10 days) and late respondents (those who responded after 55 days or more) were performed for each of the 70 variables analyzed in the results section. The means between the two groups were significantly different at the 5% level in just 2 of the 70 cases. Since the differences between these two groups were overwhelmingly insignificant, nonresponse bias does not appear to be an issue.

RESULTS AND DISCUSSION

In each subsection below, the data analysis will be organized in four parts when applicable. The first section will summarize the results obtained from the stratified sample of 2,400 builders. In addition, whenever possible, the results from the 1998 survey will be compared to the 1995 CINTRAFOR study on substitution in residential construction. The second section will discuss the survey results obtained using the segmentation analysis based on the geographic location of the firm. The third section will discuss the survey results relating to the influence of firm size on material substitution. The final section of each subsection will present the results obtained from the census of the Top 100 builders.

Profile of respondents

Sample size and response rate: Fifty-three of the 2,400 surveys were returned as undeliverable and 284, or 12.1% of the sample, were completed and returned (Table 3). Although this fell a bit short of the 300 responses anticipated, it represents a substantial improvement over the 11.7% response rate and 176 valid responses from the 1995 survey. When the responses obtained from the top 100 builders are included in the total set of responses, the overall response rate for the study improves to 12.8%.

Table 3. Sample size and response rate.

	Sample Size	Responses (N)	Response Rate (%)
Total	2347	284	12.1
Top 100	97	36	37.1

Regional distribution: The distribution of respondents by region was very even in 1998 (Table 4) in contrast to the 1995 survey, where responses from the Northeast greatly outnumbered those obtained from the other regions (Figures 4 and 5). This can be attributed to improvements made in the sampling frame as well as the survey design employed in the 1998 survey.

Distribution by firm size: Firms were asked to report their 1997 sales revenue using the mutually exclusive classifications presented in Figure 6. Respondents were later reclassified into two categories, small and large, based on their sales revenue. Firms reporting less than $1 million in annual revenue were classified as small firms, while those with more than $2.5 million in annual revenue (including the respondents from the Top 100) were classified as large firms (Table 5). This classification scheme eliminated 65 medium-sized firms from the analysis . This

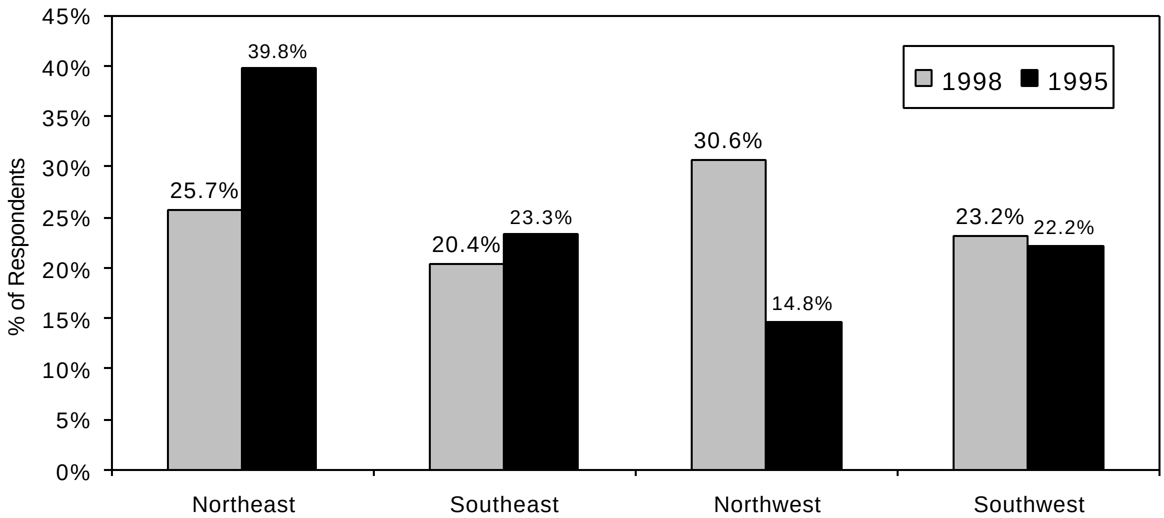

Figure 4. Distribution of respondents by region, 1998 vs. 1995.

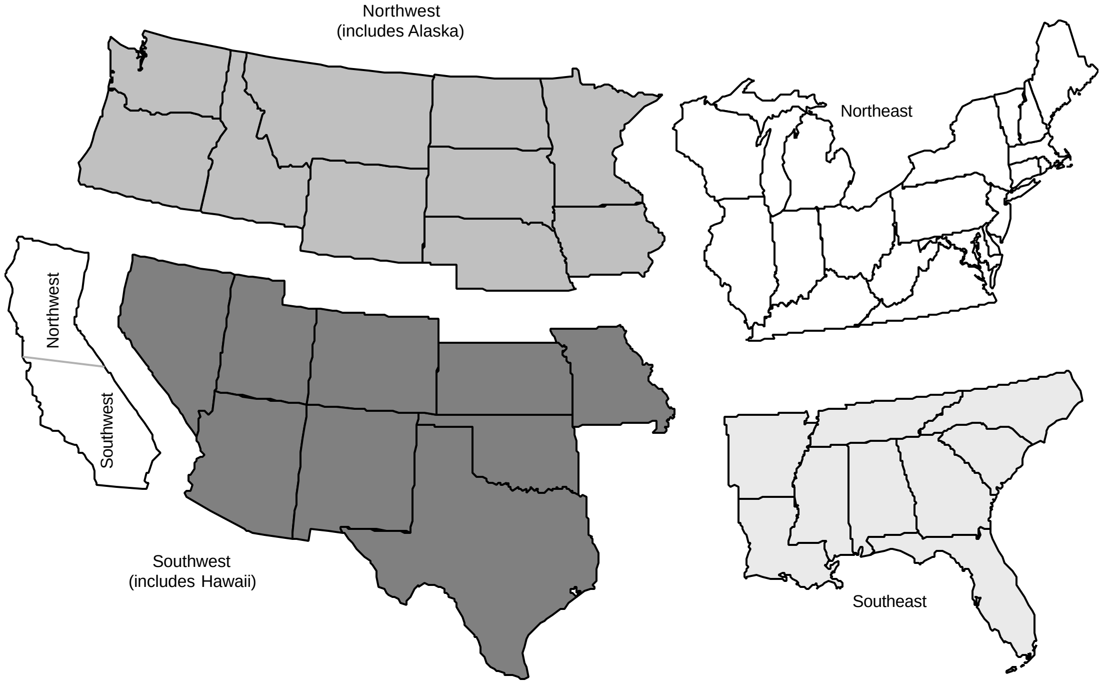

Figure 5. Regional breakdown of the US used in the survey.

Table 4. Response rate by geographic region.

	Sample Size	Responses (N)	Regional Response Rate (%)	% of Total Responses
Northeast	591	73	12.4	25.7
Southeast	585	58	9.9	20.4
Northwest	585	87	14.9	30.6
Southwest	586	66	11.3	23.2

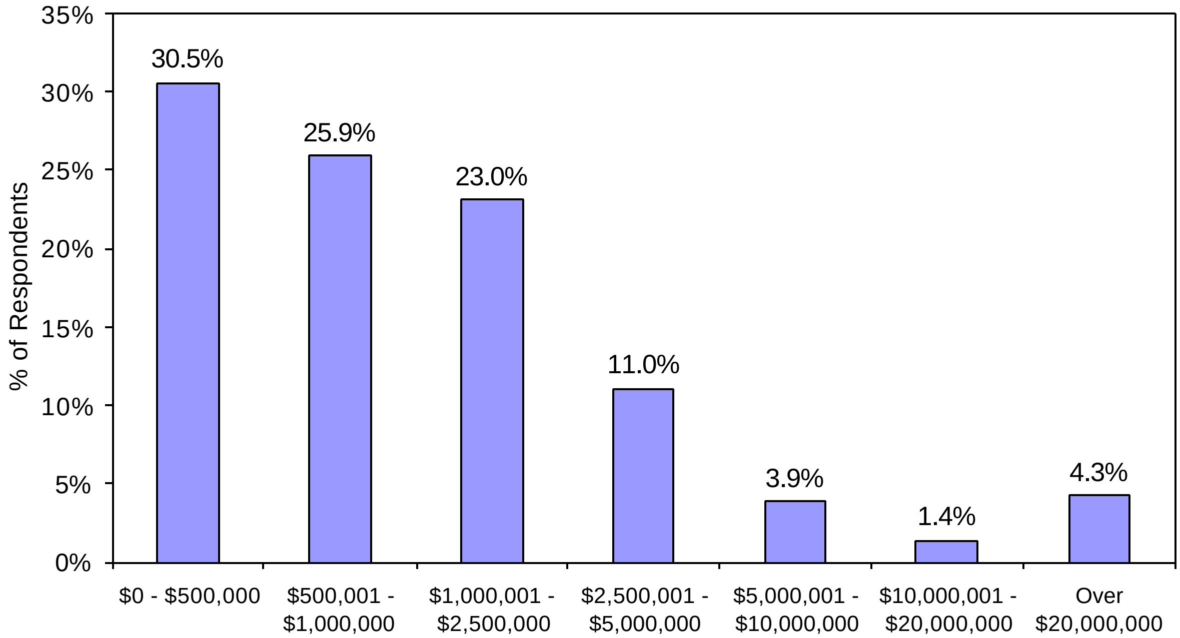

Figure 6. Respondents' 1997 construction revenue.

Table 5. Classification of respondent firm size into three groups.

	1998	% of Total	1995	% of Total
Small	159	56.4	58	33.5
Medium	107	37.9	69	39.9
Large	16	5.7	46	26.6
Total	**282**	**100.0**	**173**	**100.0**

analysis scheme resulted in two mutually exclusive industry segments (small firms and large firms), thus providing a better basis for comparison. On one hand, it simplifies statistical analysis and provides results that can be interpreted more clearly. On the other, it focuses the research on the two distinct target markets, while eliminating overlap between the two groups.

Top 100 respondents

Three of the Top 100 surveys were returned as undeliverable. Of the remaining 97 surveys, 36 were completed and returned, yielding a 37.1% response rate (Table 3). Distribution of the Top 100 firms by region (Table 6) indicates that more of the largest firms have developed in or chosen to maintain headquarters in the Southwestern US. Since this portion of the study was a census, the small number of respondents in the Northwest does not represent a source of bias in the sample selection process or in the results. However, the large differences in regional response rates indicate that the opinions of builders in the southeast and northwest are over-represented while the builders in the southwest and the northeast are underrepresented. This pattern of responses will tend to bias the results presented in the Top 100 geographical segmentation analysis.

Table 6. Distribution of Top 100 respondents by region.

	Sample Size	Responses (N)	Regional Response Rate (N)	% of Total Responses
Northeast	29	8	27.6	22.2
Southeast	26	16	61.5	44.4
Northwest	4	3	75.0	8.3
Southwest	38	9	23.7	25.0

Distribution of respondents by firm size, total sample: The distribution of respondents by 1997 sales revenue (Figure 6) is heavily skewed towards smaller builders. As discussed in the literature review, this is consistent with the industry in general. The 1995 study grouped respondents into small, medium, and large firms based on their reported earnings. Small firms reported less than $1 million in sales. Medium sized firms reported revenues greater than $1 million but less than $10 million. Large firms reported revenues greater than $10 million. The proportion of medium sized companies was nearly identical in the two studies, while the 1998 study contains a much higher proportion of small builders. This is another indication of improvements in the sampling frame. The lack of representation by small builders was cited as one of the limitations of the 1995 study (Eastin, Simon, and Shook 1996).

Regional distribution: There were no significant differences between the proportion of respondents in each region (Figure 7). This indicates that the stratification of the sample attained its desired effect, providing a representative sampling across the four regions. Please note that this does not include the Top 100.

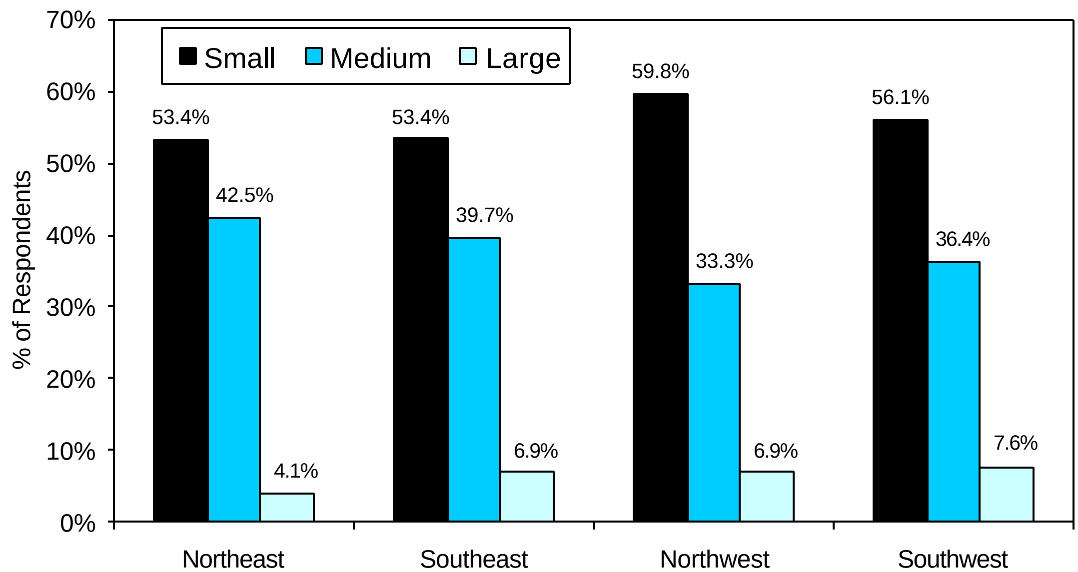

Figure 7. Regional distribution of respondents by firm size..

Distribution by firm size: Medium sized firms, with sales revenue between $1,000,001 and $2.5 million were excluded from this analysis to provide a clearer understanding of how large and small firms differ in their use of building materials. This information is very useful in the process of market segmentation. The small category remained the same as in the 1995 classification.
The large grouping contains 58 respondents from the total sample as well as the 36 respondents from the Top 100, effectively including all respondents with greater than $2.5 million in 1997 revenues (Table 7). This provides a large enough sample of the smallest and largest firms to make statistically meaningful comparisons between the two groups.

Table 7. Reclassification of firm size into two groups.

	# of Responses	% of Total
Small	159	49.7
Large	93	29.1
Total	252	78.8

Type of construction activity, total sample: Respondents were asked to estimate the percentage of their firm's 1997 sales revenue generated from each of the following business activities: single family residential construction, multi-family residential construction, repair/remodeling, nonresidential (commercial) construction, and patio/deck construction. The most interesting difference between the mean responses in 1998 and 1995 is the apparent decrease in new residential construction (both single and multi-family) and the corresponding increase in home improvement, decks, and nonresidential construction (Table 8). All three of the latter activities more than doubled from the earlier study. This undoubtedly is attributable to the differences in the response rate obtained from small, medium, and large firms in the 1998 study relative to the 1995 study. The differences between mean responses for single family construction, repair/remodeling, nonresidential construction, and deck construction were highly statistically significant. Multi-family residential construction was significant at the 7.7% level.

Table 8. Type of construction activity performed by survey respondents.

	1998 %	1995 %
Single Family	**52.3	**72.7
Multi-family	5.7	9.4
Repair/Remodeling	**26.6	**12.9
Patio/Decks	*2.4	*1.2
Nonresidential	**11.1	**3.2

Regional distribution: While none of the differences in mean activity rates between regions was statistically significant (Table 9), it is interesting to note which regions reported the highest rates of each activity. Single family construction is highest in the Southeast and is substantially higher than in the northeast and southwest. Multi-family and nonresidential construction was highest in the northwest and southwest, where employment growth and demographics drive growth in these segments. Repair/remodeling activity and deck construction was highest in the Northeast, presumably due to the increased age of the housing stock and severe climatic conditions.

