AN ANALYSIS OF THE NORTH AMERICAN SPECIFIERS OF STRUCTURAL MATERIALS IN NONRESIDENTIAL CONSTRUCTION

by

ROBERT A. KOZAK

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ABSTRACT

An assessment of the market environment for wood products as a structural material in nonresidential buildings four storeys or less has been undertaken. This was accomplished by performing extensive marketing research on the specifiers of building materials in the North American nonresidential market -- namely, architects and structural engineers. It is hoped that information obtained in this analysis will form the basis of a comprehensive market assessment which will, in turn, facilitate the development and implementation of distinctive marketing strategies aimed at improving the market situation for wood products in the nonresidential sector.

The method of mail questionnaires was utilized to sample slightly fewer than 6,000 architects and structural engineers across North America. Of the design population that were qualified to respond to the survey, 22.06% did so. This response rate is sufficient to make valid population inferences. In fact, given the vast quantities of information that were collected in the questionnaire, it is considered high. Topics in the survey included building design, structural material use (with special attention to wood products), education, promotion, the design process, environmental issues, and personal information. While the focus was on ascertaining the market position for wood in the nonresidential sector, every effort was made to gauge the attitudes and perceptions of specifiers on a wide variety of subjects pertaining to this type of design.

Results of this analysis clearly show that the market position for wood products in the nonresidential sector is, indeed, unfavourable. This is despite high levels of wood use in three of the more uncommon applications. In every other nonresidential building, especially the larger-scale structures, wood use ranks lowest. That said, the market shares reported for wood products here are relatively high, which is due, in part, to the presence of residential buildings in much of the analysis. Although wood has several benefits (e.g., aesthetics, simplicity, low cost), these seem to be outweighed by the many concerns that specifiers have towards its use in a nonresidential context (e.g., lack of fire resistance and permanence, inconsistent quality and pricing). As such, materials like steel, concrete, and masonry are often used in its place. Some recommendations for overcoming these barriers to wood use in nonresidential construction are offered here. These generally take on the form of specifically tailored marketing strategies aimed at increasing the shares of wood products in segments where wood use varies.

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"Everyone designed the same...box...of glass and steel and concrete, with tiny beige bricks substituted occasionally."

Tom Wolfe, on the state of American architecture
from *Bauhaus to Our House*

INTRODUCTION

The nonresidential construction market in North America, presently dominated by the steel and concrete industries, represents an immense opportunity for the forest products industry. This is particularly surprising given the vast array of wood products, both commodity-based and specialty engineered, that currently exist in the market place and can be viably used in this context. However, barriers into this market exist for wood products.

To determine why this is so, the root of the problem must be examined using sound marketing research techniques. This entails an analysis of the specifiers of building materials in the North American nonresidential market. Specifically, the objectives of this study are to ascertain why wood products are not being more commonly specified for applications of this type and what can be done to reverse this course. In so doing, it is hoped that marketing strategies, which address these critical issues, be implemented by the forest industry in an attempt to better penetrate this potentially lucrative market.

Objectives:

The primary objective of this study is to assess the market environment for wood products as a structural material in the construction of nonresidential buildings four storeys or less. This was accomplished by performing extensive marketing research on the specifiers of building materials in the North American nonresidential construction market -- namely, the architects and structural engineers -- in one of the largest undertakings of its kind. On an operational level, this entails the measurement and quantification of qualitative constructs, such as attitudes and perceptions, using various statistical techniques. While methodologically complex, rigid attention to issues of sampling ensure that results can be inferred to the population of specifiers as a whole.

The specific objectives of this study are as follows:

1. To measure the existing awareness, use, and perceptions of wood, relative to competitor materials, among architects and engineers involved in material specification for nonresidential construction. Data collected here is used to determine the extent to which wood is used in this sector and the reasons (perceptions or realities) that constrain and/or encourage its use.

2. To determine the product positioning of wood products, compared to their competitor materials, based on an analysis of various product attributes and uses. This helps to identify where technical research and/or marketing programs should be directed, depending on whether perceptions / attitudes are warranted or misconceived.

3. To characterize the dynamics and structure of the nonresidential design and construction markets. This assists in determining exactly who the specifiers of structural materials are and what products they generally specify for various types of buildings.

4. To identify differences and similarities among specifiers by grouping them according to factors such as demographic characteristics, familiarity and use levels of structural materials, favourability towards building materials, and/or benefits sought from structural materials. Analysis of this sort provides the base data requirements for market segmentation.

5. To profile these groups of specifiers according to such factors as demographic and psychographic information, business size, preferred methods of learning, and/or use levels. This provides the basis for the development of an appropriate marketing mix tailored to each group.

6. To use these demographic profiles as a predictive tool for such factors as amenability to wood usage, buying intentions, design intentions, future intentions, and/or likelihood of change.

7. To examine the attitudes and perceptions of specifiers towards the environmental impact of structural material use and determine how this effects the specification of building materials. This is seen as being of paramount importance given the environmentally aware climate that exists today.

8. To explore and evaluate the effectiveness of different methods of information dissemination, educational methods, and promotional activities among specifiers. The best means of educating specifiers with regards to wood use is determined with this information.

9. To identify and profile the users and non-users of wood products. An analysis of this sort has far reaching implications in the development of marketing strategies designed to increase wood specification; an appeal to users might result in the successful implementation of a "pull" or "user-demand" strategy, while well thought out efforts directed at non-users might also suffice and/or compliment the above.

The overall objective of this study is to assess the market environment for wood products as a structural material in nonresidential construction (four storeys or less). Information obtained in this analysis forms the basis of a comprehensive market assessment. With this, various generalized managerial actions are recommended based on sound marketing ideals. However, it is the job of industry to devise and implement distinctive marketing strategies aimed at improving the market environment for wood products in the nonresidential sector. If nothing else, it is hoped that the results of this research will begin a dialogue among the producers of wood products with respect to the major issue at hand: the penetration of the North American nonresidential market by the forest products industry.

Background And Justifications:

The North American nonresidential construction market is vast. It consists of commercial buildings (offices and stores), industrial buildings (manufacturing establishments and warehouses), educational buildings (schools and museums), religious buildings, recreational facilities, non-housekeeping buildings (hotels and motels), public buildings, and miscellaneous buildings that are otherwise not specified such as auditoriums, swimming pools, theatres, and passenger terminals *(33)*. For this report, the definition extends to include farm structures (livestock housing, machinery storage, and commercial / industrial farm buildings), multifamily dwelling units, and commercial / residential combinations. For the sake of clarity, it should also be noted that the term "nonresidential" is often used interchangeably with the terms "commercial", "small to medium-sized", and "light industrial". In the context of this research, it is often referred to as "buildings four storeys or less".

Recent estimates for this decade put the size of the nonresidential market at over 100 billion dollars (U.S.), accounting for more than 20% of all construction expenditures, including residential construction, nonbuilding construction, as well as repairs, maintenance and alterations *(7, 11)*. Wood products, whose total share accounts for approximately 1.25% of these expenditures, has made only modest inroads into this steel and concrete dominated market. This is especially surprising given that 90% of all nonresidential construction activity (by floor area) is four storeys or less and could viably utilize wood products, like dimension lumber, laminated veneer lumber, parallel strand lumber, composite lumber and beams, I-beams, roof and floor trusses, and lumber joists and studs, in structural applications *(33)*.

The nonresidential construction market is also exhibiting a slow, but positive growth and is considered to be relatively stable *(19)*. This can be contrasted to the cyclical residential market which, due to demographic changes, is projected to decline in the near future *(26)*. Unfortunately for the forest products industry, it is the residential housing market that is its mainstay. This suggests (and empirical evidence confirms) a decreasing proportion of wood consumption in North America over the next several decades *(9)*.

One way to mitigate these potential losses is to concentrate on either market development (entering new markets with existing products) or product development (introducing new products into existing markets). Given the vast array of wood products that already exist and can be viably used in a nonresidential context, it seems logical for the forest product industry to develop a new market by expanding into the relatively untapped and attractive nonresidential market and eroding market shares away from the steel and concrete segments. One study estimates that capturing an additional 1% of the nonresidential market share would result in almost a 2 billion dollar increase in industry income *(9)*. Furthermore, this value does not take into account the fact that the greater the use of wood is in structural applications, the greater its use becomes for decorative and finishing purposes. Thus, the successful entry into the nonresidential market by the forest products industry is seen as critical at this time.

Despite the fact that a market development strategy is recommended, the replacement of existing products in structural applications (concrete and steel) with wood products can be seen as the introduction of a new product when viewed from the customers' perspective. While no formula exists to ensure the success of a new product, it is known that one of the key factors for success is an extensive knowledge of the market in question. This can be achieved with in-depth market research and analyses.

Research of this nature is absolutely critical in ensuring an effective entry into the market place, competitiveness within the market place, and, ultimately, long-term success. In other words, to successfully enter a new market with (perceived) new products is hazardous at best. To do so, without an adequate understanding of the market, and the factors and forces at work within it, would be wasteful. By speaking directly to architects and engineers about the specification of structural materials (particularly wood), this research is attempting, for the first time from a forest products perspective, to broaden the understanding of the nonresidential construction market by establishing benchmarks of scientifically valid data which describe wood use and specification in this sector. On an applied level, this represents the crucial first step in the development of a marketing mix that is needed to successfully launch wood products into the nonresidential market place.

Potential Benefits:

This research will serve as a valuable database for many forest products firms who are presently involved with, or planning to enter, the market for wood products used structurally in the construction of nonresidential buildings. Scientifically valid data regarding the specifiers of structural materials is provided for both Canada and the United States. This will hopefully become the starting point in the development of effective marketing plans (both company-specific and industry-wide) necessary for the forest products industry to increase its share of this sizable market.

The market research information gathered here can assist the forest sector in key decision-making areas by answering the following questions with regards to architects and structural engineers:

1. Who already knows about using wood for structural purposes in nonresidential construction? Who uses wood? Do they have characteristics which separate them from non-users?

2. What do specifiers like and dislike about wood? Can specific perceived product attributes (good and bad) be identified? Are these perceptions based on reality or misconceptions? What do they like and dislike about the competitor materials? How is wood advantageous and disadvantageous in structural applications?

3. Which non-users are open to using wood instead of the existing competitor materials (steel, concrete, and masonry) in nonresidential construction? Which users are open to using more wood? Can they be identified? Are they accessible? What are their preferred methods of learning about new materials? How can the forest products industry improve in terms of education, promotion, and information dissemination?

4. By what criteria can the specifiers of structural materials in nonresidential construction be segmented? What are the similarities within segments? What differences exist among segments? Are the segments accessible?

Answers to these and other questions will provide the information necessary for interested forest products companies to develop specific marketing plans based on valid scientific information. Furthermore, it will allow them to devise marketing mixes tailored to each segmented group. As well, insight into the nonresidential sector will allow companies to determine if and when a risky market expansion program of this nature is feasible. If such a venture is warranted, information gathered here can be used in gaining a competitive advantage over companies who do not possess knowledge of the nonresidential sector and have not developed marketing plans. Finally, the results obtained here will establish the data necessary for interested parties to perform future time series analyses pertaining to the diffusion of wood products into this market.

Throughout this report, results are inferred from the outcomes of the tested hypotheses (based on the objectives stated earlier). In other words, quantitative data is restated in the form of qualitative and tangible recommendations for market expansion. However, these recommendations are only generic in nature. If the forest products industry is interested in expanding its markets to include nonresidential construction, marketing strategies and managerial actions must be devised and implemented on both a company-specific and industry-wide level. This requires, not only an understanding of corporate agendas, customer needs, and available resources, but also input from other stakeholders in the forest sector -- namely, government bodies, the labour force, and the public at large. Unfortunately, limited time and knowledge of these matters restricts the specificity of research that is potentially possible here. However, the universal recommendations offered here will likely begin a dialogue within the forest sector and, ultimately, act as a catalyst to further, more singular research.

CHAPTER 1

LITERATURE REVIEW

An exhaustive review of the relevant literature has been undertaken. In an attempt to facilitate the readability of this massive collection of information, the report has been divided into logical sections, based on the content of the literature in question. These include discussions on the North American construction markets as a whole, the characteristics prevalent in the nonresidential building market, wood use in the nonresidential sector, the specifiers of structural materials, factors affecting wood use in nonresidential construction, means of overcoming the barriers to wood use, and a review of the relevant marketing research. Finally, the methodologies used in some of the literature will be briefly discussed.

North American Construction Markets:

The North American construction market can be divided into two clearly distinctive groups: the residential and the nonresidential sectors. The latter group can further be subdivided into the nonresidential building markets (which may or may not include rural or farm construction) and the nonresidential nonbuilding market, which includes streets and highways, conservation and development, sewers, water supply facilities, utility construction, and miscellaneous construction *(34, 38)*.

The nonresidential building market includes commercial buildings (offices and stores), industrial buildings (manufacturing establishments and warehouses), educational buildings (schools and museums), religious buildings, recreational facilities, nonhousekeeping buildings (hotels and motels), public buildings, and miscellaneous structures that are not otherwise specified, such as auditoriums, theatres, swimming pools, and passenger terminals *(30, 33, 38)*. Farm structures, including livestock housing, machinery storage, and commercial/industrial farm buildings, may or may not be included in this category. Reparations, alterations, and maintenance of nonresidential structures are generally excluded.

North American Nonresidential Building Markets - An Overview:

Many estimates of the size of the nonresidential building markets have been reported. *Reid (1977)* estimates that the floor area of new nonresidential construction in the United States was approximately 1.07 billion square feet in 1963, growing to 1.61 billion square feet in 1969 and 1.74 million square feet in 1973 *(30)*.

Spelter and Anderson (1985) state that in 1982, approximately 82.5 billion dollars was spent on new nonresidential contracts in the United States, an amount exceeding that of new residential construction *(33)*.

Howatson (1987) shows that the value of nonresidential construction in the United States in 1984 was 65 billion dollars (1977 U.S. dollars), compared to residential construction which brought in approximately 90 billion dollars. In Canada, the 1985 figures for residential and nonresidential construction were 9 billion and 7 billion dollars (1981 Canadian dollars), respectively. However, *Howatson* points out that the residential construction market is far more volatile than the comparatively stable nonresidential market, which may explain the apparent reversal of results seen in *Spelter and Anderson's (1985)* data *(17)*.

Somewhat contradictory to the aforementioned results is *Anderson's (1987)* estimate of 104.7 billion dollars being spent on nonresidential construction in the United States in 1985 and 101.7 billion dollars being spent in 1984 (1982 U.S. dollars); a discrepancy which may be due, in part, to varying discounting periods being used in the analyses. It should be noted that this figure resembles *Spelter's (1987)* 1985 figure of approximately 100 billion dollars, although both researchers have used the same primary source *(35)*. Despite this variation, *Anderson's* figure for 1985 translates into 2.39 billion square feet of floor area, using *Reid's (1977)* measurement criterion *(38)*.

Anderson (1987) restates the nonresidential figures to be 101 billion dollars for 1984. This was equivalent to 32% of all construction expenditures for that year (versus 36% for new residential buildings, 14% for nonbuilding construction, and 18% for additions, alterations, repairs, and remodeling) *(38)*.

Jacques (1988) estimates that 280 billion dollars (1987 U.S. dollars) was spent on nonresidential construction in the United States in 1987. Of this, 108 billion dollars was spent on new nonresidential buildings, while 86 billion was spent on each of the non-building and renovation sectors *(source: Department of Commerce, 1987)*. This figure is larger than the residential equivalent of 194 billion dollars (134 billion dollars of which was spent on new residential construction). As well, he projected that the 1991 levels of nonresidential building construction would be approximately 75 billion dollars -- somewhat less than the 95 billion dollars projection for the residential market *(source: Resources Info Systems, Inc.)*. However, he states that, while the residential market is cyclic and forecasted to decline in the future (a point agreed upon by *Marcin (1987) (26)*), the nonresidential market exhibits a slow but positive growth and is comparatively stable *(19)*.

A *Techno-Economic Bulletin* put out by *Forintek Canada Corporation (1989)* shows estimates of the entire 1988 North American construction market to be 742 billion dollars (1988 Canadian dollars). Of this, nonresidential building construction accounted for 229 billion dollars (156 billion dollars in new nonresidential buildings and 73 billion dollars in repairs/alterations/maintenance), while the remainder was split between residential construction (323 billion dollars) and nonresidential nonbuilding construction (190 billion dollars) *(11)*.