Table 9. Type of construction activity by region.

	Northeast	Southeast	Northwest	Southwest
Single Family	49.1	58.5	53.5	48.7
Multi-family	5.3	4.2	6.8	6.2
Repair/Remodeling	32.5	27.0	20.9	27.5
Patio/Decks	2.8	2.3	2.6	1.9
Nonresidential	8.6	7.9	13.6	13.5

Distribution by firm size: In comparing the mean activity rates between small and large firms, all categories, with the exception of nonresidential construction, showed differences with a statistical significance of less than .01 (Table 10). Large firms concentrate much more on single and multi-family construction, leaving repair/remodeling and deck construction almost exclusively to the smaller firms (Figure 8).

Top 100 respondents: The Top 100 firms reported that 98.8% of their 1997 revenue was generated in either single or multi-family construction (Table 10 and Figure 8). Interestingly, multi-family construction by the Top 100 firms is substantially higher than that for large firms. By the same token, almost 10% of small firms were involved in nonresidential construction while virtually none of the Top 100 firms were.

Table 10. Type of construction activity by firm size, 1998 vs. 1995.

	Small Firms		Large Firms		Top 100
	1998	1995	1998	1995	1998
Single Family	**44.9	53.7	**62.3	80.3	57.4
Multi-family	**1.0	5.2	**25.0	17.8	39.4
Repair/Remodeling	**38.2	30.4	**4.7	0.5	0.6
Patio/Decks	**4.0	3.2	**0.2	0.0	0.0
Nonresidential	9.3	6.1	6.4	0.6	0.6

**significant at .01 level

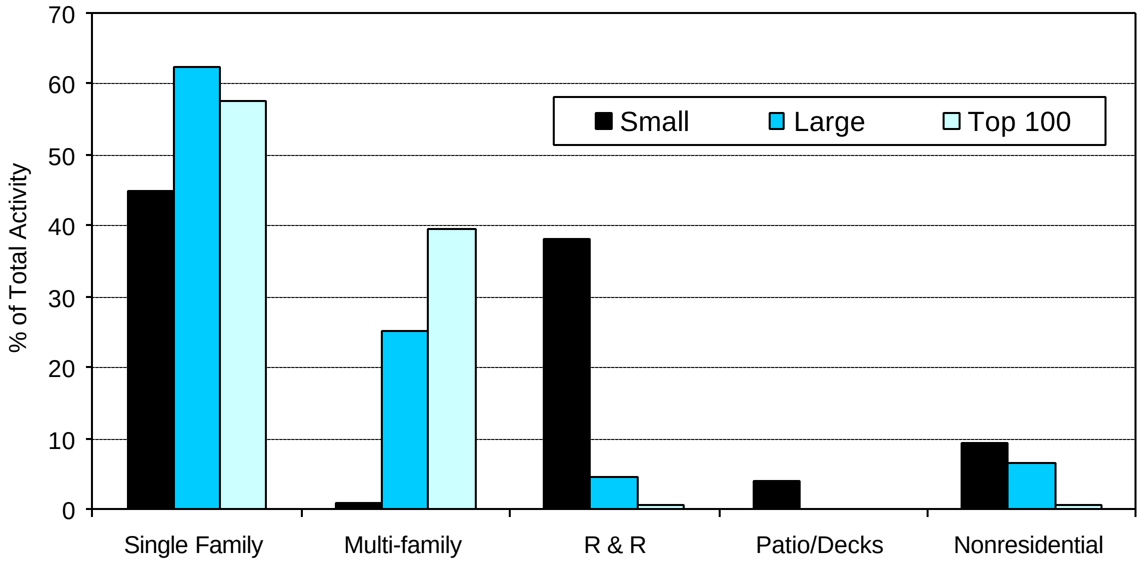

Figure 8. Type of construction activity, firm size.

Use of structural materials

Use of substitute products: For each of the 13 products listed, respondents were asked whether their usage had increased, decreased, or remained the same during 1998. They were also given the option "have never used this product." The structural products included in the survey are summarized in Table 13. In the current study just 3 of 284 respondents (1.1%) reported using softwood lumber only, thus never having used any of the 12 substitute products mentioned. This compares with 8.5% of the respondents in the 1995 study (Table 11).

Table 11. Number of respondents using at least one substitute for softwood lumber.

	1998	1995
Total respondents	284	176
# reporting usage	281	161
% who have used a substitute	98.9%	91.5%
% who have not used a substitute	1.1%	8.5

Total number of substitute products used

Total sample: This section describes the breadth of the product mix reported by respondents who have used substitutes. While it is difficult to compare the 1998 results with the 1995 results directly, since the 1998 study contained two new substitute products, the relative trends in the two data sets are very similar (Figure 9). In a general sense, the data indicates that most builders have used a variety of substitutes in structural framing applications. Approximately half of the 1998 respondents have tried at least 6 of the 12 substitutes, while approximately half of the 1995 respondents had tried only three of the ten substitutes listed (Table 12). The outward shift of the 1998 material use line shown in Figure 9 clearly shows that builders are using more substitute products over time. This would seem to imply that they are now more willing to try new materials as they gain experience in evaluating these products. If this is true, it leads to an interesting question: once a builder has undergone the process of evaluating and trying a new product, will s/he be more willing to evaluate other structural substitute products, and how does this impact future specification of structural framing products?

In the past, builders have tended to be conservative and risk averse in their specification and use of structural framing materials, relying almost exclusively on softwood lumber. However, research clearly shows that many builders have become more willing to explore the opportunities provided by substitute materials. This is a clear indication that they have become dissatisfied with some aspect of softwood lumber. Given the extent of builders'

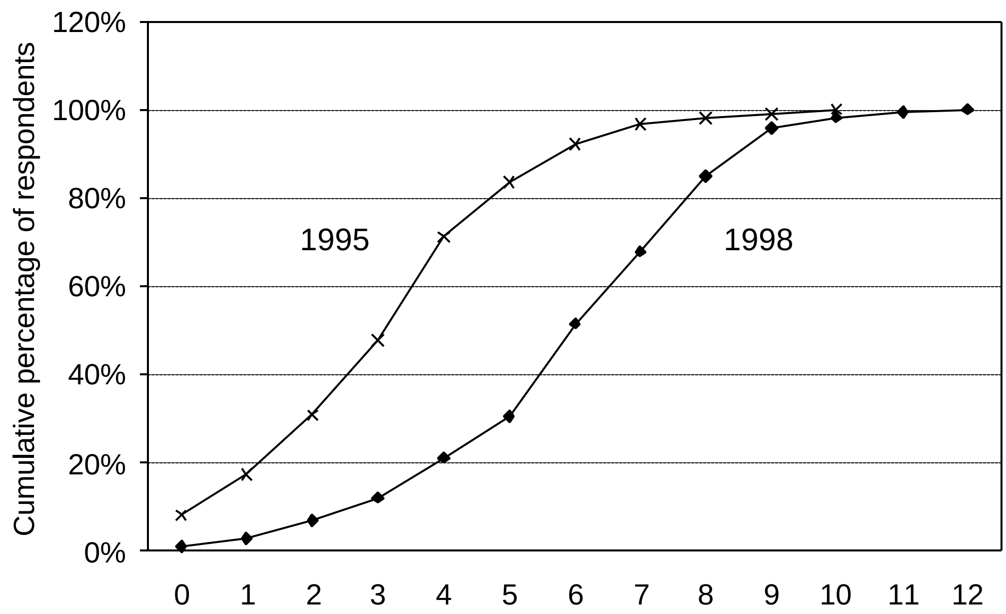

Figure 9. Total number of substitute products used, 1998 vs. 1995.

Table 12. Total number of substitute products used, 1998 vs. 1995.

	1998			1995		
Substitutes (N)	**Frequency**	**%**	**Cumulative %**	**Frequency**	**%**	**Cumulative %**
0	3	1.1	1.1	14	8.1	8.1
1	5	1.8	2.9	16	9.1	17.2
2	11	4.0	6.9	24	13.6	30.8
3	14	5.1	12.0	30	17.0	47.8
4	25	9.1	21.2	41	23.3	71.1
5	26	9.5	30.7	22	12.5	83.6
6	57	20.8	51.5	15	8.5	92.1
7	45	16.4	67.9	8	4.5	96.6
8	47	17.2	85.0	6	3.4	100
9	29	10.6	95.6	0	0	100
10	7	2.6	98.2	0	0	100
11	3	1.1	99.3	--	--	--
12	2	0.7	100	--	--	--

use of substitute materials over time, it could reasonably be concluded that their dissatisfaction with softwood lumber is not a transient phenomenon resulting from price instability in the early 1990's. This is illustrated by the fact that their use of almost every substitute product has increased significantly between 1995 and 1998. Clearly builders are not satisfied with softwood lumber and they have begun to actively look for substitutes that better meet their needs.

Distribution by firm size: The trend for small and large firms is similar to the total sample, but is slightly weighted towards the use of a greater mix of substitutes in large firms. Approximately half of the small firms responding reported use of at least 6 of the 12 substitutes listed. For large firms, approximately half of the respondents have used at least 7 of the 12 substitutes. This suggests that large firms may tend to experiment with, and potentially adopt, a slightly broader mix of building products.

Top 100: The data suggest that there is little difference between large firms and the top 100 firms with respect to the number of substitute products that they have used. The only substantial difference between the two groups of builders is that a somewhat higher percentage of the top 100 firms reported using two or fewer substitutes (8%) than did large builders in general (3%).

Percentage of firms reporting usage of each substitute product: The survey data was used to calculate the percentage of respondents who reported using each substitute product, as well as the change from 1995 (Table 13). The results clearly show that all of the substitute products were used by a higher proportion of builders in 1998, some to a dramatic extent (Figure 10). This is demonstrated by the fact that the difference between the 1998 data and the 1995 data was statistically significant for all products with the exception of finger jointed lumber. Seven of the 12 products listed (LSL, wood trusses, PSL, reinforced concrete, LVL, wood I-joists, and glulam beams) have been used by more than 60% of the respondents. Glulam beams retained their position as the most commonly used substitute product,

Table 13. Percentage of firms reporting usage of each substitute product, 1998 vs.1995.

Substitute product	1998 (%)	1995 (%)	% change
Glulam beams	**86.6	**72.7	19.1
Wood I-joists	**85.8	**55.1	55.7
LVL#	**82.3	**46.6	76.6
Reinforced concrete	**78.4	**29.5	165.7
PSL#	**70.0	**42.6	64.4
Wood/steel trusses	**64.3	**37.5	71.6
LSL#	62.1	n/a	n/a
Steel framing	**43.8	**26.7	63.9
WPC# lumber	**29.6	**8.5	248.3
Finger-jointed lumber	24.6	19.3	27.7
Structural insulated panels	*22.8	*14.8	54.0
PVC lumber	**3.9	**0.0	n/a

**significant at .01 level *significant at .05 level; #LVL, laminated veneer lumber; PSL, parallel strand lumber; LSL, laminated strand lumber; WPC, wood-plastic

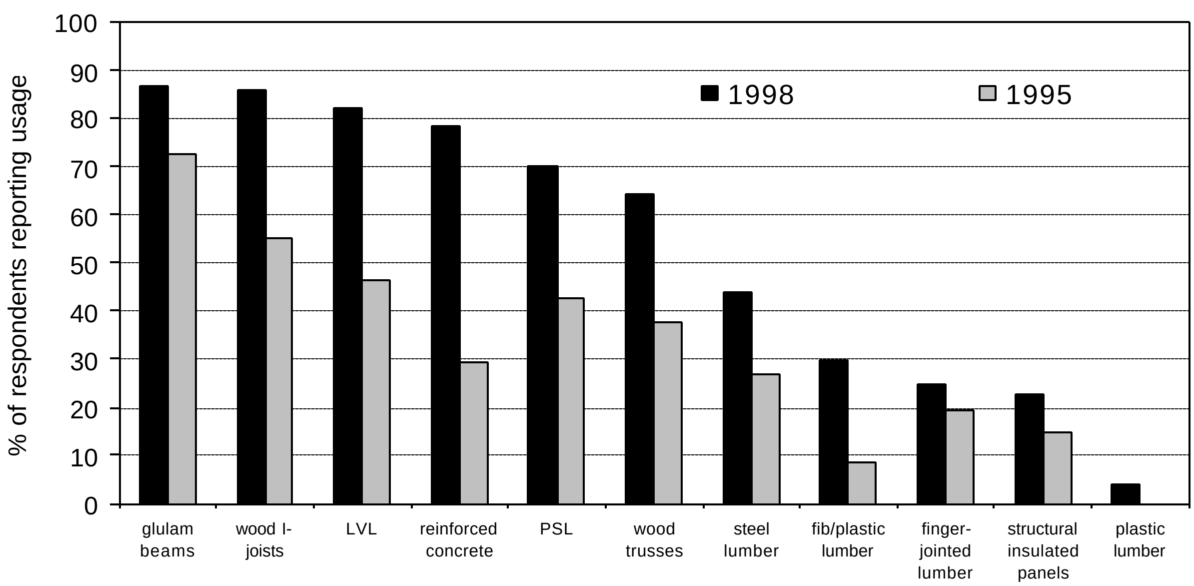

Figure 10. A comparison of substitute product usage, 1998 vs. 1995.

Table 14. Percentage of firms reporting usage of each substitute product by region.

Substitute product	Northeast	Southeast	Northwest	Southwest
Glulam beams	*81.4	*78.6	*91.7	*92.4
Wood I-joists	*83.3	*74.1	*89.4	*93.9
LVL	90.1	75.4	83.5	78.1
Reinforced concrete	71.8	80.0	77.4	85.7
PSL	*69.4	*54.5	*73.8	*78.8
Wood/steel trusses	*67.6	*63.0	*54.2	*75.0
LSL	**53.8	**47.2	**74.4	**67.2
Steel framing	*45.1	*38.2	*35.7	*58.1
WPC lumber	29.6	22.4	33.3	31.3
Finger-jointed lumber	*13.9	*17.9	*29.9	*35.4
Structural insulated panels	26.5	15.8	21.7	26.6
PVC lumber	0.0	3.4	4.8	7.6

**significant at .01 level *significant at .05 level

increasing from 72.7% in 1995 to 86.6% in 1998. Reinforced concrete, LVL, and wood/steel open web trusses showed the most dramatic increases. It is interesting to note that almost half of the respondents reported that they have used steel lumber, a 63.9% increase since 1995. While the use of wood/plastic composite lumber has increased by almost 250% since 1995, the data indicates that it is primarily being used to build decks.

Regional distribution: The results presented in Table 14 clearly indicate that builders in the US west have been much more aggressive in using substitute products. For 11 of the 12 products, builders in the west reported the highest usage, with builders in the southwest leading the way in substitute usage for 9 products. In contrast, builders in the southeast reported the lowest usage rate for almost every product. A statistical analysis of the data shows that the number of builders using half of the products (glulam, wooden I-joists, parallam, LSL, steel, and finger-jointed lumber) was significantly higher in the southwest. This dramatic difference in material use can most likely be attributed to two factors, the first related to geography and the second related to climate. First, builders in the southeast have ready access to the abundant southern pine resource and therefor appear to be less willing to try substitute materials. In contrast, with little dimension lumber production occurring in the southwest, builders in this region appear to be more willing to try substitute materials. Secondly, the hot and dry climate in the southwest provides builders with a strong incentive to use dimensionally stable materials in framing their houses and is likely the reason for their significantly higher use of substitute materials.

Distribution by firm size: Large firms reported a higher usage of virtually every substitute product than did small firms (Table 15), although in many cases these differences were small. The largest differences in usage were seen with finger-jointed lumber, structural insulated panels, LVL, LSL, and PSL. These are newer products and/or those that pose a higher degree of uncertainty, and therefore risk, to the builder. The difference in the use of these products between small and large builders was statistically significant for all of these products, with the exception of LSL.