Finally, in a more recent estimate, *Crowley (1993)* reports that $86 billion U.S. dollars was spent on nonresidential construction in the United States in 1993. The equivalent 1992 figure for Canada was 19 billion Canadian dollars. He also states that these figures have been increasing at a rate of 1.2% per year for the last ten years, and are continuing to do so *(7)*. Thus, although various discrepancies may exist in reporting the facts and figures for nonresidential construction, it can be seen, nonetheless, that this market is indeed vast.

Characteristics of the Nonresidential Market:

Reid (1977) tabulates many of the characteristics of the nonresidential construction industry. Some research highlights include the fact that, from 1961 to 1973, the northern region of the United States was by far the most active in nonresidential construction, followed by the southern region and then the west. Overall, steel was used more than concrete, which in turn, was used more than wood. Finally, commercial buildings were the most commonly built structures, followed by industrial and educational buildings. Comparatively speaking, very little construction of hospitals and nonhousekeeping units, and even less construction of religious buildings, took place *(30)*.

Spelter et al.(1987) shows that, in terms of value, small projects (less than 10,000 square feet) accounted for 33% of the 1982 nonresidential construction activity in the United States, medium sized projects (between 10,000 and 50,000 square feet) accounted for 22%, and large projects (greater than 50,000 square feet) accounted for 45%. In terms of location within the United States, 36% of these projects were located in the northern census regions (northeast and north central), 41% were located in the south, and 23% were located in the west *(33, 34)*.

The survey also includes further specifics with regards to nonresidential construction, such as the overall value of construction by building type (based on the 82.5 billion dollar base). Using this criterion, a relative ranking of building types, from most common to least common, was obtained and can be seen in Table 1.1. Note that, in each case, offices, industrial buildings, and stores accounted for the majority of nonresidential construction. Relative rankings of building component surfaces (based on area) for nonresidential structures, which show where exactly building materials are used, were also obtained and are seen in Table 1.2. It should be noted that the market share for wood based products, relative to the competition, ranged from 8% for floors to 36% for roofs, for a total share of 22% of the American market *(33)*.

Table 1.1: Comparison of U.S. Nonresidential Construction by Building Type (3,33,38).

Building Type:	**1982** ***(33)*** **% of value**	**1984** ***(3)*** **% of value**	**1985** ***(38)*** **% of value**
Offices	24.4	26.8	24.7
Industrial Buildings	22.1	13.7	12.7
Stores	17.2	24.2	28.9
Hospitals	10.7	8.1	7.5
Schools	9.3	9.3	9.5
Hotels	5.2	7.1	6.0
Public Buildings	5.2	5.5	5.2
Recreational Buildings	3.9	3.5	3.5
Religious Buildings	1.9	2.1	2.2
Total Expenditures (billions of $U.S.)	**82.5**	**101.8**	**104.7**

Table 1.2: Breakdown of U.S. Nonresidential Construction by Building Surface (3,33,38).

Building Surface:	**1982** ***(33)*** **% of value**	**1984** ***(3)*** **% of value**	**1985** ***(38)*** **% of value**
Floors	35.2	35.0	34.0
Roofs	27.0	27.0	29.0
Exterior Walls	20.8	21.0	21.0
Interior Walls	17.0	17.0	16.0

Finally, *Spelter et al. (1987)* analyzes nonresidential buildings on the basis of building height. One storey buildings accounted for 55% of the total floor area. Two storey buildings and buildings three storeys or more accounted for 23% and 22%, respectively. The market share of construction materials for buildings of varying size can be seen in Figure 1.1. These results show that wood was most popular in two storey applications, competed adequately in one and three storey buildings, and lost its market share completely to steel and concrete in applications greater than three floors. Finally, *Spelter (1987)* makes reference to the fact that nonresidential buildings generally do not contain basements. Rather, they are typically built on a slab at ground level *(33, 34)*.

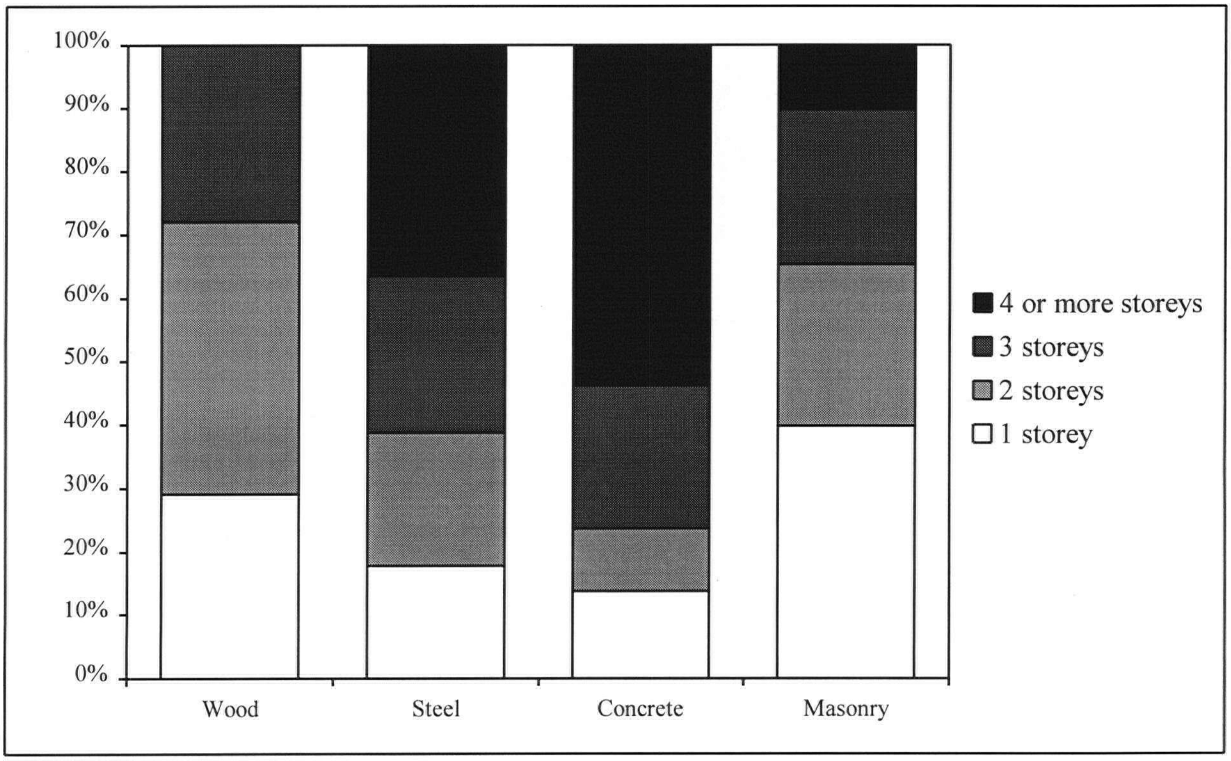

Figure 1.1: Market Share of Materials by Building Size for 1982 (34).

Spelter (1987) reports that, though the share of wood usage in nonresidential building is small, there is little justification for this. He further states that, historically, nonresidential buildings were made of wood. However, with the advent of high-rise buildings as cities became more and more congested, non-wood competitors have taken over the nonresidential market. However, he goes on to say that, since World War II, most nonresidential structures have been built in less congested suburban centres. These buildings tend to be "low-rise and separated from adjacent buildings by space reserved for parking and landscaping. The majority of these buildings could be built of wood, insofar as building and fire codes are concerned *(35)*."

By extrapolating from *Spelter's (1987)* 1982 data, *Siedlak (1987)* reports that in the United States, 45.5 billion dollars (55% of the nonresidential construction value for 1982) was invested in nonresidential buildings less than 50,000 square feet in size. This sector is representative of the market in which wood products have the greatest potential *(32)*.

Anderson (1987) finds that a total of 104.7 billion dollars was spent on nonresidential construction in the United States in 1985. The northern census regions accounted for 36% of this nonresidential construction activity, while the south and the west accounted for 39% and 25%, respectively. Small projects accounted for 34% of the value, while medium and large projects accounted for 26% and 40%, respectively. The distribution of building types (based on total value) seem to vary slightly from the 1982 figures (in Table 1.1). However, it can be seen that offices, industrial buildings and stores still accounted for the highest proportion of nonresidential construction activity. The distribution of building component surfaces, by area, is seen in Table 1.2. Like *Spelter (1987)*, *Anderson* finds floor and roof area to be larger than that of interior and exterior walls. Finally, the distribution of building types by the number of storeys (based on total floor area) was 68% for single storey buildings, 15% for two storey buildings, and 17% for buildings three storeys and greater, which seem to vary considerably from the 1982 results *(38)*.

Anderson (1987) reports on the 1984 nonresidential market in the United States. Expenditures by building type (based on a total of 101.7 billion dollars) can be seen in Table 1.1, while the associated distribution of building component surfaces are seen in Table 1.2. Again, apart from slight discrepancies, the figures seem to be in step with the previous research. Finally, it was stated that less than 15% of all nonresidential buildings were over three storeys, and accounted for less than 3% of the wood usage *(3)*.

Howatson (1987), sourcing *Construction Review*, has also attempted to describe the North American nonresidential market based on several characteristics. First, he compares building types in two separate years, 1973 and 1985, for the United States. In this period, construction of the two most common types of nonresidential structures, offices and commercial buildings, increased (on a percentage of total nonresidential construction basis). Office construction increased significantly, while construction of commercial buildings increased only marginally. Construction of miscellaneous other nonresidential structures grew, as well. Only in the industrial building sector did construction activity decrease in this time frame. He then adds that office construction is expected to level off (due to the current surplus of office space), while construction of industrial buildings, hospitals, and institutional buildings will likely increase, pending the outcomes of certain tax reforms *(17)*.

Howatson (1987) also estimates the regional shares of nonresidential construction activity for the United States in 1970, 1985, and 2000 (*source: forecasts from FORSIM Review*). These figures can be seen in Table 1.3. It can be concluded that the "sunbelt" regions of the United States (the south and the west) have increased their shares of new nonresidential construction (and will continue to do so) at the expense of the north *(17)*.

Table 1.3: Distribution of U.S. Nonresidential Construction for 1970, 1985, and 2000 (17).

Region:	**1970 %**	**1985 %**	**2000 %**
North Central	26.6	20.0	20.4
North East	27.7	16.0	16.0
West	15.6	24.1	27.7
South	30.1	39.9	39.9

Finally, *Howatson (1987)* reports on the relative values of material inputs for nonresidential construction in the United States and Canada. In 1977, 1.245 billion dollars was spent on wood in nonresidential construction in the United States, representing 2.9% of the value of commercial construction. For concrete and metal, these figures are 1.77 billion dollars (4.2%) and 3.28 billion dollars (7.7%), respectively. These relative ratings have remained somewhat constant from 1963 onwards in the United States (with wood use increasing slightly and metal use decreasing slightly). In Canada, the relative ratings are 6.2%, 2.2%, and 2.1% for metal, wood, and concrete, respectively. Furthermore, since 1963, this market has been more volatile with metal ratings increasing and then decreasing dramatically, concrete markets remaining somewhat level, and wood markets decreasing drastically. *Howatson* concludes that, over a two decade period, relative wood use has declined in Canada due to building codes and standards which favour the use of metal and concrete (as a result of substitution and/or a changing product mix), but increased in the United States (due perhaps to higher prices for substitutes). He also states that in the United States, wood, concrete, and metal accounted for 14% to 16% of the total value of commercial construction, while in Canada, they accounted for only 11% to 14%. However, commercial construction was comparatively more important to Canada, based on proportions of long-term residential averages. Metal use was dominant in both countries (at 6% to 8%), while concrete use was greater in the United States (4% versus 2% in Canada). Finally, *Howatson* unequivocally states that nonresidential markets in both countries will become more important in the near future as the residential construction market drops off *(17)*.

Jacques (1988) claims that more than half of the nonresidential construction activity was devoted to building stores and offices, while over two-thirds of the nonresidential floor area were accounted for by single storey structures. In fact, the major users of wood in this market were offices, stores, and single storey buildings. Wood can also be used in two and three storey applications which, along with one storey buildings, accounted for almost 90% of the nonresidential floor area. *Jacques* also claims that, in the nonresidential market, wood is only one of the many building materials that may be specified. The largest and most well established competitors in this sector are steel and concrete / masonry. However, competition is expected to expand with such materials as aluminum, plastic, and ceramics, penetrating the marketplace at increasing levels *(19)*.

Crowley (1993) states that, less than 75 years ago, wood was the material of choice in the North American nonresidential sector. However, the competitive position of wood products in this market was eroded by innovations in steel manufacture, excess steel capacity after World War II, and a huge demand for new wood housing. Presently, the nonresidential market is at the point of maturity, where competition is at the core of success or failure. The relative product positioning of wood products could be drastically improved in this market. While 45% to 50% of all nonresidential buildings in the North America could viably use wood as the main structural component, only 13% to 15 % actually did (accounting for 48 billion U.S. dollars of construction activity). However, an opportunity presently exists for wood to increase its share due to a flattening of new housing demand and a slow-down of remodeling and renovation throughout the 1990's *(7)*.

According to *Crowley (1993)*, most nonresidential buildings under four storeys are suitable for wood use. Because of code restrictions, assembly buildings, offices, and warehouses cannot exceed 100,000 square feet in area. Educational buildings, restaurants, health care buildings, lodging, and mercantile buildings cannot exceed 50,000 square feet. In North America, there has been a recent decline in construction activity in the office, lodging, and commercial segments, while levels for educational buildings are on the rise and healthcare buildings remain constant. Furthermore, construction activity for offices and mercantile buildings has been cyclical, while assembly buildings and warehouses display more stability. At present, most nonresidential construction activity takes place in the assembly, mercantile, office, and institutional segments. This information, coupled with high vacancy rates in the office, lodging, multifamily, and industrial segments, means that opportunities exist for wood products in the mercantile, institutional, and elderly care segments of the nonresidential sector. In other words, even if construction activity in the nonresidential sector is in decline, this does not necessarily mean that the market potential for wood products is diminished *(7)*.

Finally, *Crowley (1993)* states that, since 1980, 60% to 80% of all new nonresidential activity in the United States has been in the West and Southern regions. In Canada, the four largest provinces (British Columbia, Alberta, Ontario, and Quebec) accounted for 87% of the construction activity. All of the aforementioned markets provide an opportunity for the wood products industry to improve its competitive position. However, the Southern United States market is thought of as the most lucrative because it is large, growing, and has the greatest floor area that is suitable for wood *(7)*.

Wood Use in Nonresidential Construction - An Overview:

Reid (1977) reports on the volumes of wood products that were used in the construction of nonresidential buildings in the United States in years 1961, 1969, and 1973. Specifically, estimates of the amounts of lumber, glulam, plywood, particleboard, hardboard, structural wood-fibreboard, and insulation board used in nonresidential and nonhousekeeping construction (stratified by building type and region) are presented. The use of lumber in nonresidential construction increased from 1.5 billion board feet in 1961 to 1.8 billion board feet in 1973. Similar trends were also noted for plywood, which increased from 900 million square feet (3/8-inch basis) to 1 billion square feet in this time period. However, in both of these cases, usage per square foot in nonresidential construction appeared to decrease over time. It was hypothesized that these decreases could be attributed to a decrease in the use of lumber and plywood for facilitating purposes, such as concrete forming *(30)*.

From 1969 to 1973, decreases were noted for glulam (192 million board feet to 185 million board feet), insulation board (80 million square feet [1/2-inch basis] to 77 square feet), and structural wood-fibreboard (185 million square feet [1-inch basis] to 153 million square feet). These reductions were seen to be the result of less construction of industrial and religious buildings in 1973. Finally, in this same time period, increases were noted in the usage of hardboard (42 million square feet [1/8-inch basis] to 45 million square feet) and particleboard (14 million square feet [3/8-inch basis] to 35 million square feet). This growth was seen to be the result of a general increase in construction activity *(30)*.