Table 15. Percentage of firms reporting usage of each substitute product, by firm size.

	Small	Large	Top 100
Finger-jointed lumber	**18.5	**47.3	65.7
Steel framing	41.2	42.4	35.5
WPC lumber	33.5	34.8	41.7
Reinforced concrete	77.0	83.0	78.8
Plastic lumber	5.1	4.3	8.3
Structural insulated panels	**17.6	**40.2	48.5
Wood I-joists	82.2	82.4	83.3
Wood/steel trusses	55.6	62.9	73.5
LVL	*78.6	*88.2	86.1
LSL	59.1	70.9	79.4
PSL	**62.2	**79.3	77.8
Glulam beams	81.3	87.9	80.0

**significant at .01 level *significant at .05 level

Top 100 respondents: The largest builders reported the highest usage of the newer, more innovative products, including structural insulated panels, LSL, and wood-plastic composite lumber. They also reported the highest usage of wood I-joists, wood/steel open web floor joists, and finger-jointed lumber. Their higher use of these materials is probably related to two factors: their emphasis on multi-family projects and their greater acceptance of engineered wood systems. In contrast, it is interesting to note that this segment of the industry reported the lowest use of steel framing and glulam beams. Their use of substitute materials may be a reflection of the fact that these builders tend to focus on large housing developments incorporating standardized house designs that allow them to take advantage of the cost savings inherent in engineered wood systems.

Trial use curves

To facilitate the development of trial use curves for the various structural framing materials, survey respondents were asked to specify the year in which they first used each product. This information provided the basis for constructing trial use curves for four structural framing materials (i.e., wood I-joists, LVL, steel lumber, and finger-jointed lumber). It is important to differentiate between using a material and adopting a material. Survey respondents were simply asked if they had ever used each product and no effort was made to determine if they had since adopted the product.

The trial use of finger-jointed lumber and steel lumber are increasing, trial use of LVL and wood I-joists has continued to accelerate (Figure 11). The two former products have yet to be sampled by the majority of builders. For the sake of this discussion, we can view the trial use trends presented in Figure 12 as a reflection of the "Product Life Cycle" concept (PLC) used in marketing. The PLC concept states that every product passes through four stages during the course of its life cycle: introduction, growth, maturity, and decline. Figure 12 suggests that in 1970 all four materials were relatively new to the market. During the 1970's and 1980's, all four products hovered below the 10% use level, corresponding to the introduction phase of the PLC. However, by the late 1980's we begin to see a differentiation in the trial use curves for wood I-joists and LVL relative to steel and finger-jointed lumber. Both wood I-joists and LVL experienced tremendous growth in their trial use rates, indicating that they had entered the growth phase of the PLC. In contrast, the growth in the trial use of steel and finger-jointed lumber has been much more modest. While both products are in the growth stage of the PLC, the slope of their growth curve is substantially lower than that of wood I-joists and LVL. By 1997, both wood I-joists and LVL had reached trial use rates of 74 and 67%, respectively, and given their high trial use rates and declining rate of growth, it would appear that they are entering the maturity phase of the PLC. Steel lumber, with a trial use rate of almost 25%, and finger-jointed lumber with a trial use rate of less than 15%, are clearly in the early stage of the growth cycle and these products have plenty of room for growth.

There are some distinctions to be made, however. The steel industry has promoted a rivalry between steel studs and softwood lumber by targeting promotional campaigns at single-family housing contractors and homebuyers in an effort to expand into a relatively new segment of the construction market. Steel studs, which are more commonly used in commercial and multi-family residential construction, are a mature product with which many builders have some familiarity through their involvement in multi-family and commercial construction projects. Finger-jointed lumber is a somewhat newer product that is early in the growth stage of its product life cycle. Given the well publicized resistance of builders to using steel framing materials, it appears unlikely that steel lumber will experience tremendous growth in market share the near future. In contrast, the demand for finger-jointed lumber has the potential to continue growing if production and logistical bottlenecks can be resolved. Another factor limiting the market growth of finger-jointed lumber to date is the widely held misperception among builders that it is not as strong as solid sawn lumber.

Increased/decreased product usage ratios

While the trial use curves are useful in assessing builders' use of substitute materials, they provide no information on whether builders are increasing or decreasing their use of different materials. To better understand how builders' use of substitute materials is changing over time, survey respondents were asked to indicate if their use of different structural materials had increased, decreased, or stayed the same over the past two years. Respondents were also allowed to indicate if they had never used the product. A summary of the builder material use information is

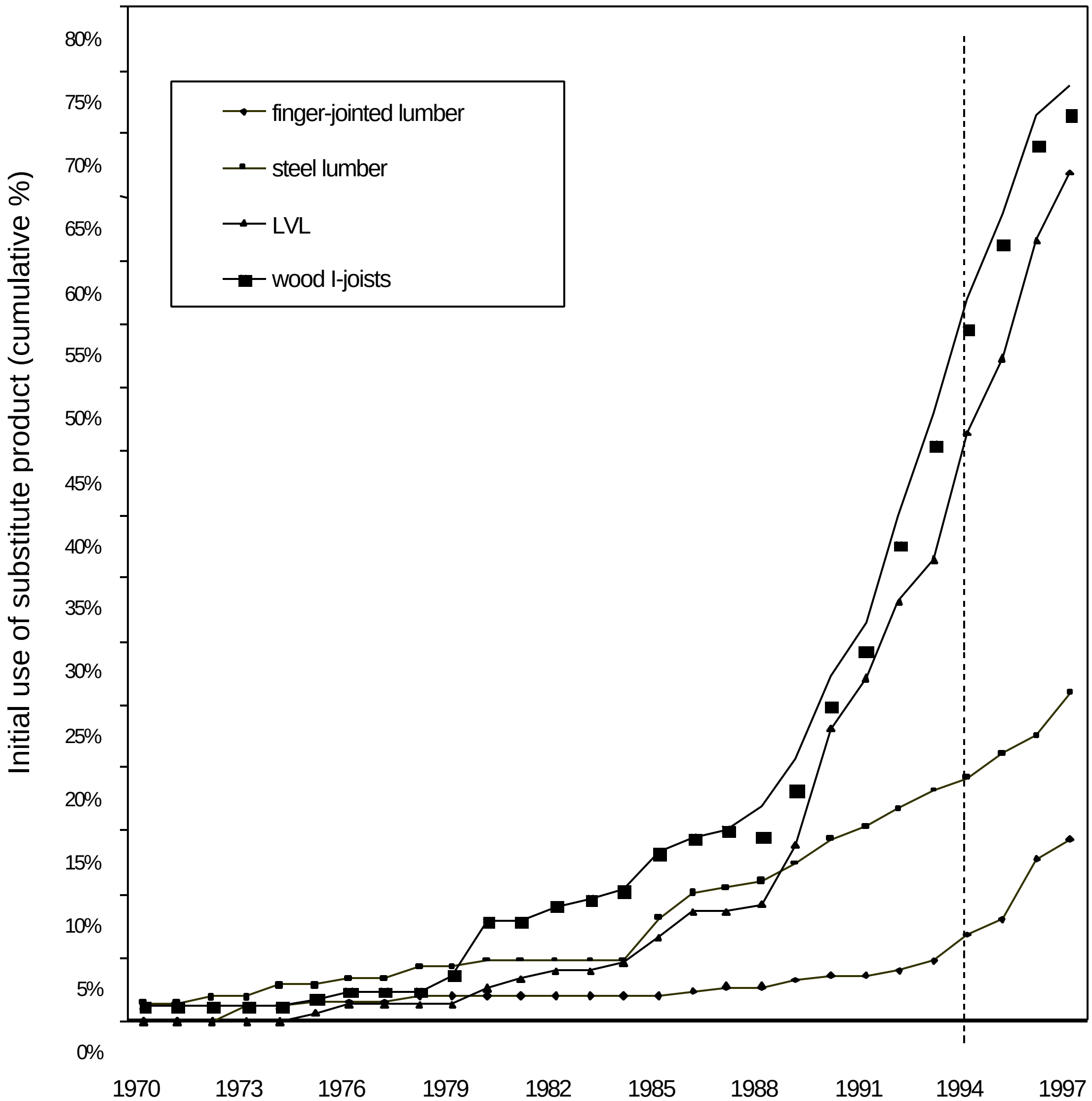

Figure 11. Trial use curves for four structural products.

Table 16. Respondents changing use of substitute structural materials.

	Increased	Decreased	Unchanged	Never used
Softwood lumber	61	76	174	0
Wood I-joists	132	13	118	46
LVL	130	8	115	54
Parallam	106	12	99	90
LSL	95	5	86	106
Glulam	82	37	143	43
Wood/steel trusses	57	14	117	112
WPC lumber	57	7	29	214
Reinforced concrete	56	15	164	65
Steel framing	46	15	66	170
FJ lumber	33	18	37	221
SIP’s	27	14	33	225
PVC lumber	4	3	6	297

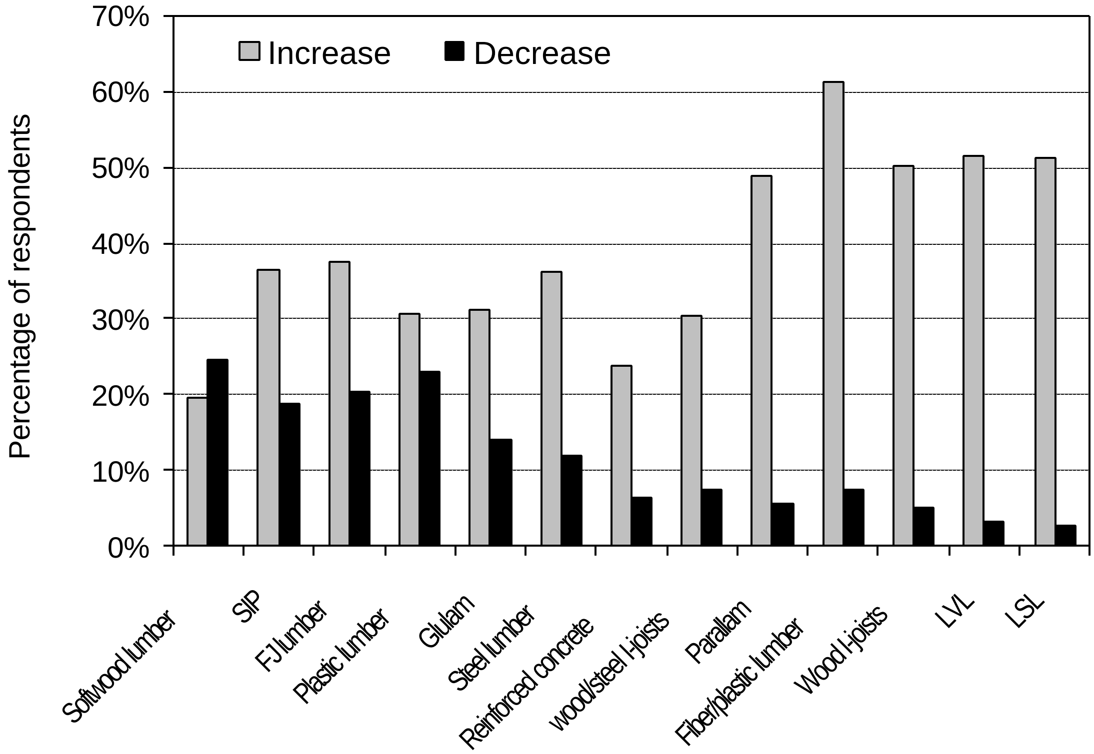

Figure 12. Trends in material use reported by respondents.

presented in Table 16 and Figure 12. The first point to note is that, of all the building materials evaluated, only softwood lumber showed a higher number of builders decreasing vs increasing use of the product. Fully 40% of the respondents reported that they have decreased their use of softwood lumber in the past two years. In contrast, for virtually every other product evaluated, the number of builders reporting an increase in use greatly exceeded those reporting a decrease in use. The greatest increases in product use occurred for wood I-joists, LVL, parallam, and LSL, all of which are engineered wood products. Other products experiencing more moderate increases in use include glulam, wood/steel open web joists, wood/plastic composite lumber, reinforced concrete, and steel. Finally, several products have been largely untried by residential contractors including, PVC lumber, structural insulated panels, finger-jointed lumber, wood/plastic composite lumber, and steel.

Product use in specific end-use applications

Respondents were asked to estimate the percentage of each of six framing materials (softwood lumber, wood trusses, finger-jointed lumber, wood I-joists, LVL, and steel lumber) they used in each of three end-use applications (i.e., wall, floor, and roof framing). Since these three end-use applications represent the largest consumption of structural framing materials, they are key indicators of material substitution patterns.

Total sample: Comparing the 1998 results with those from 1995, softwood lumber lost ground from its position of dominance in wall framing (Table 17), particularly to steel lumber. Differences in reported usage of softwood, steel framing, and LVL were all highly statistically significant. Respondents' usage of softwood lumber and open web trusses in floors declined as well. Wood I-joists, meanwhile, increased almost 70% over 1995. Once again, differences in reported usage of softwood, steel lumber, and LVL were highly statistically significant. In roof construction, wood truss usage actually overtook softwood usage, although the use of wood trusses increased only

Table 17. Product usage in specific end-use applications, 1998 vs. 1995 (%).

Product	Wall framing 1998	Wall framing 1995
Softwood lumber	**83.1	**93
Steel	**8.8	**0
Finger-jointed lumber	5.3	4
Wood truss	1.1	0
LVL	**0.8	**0
Wood I-joist	0.4	0
Product	**Floor framing 1998**	**Floor framing 1995**
Softwood lumber	**41.8	**59
Wood I-joist	**38.8	**23
Open web wood truss	10.4	16
LVL	*3.0	*0
Steel	2.2	2
Finger-jointed lumber	0.3	0
Product	**Roof framing 1998**	**Roof framing 1995**
Wood truss	47.7	46
Softwood lumber	**40.0	**51
Wood I-joist	3.4	2
Steel lumber	**2.9	**1
LVL	**2.7	**0
Finger-jointed lumber	1.3	0

**significant at .01 level *significant at .05 level

slightly. The real shift occurred in gains made by other substitute products at the expense of softwood lumber's market share. Changes in the use of softwood lumber, steel framing, and LVL were all highly significant.

Despite recent marketing campaigns and concern from softwood lumber producers, steel lumber did not exhibit market share gains in any of the three end-use applications. While there seems to be some emotional rivalry between the two products, steel framing is clearly not the biggest threat to softwood lumber's traditional dominance of the construction market. The use of steel framing is increasing over time, but the use of engineered wood products is increasing at a much faster rate.

Regional distribution: The share of softwood lumber in wall framing was fairly even across all four regions (Table 18), although it had declined substantially in all four regions, ranging from a 6.2% decline in the southeast to a 9.5% decline in the southwest. The decline in softwood lumber market share was largely offset by a gain in market share for steel framing. As a result, steel framing saw its market share increase to almost 10% across all regions, up from

Table 18. Product usage in wall framing by region, 1998 vs. 1995 (%).

	Northeast		Southeast		Northwest		Southwest	
Wall framing	**1998**	**1995**	**1998**	**1995**	**1998**	**1995**	**1998**	**1995**
Softwood lumber	86.1	95.0	83.4	89.6	82.1	90.4	80.6	90.1
Wood truss	2.1	1.3	0.3	0.0	0.9	1.3	0.8	0.3
Finger-jointed lumber	2.0	0.1	4.8	4.0	7.8	8.0	6.2	5.4
Wood I-joist	0.1	0.0	0.0	0.0	0.2	0.0	1.4	0.3
LVL	0.5	0.0	0.6	0.0	1.6	0.0	0.4	0.1
Steel	9.2	3.6	10.6	2.7	7.4	1.5	8.5	2.6

just 2.5% in 1995. Finger-jointed lumber also saw its overall market share increase from approximately 4% in 1995 to 6% in 1998. The share of finger-jointed lumber in the west was similar to that of steel framing, whereas it was substantially smaller in the east, particularly the northeast.