Spelter et al. (1987) estimates wood products usage in nonresidential construction for the year 1982 in two reports. His findings show wood products consumption in the United States for the nonresidential construction market in this year to be: 2.1 billion board feet of lumber (including 430 million board feet in trusses and 160 million board feet in laminated members), 1.7 billion square feet (3/8-inch basis) of plywood (including 30 million square feet in I-beam webbing), 41 million square feet (3/8-inch basis) of particleboard, 50 million square feet (1/8-inch basis), and 870,000 squares (at 100 square feet per square) of shingles. It should also be noted that approximately 50 million board feet of lumber and 30 million square feet of plywood in use were found to be treated with fire retardants *(33, 34)*.

Anderson (1987) uses methods, not unlike *Spelter's (1987)*, to obtain estimates for wood usage in the United States nonresidential construction market for 1985. Wood products consumption in this market for 1985 was 3.22 billion board feet of lumber and 2.65 billion square feet (3/8-inch basis) of structural panels *(38)*.

Lyons (1987) reports that an average of 2.8 billion board feet of lumber and 2.3 billion square feet of structural panels were used each year in the United States for nonresidential construction activity. As well, over 40 million feet of particleboard, 50 million feet of hardboard, and almost 900 thousand squares of shingle were consumed annually in this important market *(23)*.

Anderson (1987) verifies *Lyons' (1987)* figures for 1984 and adds that they represented 6% of the lumber and 10% of the structural panel consumption for the United States. He also states that, while residential construction accounted for 50% of wood usage, nonresidential construction accounted for only 10% *(3, 38)*.

A *Techno-Economic Bulletin* from *Forintek Canada Corporation (1989)* shows financial estimates of 1.95 billion dollars (Canadian 1988 dollars) that was spent on wood products for the North American nonresidential building market in 1988. A further 0.78 billion dollars was spent on wood products for reparations, alterations, and maintenance, while 0.23 billion dollars was spent in nonresidential nonbuilding sector. The comparable North American residential market figures were stated to be 7.63 billion dollars and 6.52 billion dollars for new building and repairs / alterations / maintenance, respectively. These residential figures, incidentally, accounted for 82% of the wood products consumed in North America *(11)*.

Jacques (1988) reports that 72% of all lumber used in nonresidential construction was as board and dimension lumber (for beams, stiffeners, plates, studs, etc.), while 20% of lumber was found in trusses, and 8% in laminated beams. He estimates that a 1% increase in the level of nonresidential wood construction (United States consumption) would require an extra 57 million board feet of lumber and 37 million square feet of structural panels. This 1% volume increase would be equivalent to approximately 22 million dollars of increased earnings (1988 U.S. dollars). Thus, it can again be seen that the nonresidential construction market represents a vast opportunity *(19)*.

Crowley's (1993) findings on wood use in the nonresidential sector are by far the most recent. In that year, the lumber demand in the nonresidential market was 3.5 billion board feet (with British Columbia accounting for one third of this production, according to his estimates), while the structural panel demand was 2.85 billion square feet. This generated 1.8 billion dollars (U.S.) in North American construction revenues (1.56 billion dollars in the United States and 283 million dollars in Canada), for an estimated market share of 15%. By taking market share away from the steel and concrete segments, the potential exists to increase wood's share in the nonresidential market to 45% (especially with engineered wood products). In other words, 5.8 billion dollars of revenues could viably be generated by the wood products industry in this sector (4.7 billion dollars in the United States and 1.1 billion dollars in Canada). In fact, *Crowley* estimates that a one billion board foot increase in lumber sales would result in a 10% share increase, while a one billion square foot increase in structural panel sales would result in a 12% share increase. Furthermore, when discussing sales increases, a "pull through" multiplier of 1.5 should be applied to market value to account for the additional use of secondary and non-structural wood products like windows, trim, doors, siding, interior partitions, and exterior infill walls *(7)*.

Much of the above information is summarized in Table 1.4 which shows lumber and structural panel consumption in the nonresidential sector from 1969 to 1993. With one exception in 1987, it can be seen that use of wood products for nonresidential applications has been increasing with time. In fact, consumption levels for both product groups seem to be increasing at approximately the same rate.

Table 1.4: Comparison of Lumber and Structural Panel Consumption in Nonresidential Construction.

	1969 *(30)*	**1973** *(30)*	**1982** *(33)*	**1985** *(38)*	**1987** *(23)*	**1993** *(7)*
Lumber (billions of board feet)	1.5	1.8	2.1	3.2	2.8	3.5
Structural Panels (billions of square feet)	1.1	1.2	1.7	2.7	2.3	2.9

Wood Use by Building Type and Region:

According to *Reid's (1977)* 1961, 1969, and 1973 data, wood use in the United States was highest in the west, followed by the north, and lastly the south. In fact, in the west, wood use was generally on par or slightly greater than steel or concrete use for all building classes, with the exception of commercial and educational buildings. Though it is difficult to determine exactly from the tabulated results, wood use was considerably less than that of its competitors in the northern and southern regions. This was most prevalent in the cases of office structures, commercial buildings, and educational institutions, while less prevalent in hospitals and nonhousekeeping units. The exception to this rule was religious buildings, where wood use was high in all regions *(30)*.

Spelter et al.'s (1987) 1982 data shows that lumber, plywood, and hardboard use (on a per $1,000 of construction basis) were highest in the west, followed by the north, and then the south. However, use of wood shingles and structural particleboard was dominant in the north. Hardboard usage was highest in the southern region of the United States. Lumber and plywood use (on a per $1,000 of construction and a per square foot of construction basis) was, by far, highest in religious buildings, followed by stores, hotels, recreational buildings, and hospitals. Lumber was not commonly used in the construction of offices, industrial buildings, and schools. Hotels were large users of structural particleboard and particleboard (public buildings are large users of particleboard only), while recreational buildings were relatively low users in comparison to other building types, which can be thought of as moderate users. Offices and industrial buildings, followed by stores and public buildings, were the heaviest users of hardboard, relative to the other building types. Finally, hospitals and offices were high users of wood shingles, while recreational buildings and hotels were not *(33, 34)*.

In analyzing his 1985 data, *Anderson (1987)* makes no explicit reference to the intensity of wood usage by region in the United States, although he does show *Spelter's (1987)* 1982 results. He refers to these results to show the intensity of wood usage by building type, as well. *Anderson* does, however, show the usage of lumber by building type in absolute terms (share of the market). Stores accounted for the largest share of lumber usage (36%), followed by offices (22%), hospitals (11%), schools (9%), and hotels (6%), with the remaining 16% being split by the other building types *(3)*.

Crowley (1993) discusses the market shares of lumber and structural panel products in North America for 1991. The regional breakdown is seen in Table 1.5 (note that each proportion represents the market share for wood products in that region). Based on these figures, *Crowley* states that there has been low wood penetration in the Southern United States and Canadian segments. He infers that these regions offer the most promise for growth in the wood products industry, while expansion in the other, more saturated, regions would be more difficult. He also states that growth is more likely to occur in metropolitan segments which accounted for 80% of all construction activity. Here, wood use is low compared to rural segments where wood had a 65% market share *(7)*.

Table 1.5: North American Lumber and Structural Panel Regional Market Shares for 1991 (7).

Region:	**Lumber %**	**Structural Panels %**
U.S. Northeast	37	37
U.S. Midwest	42	42
U.S. South	18	24
U.S. West	45	45
Canada	25	24
Total	**32**	**33**

The Specifiers of Structural Materials in Nonresidential Construction:

All of the literature reviewed seems to be in relative agreement as to who the main specifiers of structural materials in nonresidential construction are: architects, structural engineers, and, to a lesser extent, owners and building contractors. Subcontractors, framers, builders, developers, regulatory officials, and material suppliers are also frequently mentioned as being influential in the material specification process. However, it is the architect and the structural engineer who are generally thought of as the main specifiers.

This said, there is some variation in the literature as to how the specification of materials is apportioned between the various parties involved. For instance, *Anderson (1987)* defines the primary specifiers of building material in nonresidential construction to be architects, structural engineers, and owners, all of which make up the "building team". Contractors, when they are included in the building team or when they supply so-called "turnkey structures", are also considered to be specifiers *(38)*. *Jacques (1988)*, on the other hand, states that in nonresidential construction, "the builder, architect, engineer, and contractor work together to define structural options, with the engineer being the final determining authority as to the material, geometry, and shape of the structural frame *(19)*." He goes on to say that it is crucial, in the marketing of building materials, to "know who makes the material specification decisions, at what point in the construction process, and with what criteria and information *(19)*."