Whereas softwood lumber registered a moderate decline in wall framing, it suffered significant declines in floor framing across all regions, including 21.9% and a 15.9% loss of market shares in the northwest and southeast, respectively (Table 19). This represents a dramatic shift from 1995 when softwood lumber was the dominant material used to frame floors in all four regions. By 1998, the dominant floor framing materials in the west was wood I-joists while softwood lumber still managed to cling to a slight lead in the northeast, although wood I-joists experienced double-digit market share gains in both regions. Open web wood floor trusses also suffered substantial losses in market share, particularly in the south. In contrast, LVL registered increased usage in the west, increasing to 3.1% and 5.7% market shares in the northwest and southwest, respectively. The serious termite problems in the southeast helped steel increase its share of the floor framing market from 0.4% in 1995 to 7.1% in 1998.

Table 19. Product usage in floor framing by region, 1998 vs. 1995 (%).

	Northeast		Southeast		Northwest		Southwest	
Floor framing	**1998**	**1995**	**1998**	**1995**	**1998**	**1995**	**1998**	**1995**
Softwood lumber	**58.7	64.2	**45.9	61.8	**29.4	51.3	**35.5	44.6
Wood truss	10.1	11.5	14.0	21.7	8.3	8.8	10.5	19.7
Finger-jointed lumber	0.5	0.0	0.0	0.0	0.6	0.0	0.0	0.0
Wood I-joist	**26.1	15.7	**22.2	14.8	**55.9	39.9	**44.7	31.4
LVL	1.9	1.2	1.1	1.3	3.1	0.1	5.7	1.2
Steel	**0.8	2.2	**7.1	0.4	**1.3	0.0	**0.5	0.0

**significant at .01 level

In roof framing, Northwestern builders once again showed a distinct preference (Table 20). In this case, they are substituting wood trusses for solid wood lumber. Solid wood usage is significantly lower in the Northwest. Both wood truss and wood I-joist usage are significantly higher in the Northwest. Solid wood and wood truss usage are

Table 20. Product usage in roof framing by region, 1998 vs. 1995.

	Northeast		Southeast		Northwest		Southwest	
Roof framing	**1998**	**1995**	**1998**	**1995**	**1998**	**1995**	**1998**	**1995**
Softwood lumber	48.0	52.5	46.0	59.4	29.1	49.4	40.4	45.6
Wood truss	44.4	43.0	42.0	37.6	57.4	44.0	43.1	50.4
Finger-jointed studs	0.0	0.0	1.7	0.0	1.3	4.2	2.5	1.1
Wood I-joist	1.1	2.1	2.4	1.9	5.1	2.4	4.7	2.6
LVL	1.6	0.9	0.9	0.0	2.7	0.1	5.6	0.3
Steel	0.7	0.0	5.4	1.1	2.8	0.0	3.3	0.1

almost identical across every region except the Northwest. Wood I-joist usage, however, was significantly higher in the West. Softwood lumber also suffered substantial declines in roof framing, ranging from 5% in the northeast and southwest to 13.4% in the southeast and 20.3% in the northwest. Wood trusses, with moderate increases in use in most regions, exhibit market shares on par with softwood lumber, although they have twice the market share of lumber in the northwest. Wood I-joists increased to 5% of the roofing market in the west while LVL showed modest increases in all regions, particularly the southwest where it has a 5.6% market share. Steel also registered modest increases in all regions.

Steel usage varies substantially across end-uses and regions, ranging from 10.6% and 9.2% of wall framing in the southeast and northeast to less than 1% of floor and roof framing in the northeast. This variability leads to some ambiguity regarding the extent to which steel has been accepted as a framing system in residential construction. By focusing the analysis on a regional basis we can begin to estimate the share of residential housing starts that utilize the steel framing system. Logically, the share of the steel framing system would be limited by its lowest market share across the all three end-use applications. On this basis, we can estimate that, at most, the market share of the steel framing system is approximately 1% in the northeast, northwest, and southwest while it is just over 5% in the southeast.

Finger-jointed lumber is primarily used in wall framing applications with market shares reaching 7.8% and 6.2% in the northwest and southwest, respectively. In contrast, LVL is used primarily in floor and roof framing applications in the western regions. The use of open web floor trusses declined substantially in all regions while roof truss use increased in all regions with the exception of the southwest.

3. Distribution by firm size: The results show a sharp distinction in product preferences between small and large firms. In wall framing, large firms use a significantly higher percentage of finger-jointed lumber and a significantly lower percentage of solid wood lumber (Table 21). This difference in material use seems to have developed since 1995, with large firms exhibiting a 17.9% decline in softwood lumber use. This decline was offset by an 8.7% increase in finger-jointed lumber and a 6.7% increase in steel use. These changes highlight the fact that larger firms clearly favor finger-jointed lumber to a much greater extent than do small firms.

Table 21. Product usage in wall framing by firm size, 1998 vs. 1995 (%).

Wall framing	Small 1998	Small 1995	Large 1998	Large 1995	Top 100 1998
Softwood lumber	**88.8	93.0	**74.1	92.0	71.3
Wood truss	1.5	0.2	0.8	0.0	1.4
Finger-jointed studs	**1.8	0.3	**14.4	5.7	19.0
Wood I-joist	0.3	0.2	0.1	0.0	0.0
LVL	0.6	0.0	1.0	0.1	0.3
Steel	6.3	3.9	8.9	2.2	7.5

**significant at .01 level

In floor framing applications, both large and small builders decreased use of softwood lumber approximately 15% since 1995 (Table 22). Much of this decline was offset by the increased use of wood I-joists. In comparing material use across small and large firms, small firms relied almost exclusively on softwood lumber and wood I-joists while large builders' use was split between three materials: softwood lumber (28.2%), open web wood trusses (26.6%), and wood I-joists (35.2%). One big difference between large and small builders is that while large builders continue to increase their use of open web trusses, small builders appear to be moving away from this product (Figure 13).

Small builders continued their shift away from softwood lumber in roof framing, with use declining more than 15% since 1995 (Table 23). In contrast, large builders' material use patterns have remained relatively stable since 1995. In 1998, softwood lumber use in roof framing had dropped to 44.4% and 22.8% for small and large builders,

Table 22. Percentage of product usage in floor framing by firm size, 1998 vs. 1995.

Floor framing	Small 1998	Small 1995	Large 1998	Large 1995	Top 100 1998
Softwood lumber	**48.9	62.3	**28.2	45.3	18.5
Wood truss	**8.8	12.3	**26.6	24.7	46.4
Finger-jointed lumber	0.2	0.0	0	0.0	0
Wood I-joist	36.4	20.6	35.2	24.4	28.5
LVL	1.4	1.2	4.3	0.3	0.3
Steel	0.7	0.5	1.7	0.4	0.6

**significant at .01 level

Table 23. Product usage in roof framing by firm size, 1998 vs. 1995 (%).

Roof framing	Small 1998	Small 1995	Large 1998	Large 1995	Top 100 1998
Softwood lumber	**44.4	60.0	**22.8	27.2	18.3
Wood truss	**43.3	33.9	**66.9	69.0	77.6
Finger-jointed lumber	1.2	1.7	1.4	0.0	0.0
Wood I-joist	3.6	1.6	1.7	2.8	0.6
LVL	3.1	1.1	4	0.0	2.9
Steel	0.6	0.0	3.3	1.0	0.6

**significant at .01 level

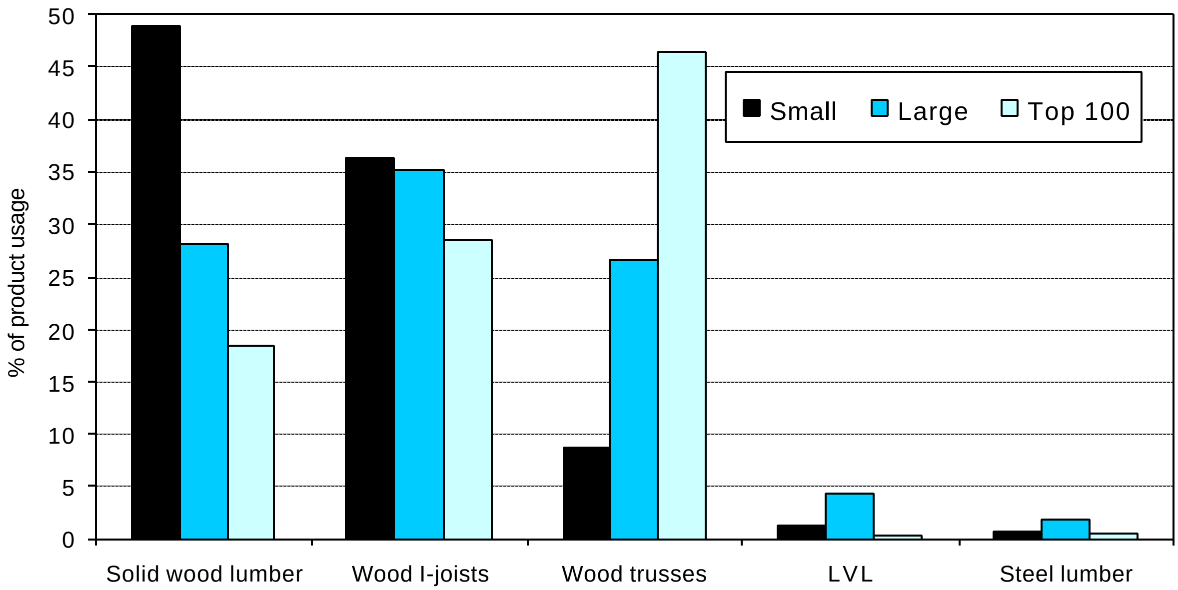

Figure 13. Product usage in floor framing, by firm size.

respectively. Whereas small builders material use was only split between roof trusses and softwood lumber, large builders used roof trusses almost two-thirds of the time.

Top 100 respondents: Top 100 results were unsurprising with regard to all three end use applications. The Top 100 respondents mirrored and/or exaggerated the tendencies of large firms quite consistently. In some cases the differences between the Top 100 firms and the small firms are extremely noticeable. In wall framing, the Top 100 builders reported lower usage of softwood lumber and higher usage of finger-jointed studs. In floor and roof framing, softwood lumber has a minor market share among the Top 100. There is a noticeable preference for open web wood trusses rather than wood I-joists in floor framing.

Change in softwood lumber use

Survey respondents were asked to indicate how their use of softwood lumber as a structural framing material had changed over the past two years using a 7-point scale (1 = no change at all, 4 = moderate change, and 7 = significant change). For purposes of comparison, the responses from the 1998 and 1995 studies have been grouped into three categories: little or no change, moderate change, and significant change (Table 24). The 1998 data mirrors that from the 1995 study remarkably well. The majority of respondents (57%) reported that their use of softwood lumber has been changing moderately, and this proportion was unchanged from 1995. Approximately one-third of the

Table 24. Change in softwood lumber usage, 1998 vs. 1995.

1995 (10-point scale)				1998 (7-point scale)			
Scale Rating	**%**	**Group %**	**Degree of change**	**Scale Rating**	**%**	**Group %**	**Degree of change**
1	7.9			1	16.8		
2	11.5	**33.9**	***Little or none***	2	14.1	**30.9**	***Little or none***
3	14.5						
4	17.6			3	15.5		
5	18.2	**57.0**	***Moderate***	4	30.3	**57.0**	***Moderate***
6	11.5			5	11.2		
7	9.7						
8	6.1			6	7.9		
9	2.4	**9.1**	***Significant***	7	3.9	**11.8**	***Significant***
10	0.6						

respondents reported that their use of softwood lumber has remained the same over the past two years while about 10% reported a significant change. These proportions were essentially unchanged from the 1995 study. From a regional perspective, the results suggest that builders' use of softwood lumber in the west is changing much more rapidly than in the east (Tables 25 and 26). Almost 40% of the builders in the northwest reported that their use of softwood lumber has decreased while just 10% of the respondents in the southeast reported a decline. In contrast, just 20% or less of respondents in all regions reported that their use of softwood lumber has increased in the past two years. The survey data also indicates that large firms have decreased their use of softwood lumber to a greater extent than have small firms (24.2% versus 18,2%), although this difference was not significant (Tables 25 and 26).

Importance ratings of product attributes

Attribute importance ratings: Any product can be viewed as a basic product that is enhanced by a variety of product attributes. These product attributes can, to a greater or lesser degree, influence the competitiveness of the product relative to other substitute products. In order to develop a better understanding of the relative importance that builders attach to specific product attributes when purchasing structural framing materials, respondents were asked to rate the importance of different product attributes using a 7-point scale. A rating of 1 indicated that the attribute was not important, while a rating of 4 indicated that the attribute was somewhat important and a rating of 7 indicated it was extremely important. The results summarized in Table 27 show that the importance that builders attach to different product attributes has not changed much since 1995. A Hotelling T^2 test revealed that all of the importance ratings results were significantly different from the neutral point of the scale (a rating of 4). Strength and straightness were rated as being the most important product attributes in both the 1998 and 1995 studies. The importance ratings for straightness and appearance were significantly higher in 1998 relative to 1995, although their relative order of ranking did not change.

There was very little difference in importance ratings across the four geographic regions. The only moderately interesting result was that the Northeast reported importance ratings higher than the other three regions for each attribute except energy efficiency. Availability of longer lengths and appearance were significantly more important to Northeastern builders.

Large firms rated price and price stability as being more important than did small firms (Table 28). Small firms appear to be more concerned with straightness, availability of longer lengths, energy efficiency, and reduced environmental impact than are large firms. These results suggest that large and small firms were influenced by the same mix of product attributes, although their relative importance ratings varied slightly. For example, overall price was rated as being significantly more important by large firms relative to small firms while the opposite was true for product straightness. In general, in looking at the highest rated product attributes, it might be argued that small

Table 25. Average change (1995-98) in softwood lumber usage, by region and firm size.

	Scale Rating
Region	
Northeast	3.16
Southeast	3.19
Northwest	3.64
Southwest	3.45
Total	3.44
Firm Size	
Small	*3.12
Large	*3.63
Top 100	3.94
Total	3.44

*Significant at .05 level

Table 26. Reported change in softwood lumber usage, by region and firm size (%).

	Increased	Decreased	Unchanged
Region			
Northeast	20.5	54.8	24.7
Southeast	22.4	67.2	10.3
Northwest	14.1	48.2	37.6
Southwest	20.0	60.0	20.0
Total	18.9	56.6	24.6
Firm Size			
Small	20.1	61.6	18.2
Large	22.0	53.8	24.2
Top 100	30.6	50.0	19.4
Total	18.9	56.6	24.6

Table 27. Average attribute importance ratings, 1998 vs. 1995.

	1998	1995
Straightness	**6.6	**6.4
Strength	6.5	6.4
Availability	6.2	6.2
Lack of Defects	6.1	6.1
Overall Price	6.0	6.2
Price Stability	6.0	6.1
Ease of Use	5.9	5.7
Little Product Waste	5.8	n/a
Longer Lengths	5.8	5.7
Tech./Eng. Support	5.6	5.6
Appearance	**5.3	**5.0
Energy Efficiency	5.1	4.9
Red. Env. Impact	4.5	4.5

** significant at .05 level

Table 28. Average attribute importance ratings, by firm size.

	Small	Large	Top 100
Straightness	*6.6	*6.3	6.1
Strength	6.4	6.5	6.5
Availability	6.1	6.2	6.4
Lack of Defects	6.0	6.1	5.7
Overall Price	**5.9	**6.6	6.7
Ease of Use	5.9	5.8	5.8
Price Stability	5.8	6.1	6.2
Little Product Waste	5.7	5.7	5.4
Longer Lengths	5.7	5.5	5.1
Tech./Eng. Support	5.5	5.4	5.1
Appearance	5.4	5.2	5.2
Energy Efficiency	**5.2	**4.7	4.5
Red. Env. Impact	*4.6	*4.1	4.1

** significant at .01 level * significant at .05 level

Table 29. Most important attributes for normal sample and Top 100.

	Normal Sample		Top 100	
Rank	Attribute	Points	Attribute	Points
1	Strength	456	Overall Price	59
2	Overall Price	315	Strength	41
3	Straightness	257	Availability	31
4	Availability	217	Price Stability	29
5	Ease of Use	98	Straightness	13
6	Lack of Defects	65	Ease of Use	9
7	Price Stability	63	Lack of Defects	7
8	Appearance	30	Energy Efficiency	3
9	Red. Env. Impact	28	Longer Length	2
10	Longer Length	27	Red. Env. Impact	1
11	Little Product Waste	25	Tech./Eng. Support	1
12	Tech./Eng. Support	22	Appearance	1
13	Energy Efficiency	6	Little Product Waste	0
	Total possible points	**837**	**Total possible points**	**105**

(3 points for most important, 2 points for 2nd, 1 point for 3rd).

firms rated quality as being most important while large firms appeared to attach a higher importance to price and price stability. The lowest rated product attributes for both large and small firms were energy efficiency and reduced environmental impact.

Most important attribute: After rating the importance of each attribute, respondents were asked to rank the three product attributes that they felt were most important. In order to convert this information into a quantitative measure, each attribute was allotted three points for being named the most important attribute, two for being named the second most important, and one point for being named the third most important. The most important, and one point for being named the third most important. The attributes were then ranked according to the total number of points each one received (Table 30). The ranking of the aggregate importance scores presented in Table 30 differ somewhat from the average importance ratings summarized in Table 29. Perhaps the two most important differences between the two tables relate to strength and overall price. Strength, which received the second highest importance rating (6.5), was clearly identified as being the most important product attribute, with 456 points. Overall price, which received the fifth highest importance rating, was rated as the second most important product attribute, with a total of 315 points. The results of the aggregate importance scores suggest that the four most important product attributes are strength, overall price, straightness, and availability.

Table 30. Average satisfaction ratings for softwood lumber attributes, 1998 vs. 1995.

	1998	1995
Availability	**5.5	**5.0
Ease of Use	5.4	n/a
Strength	5.1	5.0
Tech./Eng. Support	4.5	n/a
Longer Length	**4.5	**4.1
Overall Price	**4.5	**3.3
Energy Efficiency	**4.5	**4.1
Little Product Waste	4.2	n/a
Appearance	4.2	n/a
Price Stability	**4.2	**2.7
Red. Env. Impact	4.1	4.1
Straightness	3.6	3.7
Lack of Defects	3.5	3.5

** significant at .01 level

Satisfaction ratings for softwood lumber attributes

Total sample: Respondents were asked to rate their satisfaction with softwood lumber on the same list of attributes using a 7-point scale, where 1 = not satisfied, 4 = neutral, and 7 = very satisfied. A Hotelling T^2 test confirmed that all of the satisfaction ratings, with the exception of reduced environmental impact and appearance, were significantly different from the neutral point of the scale. It is interesting to note that, while the attribute importance ratings

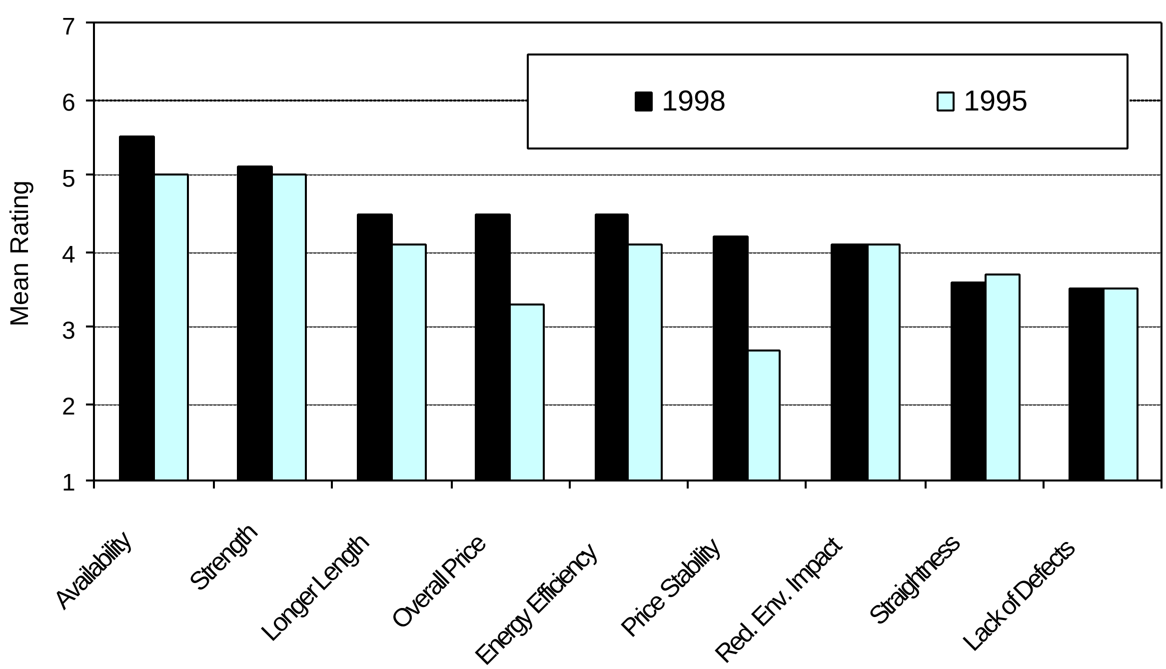

Figure 14. Attribute satisfaction ratings, 1998 vs. 1995.

changed very little between 1995 and 1998, the attribute satisfaction ratings changed quite significantly (Table 30, Figure 14).

In the comparison of satisfaction ratings obtained in 1998 and 1995, several points are notable. First, it would appear that, in general, builders' satisfaction with softwood lumber has increased since 1995. In particular, the satisfaction ratings for five product attributes (availability, long lengths, price, price stability, and energy efficiency) were significantly higher. However, the satisfaction ratings suggest that builders are only moderately satisfied with softwood lumber attributes at best, and they continue to be dissatisfied with the quality-related attributes. For example, we can see that the average satisfaction rating for the quality related attributes (i.e., appearance, straightness, and lack of defects) averages just 3.7, and is essentially unchanged from 1995. Builders were much more satisfied with both the overall price and price stability of softwood lumber in 1998 relative to 1995. This is clearly shown by the fact that the 1998 satisfaction ratings for both price-related attributes were significantly higher than the corresponding 1995 satisfaction ratings. The average satisfaction ratings for the two price-related variables jumped from just 3.0 in 1995 to 4.35 in 1998.

Further analysis of the survey data was done to explore the impact of geographic location and firm size on builders' satisfaction with softwood lumber. In general, this analysis showed that these demographic variables had little impact on builders' satisfaction with softwood lumber, with the following exceptions: large builders and builders in the northwest were significantly less satisfied with price stability than were small builders and builders in the other three regions.

Gap analysis of importance and satisfaction ratings

By graphing the mean importance levels against the mean satisfaction levels for each product attribute it is possible to provide a simple visual representation of the gap between the two measures. The magnitude of the gap between the importance that builders attach to each attribute and their satisfaction with each attribute provides a summary of which product attributes best meet builders expectations and identifies where the largest gap between importance and satisfaction exist (Figure 15). The analysis suggests that the largest gap between importance and satisfaction occurs for straightness and lack of defects followed by price stability and overall price. From a marketing perspective, these gaps between importance and satisfaction for the quality-related and price-related attributes suggest that builders may be unsatisfied with the value they derive from softwood lumber. This lack of perceived value is quite likely a strong factor in builders' increased willingness to explore the opportunities and benefits available from using substitutes for softwood lumber.

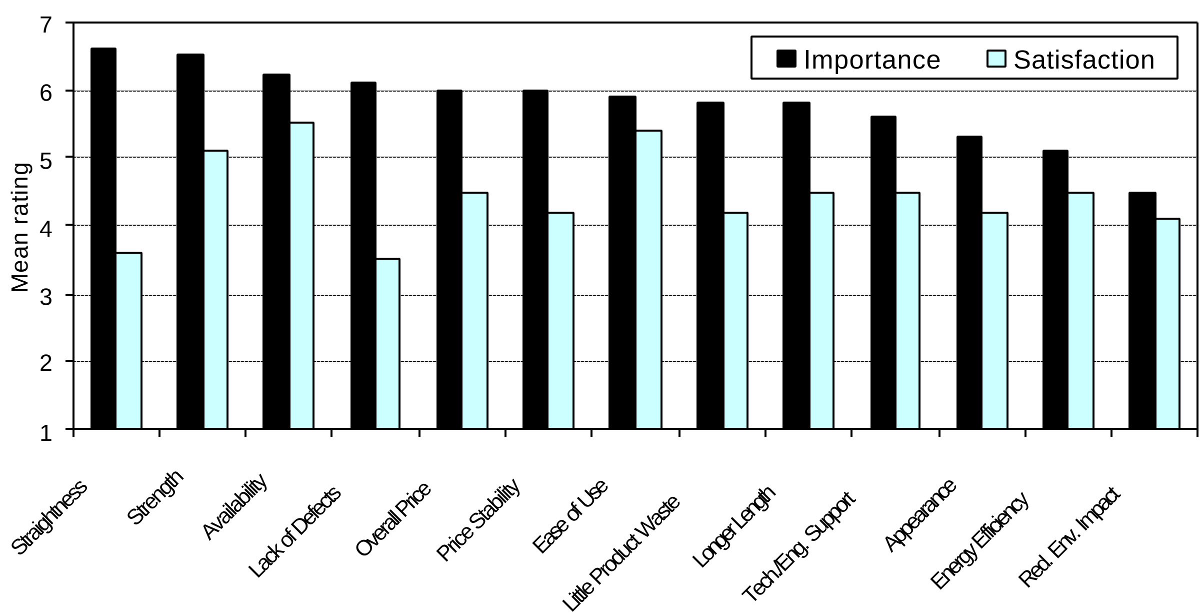

Figure 15. Gap analysis of attribute importance vs. satisfaction, 1998.

Builders' perceptions of the environmental impact of using different structural materials

The results of this study and the 1995 study suggest that, when choosing a structural framing material, builders do not place much emphasis on the environmental impact of the product. Despite this finding, substitute products such as steel framing continue to promote their products as being environmentally friendly products, while alluding to the environmental degradation associated with timber harvests and the use of softwood lumber. Given their promotional strategy, it is useful to assess what impact this message may have on builders' perceptions of the environmental impacts associated with the use of substitute materials relative to softwood lumber. Respondents were asked to compare 12 substitute materials to softwood lumber with respect to their impact on the environment using a seven point scale, where a rating of 1 indicated that the substitute material had a greater adverse impact on the environment than softwood lumber, a rating of 4 indicated that the substitute material had the same impact on the environment, and a rating of 7 meant that the substitute material had a much more favorable (less adverse) impact on the environment.

Total sample: Several trends in the results should be of concern to the forest products industry. The first observation is that builders perceive that using softwood lumber causes more harm to the environment than using any of the other substitute materials, with the exception of wood/plastic composite lumber and plastic lumber. A statistical test of the data showed that the mean scores for the substitute materials were significantly different than for softwood lumber. Of even more concern is the fact that, while a similar result was obtained in 1995, builders' perceptions of environmental impact have shifted further in favor of substitute materials (Figure 16). This would seem to indicate that the promotional programs sponsored by substitute materials have been successful in convincing a substantial number of builders that using substitute materials in place of softwood lumber is better for the environment.

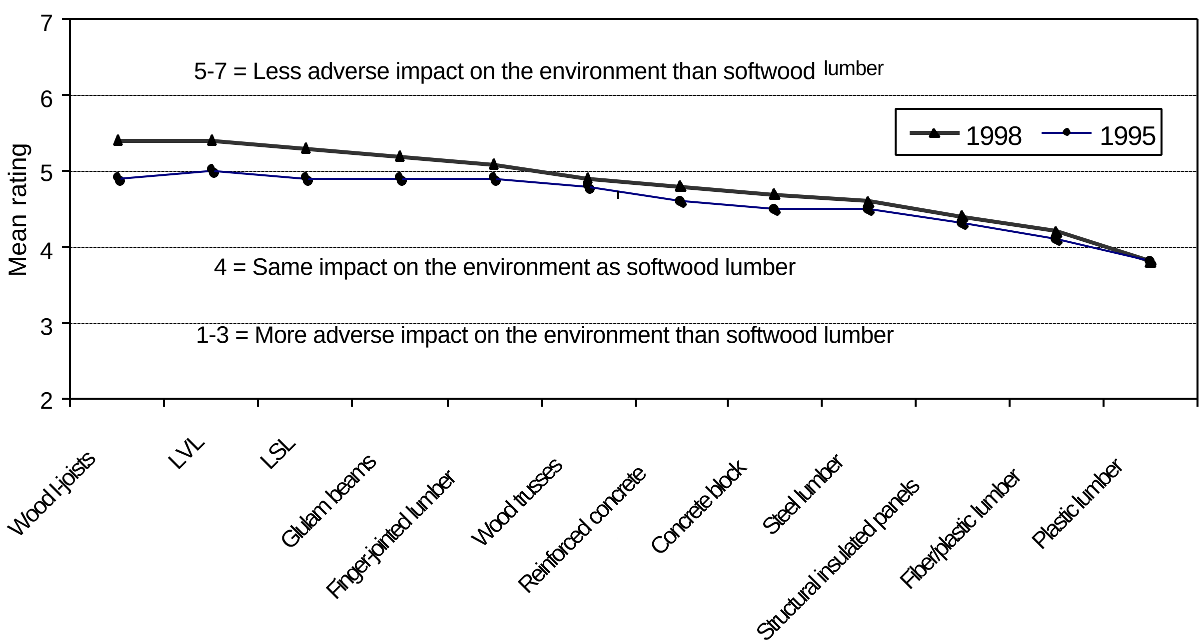

Figure 16. Perceptions of the environmental impact of substitute materials relative to softwood lumber, 1998 vs. 1995.

Regional distribution: While there were some interesting regional differences observed in the data, the only statistically significant difference was with glulam beams, which are perceived in the Northeast as having significantly less negative environmental impact than in the Southeast. The results for finger-jointed studs and LVL were almost, but not quite, significant at the 10% level. The northeast had the highest ratings for all but one of the engineered wood products, as well as fiber/plastic composite lumber and plastic lumber. Perhaps there is a higher awareness in the northeast of the recycled material content of plastic lumber products. Further analysis of the environmental ratings data failed to show any interesting differences in the environmental perceptions of builders based on geographic location or size of firm.

Several trends appear which should be of tremendous concern to the forest products industry. First, the environmental rating for virtually every substitute increased in the positive direction between 1995 and 1998, indicating that over the past several years builders have come to believe that using these substitute materials is better for the environment than using wood (Table 31 and Figure 16). The environmental ratings for four of the substitute materials, all engineered wood products, were significantly higher in 1998. A statistical analysis of the environmental ratings found that the mean ratings of all the substitute materials, with the exception of the plastic and fiber-plastic lumber, were significantly different from the mid-scale rating of 4. This is an important point because if the scores were not significantly different than the mid-scale rating we could conclude that builder's perceive that the environmental impact of using any substitute materials has the same environmental impact as softwood lumber. However, the fact that virtually every substitute material received a significantly higher environmental rating means that builders believe that using any of the substitutes in place of wood is better for the environment. The industry has extolled the environmental virtues of wood as a building material. Thus, the continued and growing misperception that using substitute materials such as steel and reinforced concrete is better for the environment clearly indicates how ineffective the forest products industry has been in promoting the renewable and recyclable aspects of wood. The industry can derive some solace from the fact that all of the engineered wood products were rated as being more environmentally friendly than were the non-wood materials.

Table 31. Perceptions of the environmental impact of substitute materials relative to softwood lumber, 1998 vs. 1995.