Spelter et al. (1987) implies that the task of material selection falls on building contractors and architects *(33)*, while *Walters (1987)* feels that the main specifiers are architects and structural engineers, with owners, developers, contractors, and buyers acting as secondary consultants *(36)*.

One theory by *Cuff (1991)* states that it is the architect that should be considered the main specifier of materials in any building project, simply because only they interact with, and do so at a level which is higher than, every other concerned party. Architects engage with clients, consultants, and other architects in the beginning phases of a project (schematics preparation, design development, construction documentation). These associations give way to interactions between architects and contractors towards the final phases of a project (bidding and negotiation, construction, completion). In fact, it has been speculated that architects have less than one-half of an hour per day of uninterrupted time. Given this paradigm, the architect is at the "helm" of the material selection process aided by a primary consultant (the structural engineer), and then, perhaps to a lesser degree, other long-term participants (clients, users, other engineers and architects, draftspeople, additional paid consultants, etc.), regulatory and approval bodies (governments, planners, etc.), interested parties (financial backers, site neighbours, etc.), informal consultants (peers, product representatives, etc.), and incidental influences (tradespeople, product manufacturers, etc.) *(8)*.

This argument is echoed somewhat by the *American Institute of Architects' Handbook (1988)*, which states that, "Beyond the first conceptual steps, however, the [design] process becomes more complex. In all but the smallest and simplest projects, the steps that follow involve a team of people. While it is true that most significant works of architecture are usually developed under the guidance of a single strong leader, it is important to realize that few projects have fewer than 10 people involved in the decision making (architects, engineers, interior designers, specialist consultants, construction managers, public agencies, and, of course, clients) *(1)*." Another chapter *(1969)* goes on to say that "the architect functions as creator, coordinator, and author of the building design and drawings and specifications with which it will be constructed *(2)*." Again, this scenario places the architect at the "hub of all activity" with a "more peripheral role for other participants [who] are to provide factual and technical data in a timely manner *(8)*."

Factors Affecting the Specification of Wood in Nonresidential Construction:

Spelter et al. (1987) conducted nationwide (United States) random telephone and personal interviews (253 and 350, respectively) with building contractors and a few architects. Questions were centred around a material breakdown of their most recent nonresidential projects. As such, very little, with regards to the specification of materials in nonresidential construction, was learned. However, the attitudes of contractors were gauged somewhat and it was learned that three aspects of wood as a building material were of particular concern to them: cost, durability, and quality *(33, 34)*.

In terms of *cost*, it was stated that "many building contractors believe that wood construction may be more costly than nonwood despite a lower price per piece, and perceive systems, particularly in metal, as having some inherent value *(33)*." The example of "turnkey" quote methods with pre-engineered metal buildings versus wood being sold piece by piece was cited *(33)*.

Durability was also stated to be a problem, especially in the southern portion of the United States, where rot and termites are more prevalent. Despite chemical treatments that exist, steel and concrete are perceived as having more permanence than wood *(33)*.

Finally, the issue of *wood quality* was of concern to building contractors, who expressed irritation towards crooked and warped lumber. In fact, "poor quality was the reason most frequently given by respondents who said they would use less wood in the future *(33)*." Contractors, it was stated, prefer to work with straight and stable building products; a problem inherent in the fact that much of the current resource base consists of lower quality, smaller diameter, second-growth timber with less clear wood and more juvenile wood *(34)*.

Given these constraints of costs, durability, and quality, contractors and architects were asked to comment on potential future wood use. Specifically, they were asked whether they would use more or less wood products in the future. The majority of the respondents said that there would be no change. Of the respondents that said that there would be a change in the future, an equal number of people "indicated that they would use more lumber in the future as indicated they would use less *(33)*." However, steel and concrete usage was expected to rise, while concrete block and brick usage was expected to decline, based on these interviews. As well, the respondents seemed more favourable towards such products as wood siding, wood trusses, glue-laminated timbers, I-beams, structural particleboard, and fire-retardant-treated wood, but less so towards lumber and plywood. Despite these negative responses, *Spelter et al. (1987)* concludes that wood products "are retaining and even expanding their share of this [nonresidential] segment of the construction industry *(33)*."

Finally, *Spelter et al. (1987)* discusses reasons why the frequency of wood use is high in small buildings, declining (per square foot) as the size of the structure increases (though this condition is not as prevalent in the western region of the United States). Specifically, "while the survey did not fully account for factors governing choice of materials, it did identify a number of factors and attitudes which may help explain the variations in wood use *(33)*."

First, as nonresidential construction encompasses a wide variety of structures, building sizes can be larger with fewer partitions, meaning that spans must be longer, loads heavier, and stresses greater than in the more familiar framing / residential construction context. Designers will typically use steel and concrete for such structures (to meet the more demanding requirements), although acceptable wood systems, such as laminated beams and structural timbers, are available *(33)*.

A second factor, according to *Spelter et al. (1987)*, is the issue of fire safety. Specifically, it was stated that "a common feature of all codes is that a category of noncombustible construction exists where wood is not permitted even if it has been treated with fire retardant *(33)*." However, these buildings are generally large, usually exceeding five storeys, with unique occupancies or site locations *(33)*.

Spelter et al. (1987) deals with the issue of complexity and variability of building codes in different regions. He states that difficulties in dealing with building codes is also a factor leading to the use of noncombustible materials, other than wood *(33)*. *Spelter (1987)* also alludes to the problem of owner preference and perceptions in material selection, which may result in increased usage of steel and concrete in cases where wood may be acceptable and/or preferred *(34)*.

Anderson (1987), in an attempt to understand what types of marketing strategies need to be implemented, uses *Spelter's (1987)* data to draw his own conclusions with regards to the attitudes and perceptions of "the various trade factors toward the use of wood in nonresidential buildings *(38)*". Despite the repeated use of the 1982 data, *Anderson's* results are more detailed and conclusive. One reason for this may be that, in addition to *Spelter's* sample of contractors and a few architects, *Anderson's* team undertook focus group sessions in the Dallas, Texas area with specifiers of structural materials (architects, engineers, owners, and contractors) as well as building material suppliers, and surveyed field marketing representatives across the United States *(38)*.

Architects from the focus group sessions identified three major factors impeding the use of wood in nonresidential construction:

1. Wood is perceived to be a warm, beautiful, and aesthetically pleasing material, whose main use should be as decoration and trim in such applications as churches, auditoriums, and board rooms. It is generally not thought of as a structural material in engineered design applications, though this is not so in small buildings. Thus, architects generally do not specify wood in larger nonresidential applications because they feel that it varies too much for engineered applications and because they do not have much experience with structural wood design.

2. Architects "perceive wood construction as not meeting structural or fire resistance requirements. They seem to say that if wood fire-resistive construction is possible, the insurance rates will be prohibitive *(38)*."

3. There seems to be no one specific delivery system in the forest products industry. In other words, with wood construction, the framing, connectors, and finishing materials come from different sources, while installation is by separate carpenter and roofing crews. That is, construction and design in wood is overly complicated with too many factors and variables compared to steel or concrete, where "specification can be written and a one-source supplier can do the complete job *(38)*."

On the upside, architects seemed genuinely interested in the prospect of utilizing wood products in nonresidential construction. They were impressed by "success storeys" of wood structures being built and found case studies and design idea sheets to be helpful. They also requested code information, insurance data, design specification data on product standards, and "a list of resources or contacts where additional information can be quickly and authoritatively obtained *(38)*."

Anderson's (1987) report also includes a survey of field representatives from wood products promotional associations, who were asked to provide information with regards to the constraints to increased wood usage in nonresidential construction and possible remedies to overcome these barriers. Ten major points were identified in this analysis, and are as follows:

1. There is a strong tradition of using steel and concrete in large nonresidential construction -- specifiers must be given a good reason to change.

2. A misconception, among specifiers, exists with regards to the inability of wood to meet fire and building regulations; a problem which is more serious than the actual code restrictions themselves.

3. Wood structures are seen as temporary or non-substantial and are perceived as lacking durability compared to steel or concrete.