Product	**1998**	**1995**
LVL	**5.4	**5.0
Wood I-joists	**5.4	**4.9
LSL	**5.3	**4.9
Glulam beams	*5.2	*4.9
Finger-jointed lumber	5.1	4.9
Wood trusses	4.9	4.8
Reinforced concrete	4.8	4.6
Concrete block	4.7	4.5
Steel lumber	4.6	4.5
Structural insulated panels	4.4	4.3
Fiber/plastic lumber	4.2	4.1
Plastic lumber	3.8	3.8

** significant at .01 level * significant at .05 level

Factor analysis of softwood lumber attributes

One of the difficulties of employing a relatively large number of product attributes (in this case 13) to describe a basic product is that it becomes more difficult to summarize and present the results in a clear and concise manner. In addition, as the number of product attributes increases, so does the possibility that there is some correlation between different attributes. For example, consider the product attributes straightness and lack of defects. To the extent that a builder considers a piece of crooked lumber to be defective, these attributes will have a certain degree of similarity to that builder. However, since straightness is only one of a wide range of conditions covered by the term "lack of defects," the extent of overlap between these terms is uncertain. To overcome this problem and to simplify the data analysis, we can utilize a factor analysis which attempts to group a large number of correlated variables into a into a smaller number of uncorrelated factors. In other words, we can assign a large number of variables to a small number of factors in such a way that the attributes included in each factor are highly correlated to each other but have a low correlation to the attributes included in the other factors.

Obviously, there is a trade-off involved in using a factor analysis to summarize and simplify survey data. For example, using the original 13 product attributes to explain the importance that builders attach to various attributes when purchasing structural framing materials allows us to include all of the variability of the data in the analysis, although considering a total of 13 attributes is very complicated. Employing a factor analysis allows us to reduce the scope of the analysis from 13 attributes to 3 factors, leaving us with a much more manageable task (Table 32). The trade-off here is that we lose some of the variability of the original data by collapsing the 13 product attributes into just three factors, in this case the explained variance is reduced to 60% (Table 32). In most cases we can just the reduced explanatory ability of the factors based on the simplification of the analysis of the reduced number of factors

Factor analysis of the importance attributes: The principal components factor analysis of the importance attributes yielded interesting results and the 13 attributes were reduced to three uncorrelated factors that cumulatively explain almost 60% of the variation in the original data (Table 32). It is interesting to note that the result of the factor analysis for the 1998 data was extremely similar to the results obtained in the 1995 study. The process of naming each factor is largely subjective and involves developing an understanding of the underlying dimensions that are common between the product attributes included in each factor. For example, Factor 2 includes the product attributes overall price, price stability, and availability, attributes which reflect the underlying economic dimensions of Factor 2. Following this type of methodology, the names of the three factors were determined to be: Factor 1: Technical Performance, Factor 2: Economic, and Factor 3: Quality. Factor 1, composed largely of technical attributes, includes the largest number of variables (six) and explains the largest amount of variation in the data (almost 40%). Factor 2, economic attributes, contains three variables that explain over 10% of the variation. Factor 3, performance attributes, contains four variables that explain over 9% of the variation.

Having reduced the original 13 attributes to just 3 factors, we are left with the task of analyzing and interpreting these factors. The analysis of the factors can be facilitated by calculating the aggregate importance rating for the factor based on an average of the importance ratings for each of the individual attributes included in it. Using the importance ratings summarized in Table 27, the average importance ratings for the three factors are: Factor 1, 6.25; Factor 2, 6.17; and Factor 3, 5.37 (Table 33). Based on the average importance ratings for each factor, it is clear that quality and economics were perceived to be much more important to builders than was technical performance.

This information is extremely useful from a strategic marketing perspective. Consider a product such as softwood lumber where quality is perceived to be stable at best and price is rising steadily and occasionally highly volatile. The combination of these two trends has an adverse impact on the competitiveness of softwood lumber since value is defined as the ratio of quality over price. Given the perception that softwood lumber quality is declining and price is rising, one can begin to understand why many builders have concluded that the value they derive from softwood lumber relative to substitute materials is declining. To a large degree this is a driving factor behind the market success of substitute building materials.

Factor analysis of the satisfaction attributes: The principal component analysis for the satisfaction attribute data is summarized in Tables 34 and 35. The three factors that emerged from the analysis explain approximately 60% of the total variation in the original data, similar to the results obtained from the 1995 study. The composition of the three factors themselves, however, was quite different from the factors obtained in the 1995 study.

The first factor in the 1995 study was named product value, based on the preponderance of price- and quality-related attributes included in the factor. This factor, which contained 8 attributes, accounted for just over 42% of the total variation in the original data. The second factor, named technical performance, included three product attributes and accounted for 10.3% of the total variation in the data. The third factor, convenience, consisted of two product attributes and accounted for almost 9% of the total variation in the data. To develop a better understanding of the three factors, the individual satisfaction scores summarized in Table 32 were used to calculate the average satisfaction ratings for the factors. The results indicate that the satisfaction ratings for each factor were: convenience (5.45), technical performance (4.37), and product value (4.22). Of the three factors, builders are only satisfied with the convenience of softwood lumber (comprised of the product attributes availability and ease of use). The mean satisfaction ratings for the other two factors, product value and technical performance, clearly show that builders are neither satisfied nor unsatisfied, in other words they appear to be minimally satisfied with the attributes

Table 32. Rotated component matrix for attribute importance, 1998.

Factor 1 Attributes	**Technical Performance**		
Energy efficiency	**0.814374**	0.14504	0.018263
Reduced env. Impact	**0.749371**	-0.00665	0.003787
Tech./eng. Support	**0.616752**	0.09803	0.390691
Ease of use	**0.611177**	0.290812	0.250724
Appearance	**0.607662**	0.260098	0.185308
Little product waste	0.585309	0.443991	0.22006
Factor 2 Attributes		**Economic**	
Overall price	0.027665	**0.875516**	0.014646
Price stability	0.230676	**0.749325**	0.182149
Availability	0.246279	**0.657682**	0.274273
Factor 3 Attributes			**Quality**
Straightness	-0.00879	0.047667	**0.842392**
Strength	0.15014	0.171618	**0.714717**
Lack of defects	0.453502	0.237521	**0.574711**
Longer lengths	0.321048	0.390289	**0.476169**

Total Variance Explained by Factors

	Eigenvalue	**% of Variation**	**Cumulative % of Variation**
Factor 1	5.14	39.52	39.52
Factor 2	1.36	10.47	49.99
Factor 3	1.20	9.26	59.25

Table 33. Characteristics of importance factors, 1998.

Attribute	**Importance Rating**	**Avg. Factor Imp. Rating**	**Factor Name**
Straightness	6.6		
Strength	6.5		
Lack of defects	6.1	**6.25**	**Quality**
Longer lengths	5.8		
Availability	6.2		
Overall price	6.0	**6.17**	**Economic**
Price stability	6.0		
Ease of use	5.9		
Little product waste	5.8		
Tech/eng. Support	5.6	**5.37**	**Technical Performance**
Appearance	5.3		
Energy efficiency	5.1		
Reduced env. Impact	4.5		

Table 34. Rotated component matrix for attribute satisfaction, 1998.

Factor 1 Attributes	Product Value		
Price stability	0.818840	-0.029950	0.218507
Overall price	0.818479	-0.079030	0.249131
Lack of defects	0.783342	0.386249	0.018241
Straightness	0.720264	0.395249	-0.07944
Appearance	0.671577	0.361083	0.140971
Longer lengths	0.542728	0.328370	0.292350
Little product waste	0.540776	0.443314	0.190373
Strength	0.466814	0.284544	0.207039
Factor 2 Attributes		**Technical Performance**	
Reduced env. impact	0.137303	0.724705	-0.05583
Energy efficiency	0.258833	0.638712	0.234358
Tech./eng. support	0.049167	0.603404	0.501128
Factor 3 Attributes			**Convenience**
Ease of use	0.081924	0.281984	0.791327
Availability	0.416775	-0.11606	0.696747

Total variance explained by factors

	Eigenvalue	% of Variation	Cumulative % of Variation
Factor 1	5.47	42.09	42.09
Factor 2	1.34	10.27	52.36
Factor 3	1.13	8.70	61.06

Table 35. Characteristics of satisfaction factors, 1998.

Attribute	Satisfaction Rating	Avg. Factor Sat. Rating	Factor Name
Lack of defects	3.5		
Straightness	3.6		
Price stability	4.2		
Little product waste	4.2	**4.22**	**Product Value**
Appearance	4.2		
Longer lengths	4.5		
Overall price	4.5		
Strength	5.1		
Reduced env. impact	4.1		
Tech./eng. support	4.5	**4.37**	**Technical Performance**
Energy efficiency	4.5		
Availability	5.4	**5.45**	**Convenience**
Ease of use	5.5		

included in these factors. Unfortunately, there is little direct correlation between the factors derived from the importance data and satisfaction data. As a result, it is difficult to provide a comprehensive discussion of the relationship between the importance factors and the satisfaction factors.

CONCLUSIONS

The US residential construction industry, traditionally the largest market for softwood lumber, has undergone a period of uncharacteristically rapid change over the past decade. The effects of timber harvest restrictions in federal and state forests on softwood lumber price, price stability, and product quality, combined with technological advances by producers of substitute materials, have contributed to the increased use of material substitutes in residential construction. The objective of this research was to assess the extent of material substitution in structural applications in residential construction and provide insight into the factors driving these changes. The results show that softwood lumber continues to lose market share and builders remain concerned about softwood lumber quality and price. The study also shows a continued shift on the part of builders towards a more favorable impression of the environmental impact of using substitute products, including steel and concrete, relative to softwood lumber.

Survey Results

This study randomly sampled 2,400 residential construction firms, segmented by geographic region and firm size, plus the 100 largest home builders as reported in *Builder* magazine. The overall response rate was 12.8% (12.1% of the random sample and 37.1% of the 100 largest firms). The results show that residential builders have steadily increased their use of substitute structural materials since 1995. Respondents reported increased use of all of substitute materials included in the survey; almost 99% used at least one substitute product (compared to 91% in 1995). While use of steel, reinforced concrete and plastic-fiber lumber increased, engineered wood products emerged as the clear winners: over 80% of the respondents reported using glulam beams, wood I-joists, and LVL. Builders in the western US reported higher usage of all substitute products. In addition, the survey data suggest that large firms were more likely than small firms to try new substitute products, particularly finger jointed lumber, structural insulated panels, and LVL, as well as newer engineered wood products such as parallel strand lumber and laminated strand lumber.

The data were analyzed to assess the extent to which various structural products were used in walls, floors, and roofs, the three end-use applications that consume the greatest volume of structural lumber. The most commonly used products were softwood lumber, steel framing, finger-jointed lumber, wood trusses, LVL, and wood I-joists. Softwood lumber dominated wall framing in 1998, with an 83% market share, but it has lost market share since 1995 (down from 93%), particularly among large firms. Softwood lumber's share of the floor framing market declined from 59% in 1995 to 42% in 1998. While it is still the most widely used product, the market share of wood I-joists increased from 23% to 39% in the same period. Softwood lumber framing is no longer the dominant material in residential roof systems. Survey data show that wood trusses increased slightly from 46% to 48%, while softwood lumber declined from 51% to 40%.

To assess builder satisfaction with softwood lumber, respondents were asked to rate the level of importance of, and their corresponding level of satisfaction with, 13 softwood lumber attributes. The importance ratings obtained in 1998 were virtually identical to those reported in 1995. Softwood lumber straightness, strength, availability, and lack of defects were rated as the most important attributes. Price appears to be much more important to large firms than small firms. Builders reported that, while they were somewhat more satisfied with the price and price stability of softwood lumber in 1998, they remained unhappy with softwood lumber quality, particularly straightness and the overall occurrence of defects. While builders appear to be less concerned with price and price stability than in 1995, they remain very concerned about the perceived decline in softwood lumber quality, expressing the least satisfaction with those product attributes they rate as being most important. This suggests that they are dissatisfied with the value (defined as the ratio of quality/price) of softwood lumber.

To provide a more concise interpretation of the importance and satisfaction of the different softwood lumber attributes, a factor analysis was performed to group together attributes that are highly correlated. The results are almost identical with those obtained from the 1995 survey and suggest that the 13 product attributes used to describe softwood lumber can be summarized into three factors: performance, economic, and technical attributes.

Finally, the survey assessed builders' perceptions of the environmental impact associated with using substitute products. Although environmental marketing is not prevalent in the US forest products industry, most industry observers believe that it will become more important. While reduced environmental impact had the lowest importance rating of the 13 softwood lumber attributes, the 1998 survey data indicates a definite shift on the part of builders towards a more favorable perception of the environmental impacts associated with using substitutes, including steel and concrete, than in 1995.

Softwood lumber continues to be displaced by substitute materials in segments of the residential construction industry that it traditionally dominated: wall, floor, and roof framing. To a large degree, this loss of market share can be attributed to a perception among residential builders that the value of softwood lumber has declined: a direct result of rising prices and a perceived drop in lumber quality. Much of the loss in market share can be attributed to the increased use of engineered wood products. Many would argue that this is a normal process of product evolution within the forest products industry that can be attributed to technological advances in manufacturing processes driven by the changing forest resource. However, two trends should concern managers in the forest products industry. First, the use of non-wood substitute building materials has increased significantly since 1995. Second, there is a growing perception among home builders that using non-wood building materials (including steel and reinforced concrete) is better for the environment than using softwood lumber. This trend away from wood products is likely to continue unless there is an effective response to the challenge posed by substitute materials.

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APPENDIX A

SURVEY QUESTIONNAIRE

APPENDIX B

SURVEY COVER LETTERS

DATE

ADDRESS

Dear ,

The successful introduction of new building materials and technologies into the U.S. residential construction market presents numerous challenges. Unfortunately, very little research has been conducted to identify builders' perceptions of the wide range of building materials available in the residential construction industry. Understanding your perceptions is critical since they affect how products are developed and introduced to the market.

Your company is one of a small number of residential construction companies being asked to provide their opinions regarding a variety of wood and nonwood residential construction materials used in structural end-use applications. Your company was selected through a random sampling of residential construction companies located throughout the U.S. In order for the results to truly represent the opinions of the residential construction industry, it is important for each survey to be completed and returned. Therefore, the answers that your company provides will be of significant importance to the success and accuracy of this research project.

I hope that you can spare about 10 minutes to help with this project by completing the enclosed survey. I ask that it be completed by the person in your firm most involved in decisions relating to the purchase and use of building materials.

You can be assured of complete confidentiality. All information that you provide will be held in the strictest confidence and will only be reported in combination with the information provided by other residential construction companies. You will notice an identification number on the front page of your survey. This number is for mailing purposes only. It provides me with a means of removing your name from the mailing list once your completed survey has been returned. If you are interested in receiving a summary of results, please print your name and address on the last page of your survey or, if you prefer, request the information in a separate letter.

Again, your participation is very important to the success and reliability of this project. I would be more than happy to answer any questions you might have. Please call or write. Thank you for your assistance.

Sincerely,

Ivan L. Eastin
Associate Director and Professor
Center for International Trade in Forest Products
University of Washington
Telephone: (206) 543-1918
Fax: (206) 685-0790
Email: eastin@u.washington.edu

DATE

ADDRESS

Dear ,

The successful introduction of new building materials and technologies into the U.S. residential construction market presents numerous challenges. Unfortunately, very little research has been conducted to identify builders' perceptions of the wide range of structural building materials available in the residential construction industry. Understanding your perceptions is critical since they affect how products are developed and introduced into the market.

Our research is specifically focusing on the Top 100 U.S. residential construction companies (as reported in *Builder* magazine). In order for the results to truly represent the opinions of large-scale residential construction companies, it is important for each survey to be completed and returned. Therefore, the information that your company provides will be of significant importance to the success and accuracy of this research project.

I hope that you can spare about 10 minutes to help with this project by completing the enclosed survey. I ask that it be completed by the person in your firm most involved in decisions relating to the purchase and use of building materials.

You can be assured of complete confidentiality. All information that you provide will be held in the strictest confidence and will only be reported in combination with the information provided by other residential construction companies. Furthermore, all identification information will be stripped from the data and final research reports. You will notice an identification number on the front page of your survey. This number is for mailing purposes only. It provides me with a means of removing your name from the mailing list once your completed survey has been returned. If you are interested in receiving a summary of results, please print your name and address on the last page of your survey or, if you prefer, request the information in a separate letter.

Again, your participation is very important to the success and reliability of this research project. I would be more than happy to answer any questions you might have. Thank you for your assistance.

Sincerely,

Ivan L. Eastin
Associate Director and Professor
Center for International Trade in Forest Products
University of Washington
Telephone: (206) 543-1918
Fax: (206) 685-0790
Email: eastin@u.washington.edu

DATE

ADDRESS

Dear ,

I recently sent you a letter requesting your company's participation in a national survey being conducted by the University of Washington regarding residential building materials. If you have already returned your survey, please disregard this letter ? thank you for your help!

I realize that you are likely to be busy and may not yet have found the time to complete your survey. However, I would like to strongly encourage you to do so. The survey takes about 10 minutes to complete, and you need not identify yourself or your company.

Your participation in this project is important. Your company is only one of a small number of companies in the United States that are being asked to give their opinions regarding residential building materials. Therefore, the answers that your company provides will be of significant importance to the success and accuracy of this research. In case you have misplaced the survey that I sent previously, please contact me either through phone, fax, or email to request another copy.

This study is strictly an academic survey of residential construction companies ? it is not being sponsored by any product manufacturer, industry association, or rival company. **Please be reminded that all information that you provide will be held in confidence and will only be used in combination with information provided from other companies. Upon receipt of your survey, all identifying information (e.g., your company name, address) will be stripped from the data that you have provided to the study.**

Once again, thanks for your cooperation and help!

Sincerely,

Ivan L. Eastin
Associate Director and Professor
Center for International Trade in Forest Products
University of Washington
Phone: 206-543-1918
Fax: 206-685-0790
email: eastin@u.washington.edu

DATE

ADDRESS

Dear ,

During the last few months, we have sent you two letters requesting your company's participation in a national survey being conducted by the University of Washington regarding residential building materials. I realize that you are busy and may not yet have found the time to complete the survey. However, I would like to strongly encourage you to do so. The survey takes about 10 minutes to complete and you need not identify yourself or your company.

Your participation in this project is very important. Part of the research specifically focuses on the Top 100 U.S. residential construction companies (as reported in *Builder* magazine). Thus, your company is one of a select group of companies that are being asked to give their opinions regarding residential building materials. Therefore, the information that your company provides will be of significant importance to the success and accuracy of this research. We have enclosed another copy of the survey as well as a $1 bill as a token of both our appreciation for your time.

This study is strictly an academic survey of residential construction companies ? it is not being sponsored by any product manufacturer, industry association, or rival company. **Please be reminded that all information that you provide will be held in confidence and will only be used in combination with information provided from other companies. Upon receipt of your survey, all identifying information (e.g., your company name, address) will be stripped from the data that you have provided to the study.**

Once again, thanks for your cooperation and help! If you have any questions, please feel free to contact me.

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APPENDIX C

DESCRIPTION OF SUBSTITUTE PRODUCTS DISCUSSED IN THE STUDY

ENGINEERED WOOD PRODUCTS

Finger-jointed lumber

Description: Dimensional lumber made by connecting 2- to 3-foot long segments of processed 2"x4" or 2x6" lumber from lower quality wood with glued finger joints. Even though many people find it hard to believe at first, the glue bond is stronger than the surrounding wood fiber.

Usage: This is a direct substitute for solid softwood lumber. Thus, it has many uses, but its largest potential market is in wall framing.

Performance attributes: This product has had a difficult time rebuilding its reputation after a series of early failures in the 1970's. Now, however, it is gaining recognition as a high-quality product that saves the builder time and money. Since the defects have been removed from the wood and it has been dried during production, it does not warp or twist. In vertical weight bearing applications, it offers consistent strength and straightness in lengths up to 32 feet. It can also be stored up to six months without adverse effects. Understandably, better source lumber yields better finger-jointed lumber. Variability between segments is another potential problem. Finger-jointed lumber is graded by the lowest-quality segment, since wider-grained segments weaken the stud. Quality control is thus extremely important throughout the manufacturing process (Tuvey 1998).

Economic attributes: Finger-jointed lumber normally carries a price tag 10-15% higher than softwood lumber, but often virtually eliminate builders' replacement costs (Jones 1993). Production and distribution are quite spotty, making availability a problem in many areas. Production, distribution, and sales are concentrated in the Southwest, from Louisiana to California.

Technical attributes: Finger-jointed studs are superior to solid wood studs in ease of use (due to lower maintenance requirements), little product waste, and reduced environmental impact (by making a better quality product from lower quality plantation timber). They are equally energy efficient and require no special technical support beyond load ratings. Their primary drawback is their appearance, which seems connotes lower quality to those who lack knowledge and experience in their use.

Future outlook: As mentioned before, production and distribution are spotty. Information on the production of finger-jointed lumber is also scarce. One recent report discussed current research in green finger-jointing (i.e., eliminating the need to kiln-dry the lumber). This represents the latest attempt to deliver a structurally stable product at competitive prices. The few indications that are available indicate that finger-jointed lumber is a promising product, that many of its users are very satisfied, and that it offers one possible solution to declining timber quality.

Glue laminated timber (Glulam beams)-

Description: Glulam beams, one of the first and most widely-used engineered wood products, are produced from two or more layers of standard dimension lumber glued face to face. Through finger-jointing, lengths of over 100' are possible. Some European structures built with glulam beams in the 1890's still stand today.

Usage: Glulam beams are extremely versatile and can be shaped into many curved or straight forms. They are most commonly used as beams, headers, or columns. The APA reported that 47% (141 million bf) of glulam production went into the residential construction/R&R market (APA 1998).

Performance attributes: The structural integrity of glulam beams is unquestioned. They are made with high-grade laminating stock, with the strongest timber placed in the faces. It has actually been found that many of the glulam beams installed over the years are up to 20% stiffer than originally estimated. New regulations resulting from this finding could save an average of one lamination per beam (Thompson 1993).

Economic attributes: Since glulam is manufactured from high quality laminating stock, it is subject to many of the same price and availability constraints as solid wood lumber. Consequently, production dropped to its lowest point when timber prices were at their peak in 1993 and 1994. LVL and LSL (which are described below) gained market share in beams and headers during this period (APA 1998). The Asian crisis had two opposing effects upon the glulam market. On the positive side, low Asian demand increased the amount and quality of softwood lumber available for laminating stock. On the negative side, this also virtually eliminated the sales revenue derived from the export of glulam beams (Taylor 1999). Nevertheless, glulam production capacity has expanded over the past decade. Glulam beams are generally available from distributors as "stock beams" that can be cut to the desired size and shape (Williamson 1994).

Technical attributes: Many builders have experience with glulam beams and technical support is readily available. There is very little product waste and the appearance of architectural grade glulam is quite attractive. Fire resistance is high, while energy efficiency and environmental impact are the same as solid softwood lumber.

Future outlook: In the 1995 CINTRAFOR survey on material substitution, 73% of the respondents reported having used glulam beams at least once (Eastin, Simon, and Shook 1996). APA forecasts predict moderate increases in glulam production fueled by growth in residential stock beams and the Japanese market (APA 1998).

Laminated veneer lumber (LVL)-

Description: LVL is manufactured similar to plywood, by bonding veneer panels with a phenolic adhesive to produce a continuous billet of lumber up to 1¾ inches thick by 4-feet wide and up to 100 feet long. Unlike plywood, however, LVL veneers are layered parallel to each other. Layers are also staggered to meet engineered strength requirements. The billets are then hot pressed to cure the adhesive and cut into the desired lumber sizes.

Usage: The APA (1998) estimates that 55% of LVL production in 1997 was used as I-joist flanges, while another 37% ended up as beams or headers.

Performance attributes: LVL offers the straightness, strength, and versatility of glulam beams at a lower cost, lighter weight, and smaller size requirement.

Economic attributes: Although three times the price of dimension lumber on a lineal foot basis, LVL covers long spans more cheaply than glulam beams or solid wood lumber (Vlosky et al. 1994). LVL is also noted for its price stability (Guss 1995). Production, production capacity, and the availability of LVL are all on the rise.

Technical attributes: Ease of use and technical support are definitely key issues in the growing acceptance of LVL. The study by Vlosky et al. (1994) reports that, "in markets where dealer support has been strong, growth has been more than twice the company average." Installation guides and some specialized hardware are necessary. LVL leaves little product waste and has a lower environmental impact than many other similar products. It is not generally used for appearance applications.

Future outlook: LVL was first produced in the 1940's as part of the war effort, but was not marketed commercially until 1971. Trus Joist MacMillan (TJM) was the only producer for ten years and continues to be the market leader. Increased competition, however, is now coming not only from North American firms, but also from the Pacific Rim and, eventually, the plantations of the Southern Hemisphere. Global capacity has averaged over 20% growth throughout the 1990's, and is expected to grow at that rate for the next five years. Most of that growth is due to I-joist production, but use as beams and headers should increase as well (Taylor 1999).

Laminated Strand Lumber (LSL)-

Description: LSL (also known as oriented strand lumber and by the trade name TimberStrand) and LVL together are often referred to as structural composite lumber (SCL). The difference between LSL and LVL is analagous to the difference between OSB and plywood. LSL is manufactured from oriented strands of flaked wood rather than peeled veneers.

Usage: LSL is used in similar applications as LVL, but is more often used for trim applications such as windows and doors.

Performance attributes: LSL is engineered to provide the same structural integrity and versatility as LVL.

Economic attributes: As a relatively new product, LSL is not universally available or commonly used. Because it uses a lower quality raw material, it has the potential to develop a definite cost advantage.

Technical attributes: Again, LSL has the same technical properties as LVL. The most notable exception is a reduced environmental impact due to the ability to reuse mill byproducts and lesser-used species such as poplar and birch (Widman 1997).

Future outlook: LSL is a very new product. The biggest advantage it has, looking to the future, is the aggressive marketing support of its manufacturer, TJM. First of all, TJM has a successful track record introducing, marketing, and supporting new products. Secondly, the firm is now promoting FrameWorks, a bundled package of engineered wood framing products that includes LSL. Most of the larger integrated forest products companies are now promoting building systems that incorporate a similar range of products as well.

Parallel strand lumber (PSL)

Description: PSL was first introduced in 1986 by TJM. Its production is based on a blend of veneer slices that are sliced into long, ruler-width pieces with all of the defects removed and bonded with phenolic resin This mix is then extruded through a forming band where it is cured in a patented microwave curing process. This process facilitates the manufacture of beams to a wide variety of size specifications.

Usage: It is used in beams, headers, and columns.

Performance attributes: PSL can be produced in broader beam dimensions than other similar products. Results of extensive testing indicate that PSL outperforms all other engineered and solid wood products in stability and reliability. The removal of knots and the uniform density of PSL allow higher design values (Crowley 1990).

Economic attributes: PSL carries a price premium, but supports heavier loads than comparably-sized glulam beams, solid wood beams, or even other SCL products (Abbott 1993). Availability is somewhat limited, but growing rapidly.

Technical attributes: The only significant technical difference between PSL and other SCL products are in appearance and ease of use. The unique appearance of PSL does not appeal to every consumer, but it does appeal to many. It is unquestionably an improvement over the appearance of LVL and LSL. The installation of PSL is somewhat more labor-intensive than its cousins because it is substantially heavier.

Future outlook: PSL's future is very similar to LSL. Both are new product lines pioneered by TJM, although PSL is not as new. PSL production is rapidly increasing and it is backed by the full support of TJM's successful marketing campaign.

Wood trusses

Description: Wood trusses are I-beam shaped roof components utilizing triangular webbing that transfers loads with minimal deflection. Trusses are manufactured to the specifications of each project, using interconnected 2x4's rather than the 2x8's, 2x10's, and 2x12's normally required to support rafter system roofs.

Usage: Roof trusses are much more commonly used than floor trusses.

Performance attributes: The engineered components of a wood truss represent an improvement over the dimensional stability of stick frame roofs and floors. The strength and straightness may lag a bit behind wood I-joists, but one commentator stated, "good marketing and reality aren't always one and the same. Most floor squeaks are between the plywood (or OSB) subfloor and the top of the joist. This isn't to say that these products aren't wonderful. The trusses don't squeak. But the plywood sure can if it's not secured well to the trusses or joists." (Hay 1999) Trusses can cover spans up to 38 feet. Since they are pre-manufactured to the specifications of each structure, trusses are less convenient for custom builders who may require more flexibility (Wardell 1993). If the builder makes design changes during construction, the truss must be reengineered. They are, however, more convenient for builders of tract or manufactured homes.

Economic attributes: Trusses definitely require less onsite labor than stick framing, since they are mass produced off site and have open webs that make it simple to run utilities. Since they are spaced wider than wood I-joists or rafters, builders require fewer trusses and less installation time. They are also cheaper and more readily available than good quality 2x8's, 2x10's and 2x12's. On the other hand, roof truss installation often requires a crane, while rafter systems do not.

Technical attributes: Wood trusses are easier to use in many, but not all, situations. They are easy to install and integrate with other components of the home and, since they are delivered in complete form, there is no substantial product waste. Environmentally, trusses are an improvement over rafter framing, because they utilize wood more efficiently.

Future outlook: Wood trusses have the strongest future with large builders, who are better equipped to handle them. Wood I-joists compete fiercely with floor trusses, and are generally favored by smaller builders. In general, wood trusses should maintain a consistent market share among those builders for whom they are appropriate.

Wood I-joists

Description: Like wood trusses, wood I-joists mimic an I-beam by relying on the top and bottom flanges for the vast majority of their structural strength. Grooved flanges, made from machine stress rated lumber or LVL, are connected by a thin web of plywood or OSB. I-joists can be produced in widths up to 7 inches, depths up to 30 inches, and lengths up to 66 feet. Introduced and popularized by Trus Joist MacMillan, wood I-joists are now produced by most of the larger integrated forest products companies.

Usage: Primarily (80%) used as floor joists, wood I-joists are also used as headers, rafters, and a few other specialized applications (APA 1998).

Performance attributes: When properly installed, wood I-joists offer extremely dependable dimensional stability and durability. As production continues to expand every year, they are becoming more widely available and cost competitive.

Economic attributes: On a per unit or lineal foot basis, wood I-joists are more expensive than solid wood lumber. Many builders find that they end up saving money with wood I-joists, though, because of fewer callbacks, lower labor costs, and increased speed of construction. Wood I-joists are light, easy to handle, and can potentially span the entire width of the house.

Technical attributes: The only notable technical problem with wood I-joists is the difficulty of running utilities through the web. They may be ordered prepunched or small holes can be drilled. Only a small number of new products have webs that can be trimmed at the ends.

Future outlook: The outlook for wood I-joists is very positive. The APA reports I-joists had a 25% share of single family floor framing and a 33% share in multifamily construction. This share is now most likely approaching 40%, and is projected to reach 55% by 2002 (APA 1998).

NON-WOOD FRAMING SUBSTITUTES

Plastic lumber

Description: Plastic studs are usually high-density polyethylene (HDPE), low-density polyethylene (LDPE), or polystyrene products extruded in the form of dimensional lumber. They can be produced from virgin or recycled plastic. Many firms that actively seek the environmental high ground use recycled materials exclusively. Post-industrial recycled plastic yields a better, more consistent product than post-consumer plastic.

Usage: It is widely accepted that plastic lumber is not well suited for framing applications. It does possess some attributes that make it advantageous for certain exterior applications.