4. Cost savings from using wood structures are often lost because contractors, who do not have much wood systems experience, tend to add on large premiums to cover contingencies; a factor which contributes to the perception that there are no cost savings to be had with wood construction.

5. Wood is seen as being an uneconomical alternative because of fire safety concerns and insurance cost penalties -- a full understanding of insurance rate structures must be obtained to overcome this drawback.

6. In-place cost estimates for wood structures are difficult to obtain which is disadvantageous in competitive bidding situations.

7. Very few "turnkey" packaged wood building systems exist, which would prove to be a marketing advantage.

8. Wood buildings are generally not competitive above two storeys and do not exist above four;

9. Contracting crews are generally educated in steel and concrete and have little desire to learn about wood.

10. Specifiers of building materials are concerned about some of the properties of wood, namely the lack of uniformity, problems associated with long-term maintenance, the variability in workmanship, and the existence of wood-eating pests *(38)*.

Jacques (1988) claims that architects and engineers have varied perceptions about wood, many of them invalid. These include the fact that wood is a warm and beautiful substance, that it is only suitable for small buildings, that it does not meet fire and building codes, and that it varies too much for engineering design. These perceptions, coupled with a strong steel and concrete tradition, inexperience with wood as an engineering material, the belief that wood is not durable and uniform, the lack of consistency seen in design manuals, and the belief that wood has long-term maintenance problems, constrain the entry of wood into the nonresidential market place *(19)*.

Crowley (1993) discusses two issues which affect the specification of wood products in the nonresidential sector. First, he feels that specifiers have a negative perception (and therefore, a lack of knowledge) of wood as a viable and appropriate material in terms of cost, strength, durability, environmental impact, and combustibility. These viewpoints, which result in many wood-suitable buildings being made of steel (often at a cost premium), are generally misguided. For instance, although wood does have unique construction requirements, it is competitive with steel up to spans of fifty feet. After that, wood's aesthetic attributes must be used to justify any additional costs. Furthermore, on a yearly basis, price fluctuations in wood compare to those of steel. This is not true on a seasonal level, where wood prices are more volatile. However, this can be dampened somewhat, according to Crowley, by adding value to the manufactured goods (for example, engineered wood products out of lumber stock). Finally, wood is a renewable resource with a positive environmental record *(7)*.

The second factor affecting the specification of wood products in nonresidential construction occurs on the supply side. According to *Crowley (1993)*, wood suppliers simply do not understand the needs of the marketplace and industry focus is weak and fragmented. This is due primarily to a reliance of traditional (residential) chains of distribution and a lack of coordination between industry, associations, government, and universities. Consequently, "the infrastructure for delivering nonresidential buildings made of wood is disjointed and difficult to access *(7)*". There exists a large segment of specifiers who would desire "turnkey" construction, whereby engineering, component manufacture, and site erection are included in one package. However, the capacity to deliver such value-added systems is presently insufficient in the wood products industry *(7)*.

Lyons (1987) states that the greatest problem that wood producers must overcome in order to penetrate the nonresidential market is the misconception that wood has no place in this market. He claims that potential customers in this sector perceive that wood buildings are unsafe (they burn), wood is not adequate for medium to large sized buildings, wood is not a true structural material while steel and concrete are, wood is not durable, and the wood resource base is in declining supply. *Lyons* further contends that, while none of these issues are true (wood is a safe and economical alternative, wood buildings are durable and usually outlast the usefulness of the building, wood is a structural material like steel and concrete, wood use in nonresidential construction can be doubled without further relaxation of forestry set asides), the perception issue is a long way from being resolved. In other words, these untruths about wood products must be dispelled and communicated to the decision makers responsible for material selection in the nonresidential industry *(23)*.

Another factor affecting the specification of structural materials in nonresidential construction may be how architects and structural engineers view the "greenness" or "environmental friendliness" of wood products compared to other structural materials used in nonresidential construction. In other words, the use of wood products may be perceived as environmentally detrimental by some specifiers, either in the resource extraction, processing / manufacturing, construction, occupancy, or demolition / disposal phases of the building process.

Taking a *"Life Cycle Analysis (LCA)"* approach, whereby natural resource inputs and waste outputs are measured for each of the above building phases, the impact of various structural materials on the environment can be quantified *(12)*. In fact, all structural material have their drawbacks, and the material which is best suited for a building (in terms of minimizing environmental impact) depends largely on the nature of the project. However, preliminary research by *Forintek Canada Corporation (1993)*, *Malin (1994)*, and *Marcea and Lau (1992)* shows the position for wood products to be healthy in this regard *(12, 24, 25)*. This is in spite of a concern for harvesting and forest management practices, which may explain why wood is often thought of as an environmentally unfriendly material *(24)*. If this concern is, indeed, wide-spread, this could be seen as a major deterrent to the successful entry of wood products into the nonresidential market.

Although little, if any, literature exists to support or contradict this claim, it is believed that the environmental impacts of structural material selection are, nonetheless, becoming more and more important in design considerations. This is best illustrated by the following letter to the editor from a group of prominent Canadian architects and patrons responding to the British Columbia government's decision to allow logging in the Clayoquot Sound. It appeared in *the Globe and Mail* in November of 1993 under the by-line, "B.C. wood sanctions" *(15)*:

> *"Architects are among those that determine the use of Canada's resources. We are conscious of the energy consumed and the environmental effects in both the manufacture and use of building construction materials. Architects have, therefore, an understanding of the need to husband resources, to conserve energy, to reduce pollution and to preserve our heritage. It is our conviction that we must, for everyone's sake and the sake of future generations, work toward a sustainable environment.*
>
> *In this context we have the greatest concern in regard to the decision to allow the logging of Clayoquot Sound. Because of our concerns, therefore, we will make every effort not to use wood products from British Columbia until the forest industry and the government of British Columbia stops logging old-growth forests and develops environmentally acceptable harvesting practices."*
>
> *Douglas Cardinal, Ottawa*
> *Phyllis Lambert, Montreal*
> *A.J. Diamond, Toronto*
> *Brian Mackay-Lyons, Halifax*
> *Arthur Erickson, Vancouver*
> *Eb Zeidler, Toronto*

This may represent an extreme viewpoint or may, in fact, be the status quo. Regardless, it is essential that the concerns of the specifiers regarding the environment be fully understood and documented.

Lembersky (1987) discusses several factors impeding the entry of wood products into the nonresidential construction market, especially east of the Rocky Mountains, where this issue is most prevalent. The first factor is that there are established competitors in the nonresidential market, namely the steel and concrete industries. Furthermore, there exist only a few large suppliers of these nonwood products (entrenched suppliers with more than 90% of the market), while thousands of wood products suppliers exist in the marketplace. A related problem is that there are established relationships in the marketplace. That is, there are strong bonds between steel suppliers, architects, developers, and bankers which result from doing business together for many years. As a result, steel for a nonresidential project is often ordered before the project goes out for bid. Established codes often penalize the use of wood in situations where they can be generally used. Finally, there exist established misconceptions with regards to the use of wood in a nonresidential context, which result in wood not even being considered as an alternative in many situations. These include misconceptions about fire performance, rot, pest damage, wood buildings being more difficult to rent, and wood buildings being inherently more financially risky *(22)*.

These same problems are also prevalent in the United Kingdom. *Gill (1987)* reports that, typically, views expressed by design professionals and laymen with regards to wood usage are that wood burns, only noncombustible materials should be used in large structures, wood rots, wood is not a serious structural material, architects and engineers cannot think in terms of timber, timber artisans are scarce, and there is a lack of "turnkey" timber buildings in the nonresidential sector. The present lack of wooden nonresidential structures in the United Kingdom can be attributed to the continuing recessionary climate and poor timber design education for architects and engineers *(14)*.

Moody and Freas (1987) elaborate on *Gill's (1987)* last point by discussing the topic of educating structural engineers on the use of wood in detail. They state that, given that the need (markets) for wood exists in nonresidential construction, the products are available, and wood is a viable and competitive alternative, there are only a select few designers and design firms with a high degree of competence in the area of timber engineering. Thus, the education of design professionals, both engineers and architects, is a major issue. Based on various surveys with regards to the teaching of timber engineering at universities and technical schools (at all levels), several conclusions were drawn with respect to the fact that only 13% of the engineering curricula surveyed required a timber engineering course, while 75% required steel and concrete courses *(27)*.