Performance attributes: Plastic lumber is usually straight and without defects, although it can be adversely affected by contaminants in the mix (Pacitti 1993). It normally will not check, split, shrink, swell, or rot. Its fatal flaw in framing applications is its lack of stiffness. Tests have shown that it typically has just 10-25% the stiffness of wood (Simonsen 1995). Testing standards, which ensure product uniformity, were not in place until 1999.

Economic attributes: Plastic lumber is much more expensive than solid wood lumber. It is still viable for some (nonstructural) framing end uses because of its extended durability and low maintenance, especially in outdoor use. Availability is a common problem as well, although distribution is improving rapidly. More firms are producing plastic lumber, large firms such as U.S. Plastic Lumber Co. are developing economies of scale, and distribution networks are widening with the passage of time.

Technical attributes: Plastic lumber is much heavier than wood, making it more difficult to handle. It is easily machinable with standard hand tools. It is also widely regarded as an environmentally friendly product. By simultaneously reducing wood demand and promoting recycling, it is especially attractive to specific market segments.

Future outlook: Plastic lumber, without the added strength of glass or wood fibers, is not a threat to framing lumber. It may become popular as a decking material, but that is outside the scope of this research.

Steel lumber

Description: Steel framing, utilizing structural "C" studs connected to channeled tracks by screws, has been commonly used in commercial and multi-family construction for many years. Steel producers, looking for new markets, hoped to substantially increase steel framing in the residential construction industry when lumber prices rose dramatically and became extremely volatile. The steel industry's goal of 25% of US housing starts by 1997 was highly publicized. While the use of steel framing in residential construction has increased, those forecasts proved to be highly optimistic. Most estimates place the current market share below 5%. The limiting factor in the growth of steel framed residential homes is the need to retrain the labor force and dramatically change the habits of the builder. When lumber prices eventually stabilized, engineered wood products emerged as the clear winner. As a group, they gained and kept much more market share than did steel framing.

Usage: Steel can be incorporated in all or part of the framing system.

Performance attributes: Steel is straight and strong. With a high strength-to-weight ratio, it is also lighter than solid wood. It is particularly attractive to builders and homeowners in areas subject to hurricanes or earthquakes. The quality is also much more consistent than solid wood lumber. As one steel frame builder in Vancouver, B.C. stated, "steel is easier to work with than wood. It is lighter, straighter, and every piece is grade A. Wood is graded either A, B, C, or D. But there is no such thing in steel." (Whysall 1994) There are some problematic issues with availability. Steel manufacturers are actively improving distribution and making some inroads into the home center market. It is still often difficult, however, to purchase small lots of steel studs at short notice.

Economic attributes: After federal timber harvest restrictions sent log prices soaring, it was common for steel industry experts to make calculations determining the price level at which steel framing was cost-competitive with wood framing. It cannot be disputed that wood prices have increased dramatically while steel prices have held stable. Nor can it be disputed that wildly swinging lumber prices often hurt builders who unexpectedly have to go over-budget on materials. On the negative side, the transition to steel framing implies a potentially costly learning curve. Many builders have stated that their first experiences with steel frame construction were troublesome.

Technical attributes: As mentioned previously, unfamiliarity is the key drawback to steel framing. The complex engineering of the system also requires manufacturers to offer extra technical support. Steel framing does, however, offer many advantages to the proficient builder. While steel is inferior to wood in thermal conductivity and sound transmission, steel frames do provide room for thicker wall cavities that allow the use of thicker insulation (Pacitti 1993). An experienced crew can save time and labor installing steel frame systems. Steel is pre-cut to reduce waste and is resistant to fungus, fire, and termites. Steel producers are eager to promote the fact that the average steel stud contains 66% recycled material. The timber industry's rebuttals point to the energy and pollution caused by steel production as well as the renewability of the timber resource.

Future outlook: The raging debate over steel framing that took place in the mid-1990's has subsided. While solid wood lumber producers and steel manufacturers waged war against each other, engineered wood products quietly accomplished what neither of the latter industries could. They gained market share and convinced many builders to adopt an entirely new generation of building products. Steel lumber is a viable industry and has some regional strongholds. While steel producers hoped to develop the residential construction industry into a major growth opportunity, it appears that they will have to settle for a more modest level of success.

Concrete

Description: Traditional concrete and rebar construction has been widely practiced in warmer climates for quite some time. According to Lee Fisher of the NAHB Research Center, 40% of the single-family homes in Florida and 30% of those in Georgia are built with concrete masonry walls (McLeister 1993). Many of these homes have reinforced concrete slab floors on the ground floor as well. Because of their poor thermal insulation properties, concrete homes have been unpopular in colder climates. A wide variety of new insulated concrete wall systems have addressed this problem in an attempt to capture more of the framing market. All of these systems have been produced to provide higher R values than wood frames. Insulated concrete wall forms (ICF's) create foundation and exterior walls by either pouring concrete between two polystyrene foam panels or into the cores of stacked, interlocking foam blocks. Insulated concrete wall systems are made by pouring concrete into standard forms while connectors hold foam insulation in the center of the wall column. Welded-wire sandwich panels have foam insulation surrounded by a welded-wire frame. Upon installation, the frame is filled with shotcrete. Other systems use stackable, interconnecting concrete blocks with insulation that is either pre-installed or that require onsite foam spraying. Still other new systems attempt to re-engineer the concrete itself to make it stronger, lighter, and easier to work with (NAHBRC 1993).

Usage: Concrete is suitable for wall systems and ground floor slabs. It is far too heavy for above-ground floors and roof framing in the typical residential home.

Performance attributes: When constructed properly, concrete wall systems are straight, strong, and free of defects. Incorporating the insulation into the wall system also increases durability (NAHB 1993). One contractor, writing in the *Chicago Tribune*, stated that, "Once the concrete hardens, this wall system outperforms standard wood-frame construction in the following categories: heating and cooling insulation; strength; fire resistance; structural pest resistance; sound-deadening; and natural disaster resistance, just to name a few." He claims that ICF systems will eventually revolutionize the building industry as much as asphalt shingles and drywall (Carter 1999).

Economic attributes: Like most of the other product substitutes discussed, concrete wall systems are still priced above solid wood, based on cost per square foot, but quicker installation and the need for less-skilled labor often offsets the cost difference. Not all of the concrete wall systems offer this advantage at this writing. One builder insists that ICF walls are over-engineered. Once the standards for rebar are clarified, load capacities can be accurately defined and reductions in steel use could lower costs significantly (Binsacca 1997).

Technical attributes: Concrete wall systems are generally easy to use for builders who are experienced with block homes. Some products require more technical support than others, use special proprietary connectors, or have potential pitfalls in the installation process. In general, concrete wall systems decrease design flexibility and increase the difficulty of remodeling (Pacitti 1993). Only a few of the better concrete wall systems have provided holes for utilities. They do provide increased energy efficiency, and are often felt to have a lower environmental impact than wood framed houses. Once again, that is a point of contention between the different industries.

Future outlook: These products have a small number of devotees. The Portland Cement Association estimates that 4,000 ICF homes were built in 1996, a 400% increase over 1995 (Binsacca 1997). Unless lumber prices soar upward again, there is not a very strong impetus for builders to try this building system. Binsacca also reports that, in the busier housing markets, subcontractors can turn down ICF work rather than learning the system. ICF's are unique products that draw attention at trade shows, but many builders are still too suspicious to switch from lumber and engineered wood.

COMPOSITE FRAMING MATERIALS

Fiber/plastic composite lumber

Description: These products are the plastic industry's response to the lack of stiffness in plastic lumber. By adding wood flour or fiberglass, studs are not only stiffened, but they are also made to resemble wood more closely and resist heat better.

Usage: Fiber/plastic composite lumber is targeted for outdoor use, particularly decks, exterior walks, and exterior furniture. Other specialized niches exist. Because they use a large amount of recycled material and industrial byproducts, governments often purchase these products for public projects. Fiber/plastic lumber is not approved for structural uses. For more information on product attributes and future outlook, see the section on plastic lumber above.

Structural insulated panels

Description: Of all of the substitutes discussed thus far, structural insulated panels (SIP's) may have the greatest potential to supplant stick frame construction over the long term (Heavens 1999). NAHB research has confirmed the obvious: labor, not materials, is the average builder's primary concern. The labor market has been aptly described as "tight as a drum." Both the quantity and quality of construction labor are suspect. One SIP manufacturer states, "We hear from big and small builders that labor is not only scarce, but lacks overall skill." (Binsacca 1998). This issue has a direct impact on the appeal of SIP's and other modular building systems. The other major differentiation between SIP's and stick frame construction is the improved insulative properties of SIP's. These systems, generically referred to as sandwich panels, all contain insulation framed between two wood-based composite panels that are connected with splines. SIPs vary in thickness from 4 to 12 inches and in size from the standard 4-by-8-foot panel to full walls measuring 8 feet high by 24 feet wide. The panels are usually OSB, but are also produced with plywood, waferboard, or gypsum wallboard. The insulation, usually expanded polystyrene, is also produced with a few other types of foams. Splines are made of dimensional lumber, steel, plastic, or wood I-joists. Most manufactures design SIP houses on a CAD system and produce the panels to spec at a manufacturing site. They are delivered ready to assemble, with color and letter coding systems. In this respect, SIP construction has been compared to putting together a jigsaw puzzle with numbered pieces. Windows, doors, and utility conduits may be precut as well. A builder experienced with SIP construction can save on both the speed of construction and the cost of labor. The labor needed to manufacture the panels is less skilled and more efficient than traditional framers. The amount of time needed to frame the house and erect the roof can be much lower than that needed for stick framing. A typical house can be framed and closed to weather in less than two days. Although its adoption has been slow in the US thus far, panelized wall construction has many advocates and is making sense to an increasing number of builders.

Usage: SIPs are used for subfloors, roofs, and exterior walls.

Performance attributes: SIP's are straight, strong, and free of defects. The sandwich panel has the structural properties of an I-beam. The panels act as flanges, while the foam insulation acts as a web. Furthermore, since there are fewer thermal breaks, SIP homes are typically more airtight and quiet.

Economic attributes: SIP's have become increasingly cost-competitive with dimensional lumber. One San Diego builder, who built 319 homes with SIP framing, estimated that it costs $1 per square foot more than a stick frame home (McLeister 1998). The builder may be able to make up the marginal cost by reducing labor costs and construction time. Chris Fennell of the NAHB Research Center states that "alternative materials are reducing the skill level and the number of workers required at a job site to assemble a house. In Hawaii, for example, framers are getting $50 to $60 an hour. By using factory-built wall panels, for example, the cost could be reduced to $8 to $12 an hour." (Heavens 1999) One builder states, "I pay $2 a foot for frame labor using SIP's vs. $7.50 a foot for stickframing. A three-man crew and a sky crane can get a 2,800 square-foot house ready for mechanicals in 28 working hours." This only happens after the initial learning curve has been passed. That learning curve has the potential to easily wipe out any labor savings. Another builder experienced with SIP's advises other builders to order a few uncut panels in case changes are needed (Binsacca 1998). The added cost of SIP construction may often be passed onto the home buyer, who can expect to save 40-60% on utility bills over the lifetime of the house (Selover 1999).

Technical attributes: An experienced crew can become very good at SIP construction. Sandwich panels are lightweight and combine four distinct steps of traditional wall framing into one, easily-installed product. Technical support is obviously very important. One builder stated that he likes to go one step further and visit his supplier's manufacturing site occasionally, especially if there are problems with quality and consistency (Schwolsky 1997). SIP construction leaves almost no wasted product and drastically decreases the amount of time materials are subjected to the elements. The appearance of SIP walls is typically smoother than stick frame walls and the panels provide a greater nailing surface than studs. The computer software programs currently available can convert almost any design into a panelized system. SIP construction does require more comprehensive pre-planning than stick frame construction, and complex designs may eliminate cost advantages. No system is perfect for every application. SIP walls provide higher energy efficiency than stick frames, and use resources that have a much lower impact on the environment. Panels are produced from mill residues and lower quality tree species. The foam insulation is usually recyclable and provides a more efficient barrier due to the lack of thermal breaks in the wall cavity.

Future outlook: The Structural Insulated Panel Association (SIPA) reports that the industry has averaged a 24% annual growth rate per year between 1991 and 1994. Growth from 1995 to 1996 accelerated to 36%. Panel production grew to more than 30 million square feet in 1996, enough to build all of the walls and roofs in approximately 8,000 homes. Since the first SIP house was built in 1952, market share has increased steadily. Will Zachmann of SIPA expects the rate of growth to remain high in the near future, as long as the current robust economic climate continues (McLeister 1998). Dan Krawczyk, president of Wickes lumber, stated that, "panels are going to become the primary way lumber is delivered to job sites. Systems will evolve too. All builders should have to do is call their framing supplier with a lot number, a model number, a list of options, and a date they'll be foundation-ready. The rest should be up to the supplier." (Schwolsky 1997) Predictions like these may be overly-optimistic, but they do show the enthusiasm felt by SIP advocates.

APPENDIX D

DISTRIBUTION OF SUBSTITUTE PRODUCTS MANUFACTURERS BY STATE AND REGION.

LVL & PSL	# Of Manufacturers
Northeast Region	3
Ohio	1
Kentucky	1
West Virginia	1
Southeast Region	7
Georgia	2
Louisiana	2
Mississippi	1
North Carolina	2
Northwest Region	13
Minnesota	1
Northern California	1
Oregon	11
Southwest Region	2
Nevada	1
Southern California	1
US Total	25
Western Canada	3
Eastern Canada	1

Wood I-Joists	# Of Manufacturers
Northeast Region	6
Illinois	1
Indiana	2
Kentucky	1
New Jersey	1
Wisconsin	1
Southeast Region	7
Florida	1
Georgia	1
Louisiana	1
North Carolina	3
Tennessee	1
Northwest Region	9
Idaho	1
Minnesota	1
Northern California	1
Oregon	6
Southwest Region	4
Nevada	1
New Mexico	1
Southern California	1
Texas	1
US Total	26
Western Canada	7
Eastern Canada	7

Source: C.C. Crow Publications, Inc. 1998

HUD Mfd Home Truss Program	# of Manufacturers
Northeast Region	9
Indiana	2
Michigan	3
Pennsylvania	3
Wisconsin	1
Southeast Region	3
Arkansas	1
North Carolina	2
Northwest Region	1
Oregon	
Southwest Region	5
Arizona	1
Colorado	1
Southern California	1
Texas	2
US Total	18

Source: C.C. Crow Publications, Inc. 1998

Glulam Beams	# of Manufacturers
Northeast Region	**4**
Kentucky	1
New York	1
Pennsylvania	1
Wisconsin	1
Southeast Region	**9**
Alabama	2
Arkansas	2
Florida	1
Georgia	1
Louisiana	1
Mississippi	1
North Carolina	1
Northwest Region	**13**
Idaho	3
Minnesota	1
Montana	1
Oregon	7
Washington	4
Southwest Region	**3**
Arizona	1
Southern California	1
Utah	1
US Total	**26**
Western Canada	6
Eastern Canada	1
Mexico	1

Structural Insulated Panels	# of Manufacturers
Northeast Region	**9**
Indiana	1
Kentucky	1
Michigan	3
New Hampshire	1
New York	1
Ohio	1
Pennsylvania	1
Southeast Region	**2**
Alabama	1
Mississippi	1
Northwest Region	**8**
Idaho	1
Iowa	2
Minnesota	1
Washington	4
Southwest Region	**4**
Arizona	1
Kansas	1
Missouri	1
Texas	1
US Total	**23**

Source: C.C. Crow Publications, Inc. 1998

HUD Mfd Home Truss Program	# of Manufacturers
Northeast Region	**5**
Michigan	1
New Jersey	2
Ohio	2
Northwest Region	**5**
Iowa	1
Minnesota	2
Nebraska	1
Washington	1
Southwest Region	**5**
Colorado	2
Missouri	2
New Mexico	1
US Total	**15**

Source: *Builder* 1997.