Knight (1987) concurs with *Moody and Freas (1987)* and states that, "it was apparent that the post frame building industry was losing out on a tremendous volume of potential business because engineers and architects were not familiar with post frame building design concepts, and therefor they specified construction methods that they were familiar with on the projects they designed *(21)*." This problem, he concludes, stems from a lack of formal education in post frame design from teaching institutions *(21)*.

Finally, *Wolfe (1981)*, in an hilarious and cutting critique of American architecture, accounts for a lack of wood usage by putting the blame squarely on academia. Though his thesis does not explicitly centre around issues of wood use, he is concerned with the state of architecture in America; namely the repetitious and unattractive glass, concrete, and steel "boxes" that he sees as prevalent. This type of design stems from the German *Bauhaus* school of the 1920's and 30's, where utopian, nonbourgeois ideals, coupled with the use of simple lines and materials, produced one of the most influential design aesthetics ever. The *Bauhaus* movement came to America in the late

1930's, and with it, a complete lack of understanding of the social constructs inherent in its manifesto. This left the issues of simple lines and materials to be taught in design institutions across America. Unfortunately, while glass, steel, concrete, and occasionally masonry were upheld as the materials of choice for this movement, wood was generally excluded to the point where "the principle of 'the integrally jointed wooden frame' seemed exhilaratingly rebellious *(37)*." Throughout the twentieth century, architecture evolved in a variety of directions. However, material use and the notion of the repetitious "box" did not change. Today, steel and concrete remain the dominant structural materials, both in terms of what is taught at design school and what is used in practice *(37)*.

Overcoming Barriers to Wood Use in Nonresidential Construction:

Despite the numerous results obtained by *Spelter et al. (1987)* and *Spelter (1987)*, few suggestions for improving the market position for wood products in the nonresidential sector were made. This said, it was recommended that an approach, similar to the steel industry, whereby a complete "turnkey" wood building package is offered, be taken to increase building efficiency and potentially reduce costs. As well, it was suggested that engineered wood systems would be used more frequently in nonresidential applications if specifiers became more familiar, experienced, and trained in the methods of wood design. Issues of wood quality, costs, and durability must also be addressed and somehow disseminated to the specifiers *(33)*. Finally, *Spelter (1987)* briefly discusses ways in which designers can overcome complex and variable building codes which are not conducive to the use of wood. These include careful occupancy classification selection, increasing allowable heights and areas by using open spaces and automatic sprinkler systems, and the use of fire-retardant-treated-wood *(34)*.

Anderson (1987), in a focus group with wood promotion and wood roof supply firm representatives, discussed what actions could be taken "to enhance the acceptance of wood systems by designers and specifiers of nonresidential construction *(38)*." The conclusions drawn from these discussions parallel what the architects stated, and can be summarized by the need for education. In other words, architects and engineers must be shown that wood does have engineering and design values and can, in fact, withstand seismic and wind loads. Furthermore, wood systems can often compete with and out-perform steel and concrete. As well, the need to convince specifiers that "wood construction can meet fire codes and be free of unreasonable insurance cost penalties" was stressed *(38)*. Finally, reasons for switching from the standard usage of steel and concrete, such as design flexibility, energy savings benefits, and cost savings through faster construction, must be put out to the specifiers *(38)*.

Anderson (1987) concludes this investigation by restating that the most pressing need, in terms of increasing wood usage in nonresidential construction is education; education not only of the specifiers and clients, but secondary groups as well. This list of groups that need to be educated include designers (architects and structural engineers), educators of designers and construction workers, clients (owners and developers), building contractors and subcontractors, design construction firms, building code officials, fire insurance raters and inspectors, lending institutions, corporate building departments, and government building departments. Methods of training recommended include "personal calls, seminars, meetings, and developing new curricula for engineering schools and trade schools *(38)*."

Anderson (1987) later reiterated his plan to increase wood usage in the nonresidential sector. He states, "first, we would identify the target owners and specifiers. Then we would provide an effective educational program to convince them that the use of wood in their [nonresidential] buildings would be to their advantage. Then, once the owners and specifiers have been interested, detailed training design seminars would be set up for the architects and engineers who actually must specify the design and supervise the construction *(4)*." An educational program, he claims, would serve to offset the prevalent attitude that wood cannot be used in nonresidential applications because of fire and building code concerns or higher costs. Only then could wood compete fairly with concrete and steel based on its true merits and not false perceptions *(4)*.

This sentiment is echoed by *Jacques (1988)*, who claims that the solution to increase wood usage in nonresidential construction lies in educating the main specifiers of building materials (architects and engineers) and changing their misconceptions about wood products. One possible method would be through the production and distribution of a new and comprehensive reliability-based wood design manual (*Load and Resistance Factor Design*). Another possible solution would be through the use of case studies *(19)*.

This need for education is one of the main thrusts of a *Techno-Economic Bulletin* put out by *Forintek Canada Corporation (1989)*. In it, it is stated that "more effective penetration of existing wood products could begin immediately if the products and associated design procedures were accepted by local building officials, designers, engineers, etc. A well-coordinated effort should be implemented in Ontario and Quebec and aimed at specifier's misconceptions with respect to product limitations, fire considerations, and availability of technical information *(11)*." Changes to the Canadian wood products industry distribution and marketing schemes are also recommended.

This need for education is made all the more important now that a movement towards a reliability-based, systems design approach is in place. Education must go hand in hand with research and development into predicting product performance and producing wood systems that are less expensive and offer unique and desirable characteristics *(11)*.

Howatson (1987) shares these views and states that wood producers must take a two-pronged approach to increasing wood usage in the nonresidential sector. First, on the marketing side, the correct groups - architects, engineers, designers - must be reached. Second, on the technical side, research must demonstrate that wood systems can meet reliability-based design codes and nonresidential fire standards *(17)*.

Moody and Freas (1987) state that to increase wood usage in nonresidential construction, first the situation of timber design not being taught to structural engineers and architects must be addressed. Short-term solutions to reach today's designers must include extensive continuing education in wood usage, while long-term solutions must include improved education in timber design at both the undergraduate and graduate university levels. They state that, "these solutions must be approached with a team effort between the universities and the wood products industry. Professional societies can be a catalyst, and industry representatives need to take an active role in their education task committees *(27)*." As well, effective and easy to read resource materials must be made available, wood product seminars must be put on (as long as their values exceed the costs), and technical schools must also try and incorporate timber engineering courses into their curricula. *Moody and Freas* conclude by stating that engineering education, and particularly timber engineering education, is of paramount importance if wood is to make inroads into the nonresidential construction market *(27)*.

Knight (1987) concurs with *Moody and Freas (1987)* on these points and adds that one way of remedying this situation is to disseminate literature and documentation (from wood products associations) to the architecture and engineering schools *(21)*.

Siedlak (1987) adds that interest in wood usage can also be increased through design competitions put on by wood products associations. This would serve to effectively educate architects, builders, and engineers in the use of wood in nonresidential construction. He goes on to talk about the often overlooked importance of the owner / developer in the specification of building materials. That is, the architect or contractor may suggest a material to be used, but inevitably, he/she will abide by the owner's recommendations as a commission and reputation is at stake. Finally, the importance of "single-source responsibility packages" or "turnkey" buildings is discussed. Delivery, execution, and erection of a wooden building from one source (tied into one company) would give forest products companies a competitive advantage which does not presently exist (this concept has existed for many years but has not been widely implemented in the forest products industry). In other words, clients need only talk to one supplier to put a building in place *(32)*.

Schuler et al. (1987) expands on the notion of marketing and research needs. They concede that a major opportunity exists for the forest products industry to make inroads into the nonresidential construction market. However, penetration of this market will not only require a strong, customer-oriented marketing approach, but will also require "an extensive research program in engineering and fire related research *(31)*." This will be required for wood products to compete effectively with highly engineered nonwood products and systems. Specifically, the areas of safety, economy, time required to complete projects, cost competitiveness, quality, and durability must be explored. Characteristics of wood, including its low cost and lightness, its variable short term stiffness and strength properties, its long term performance properties, its end uses, and the changing resource must be extensively examined. Engineering research, including analyses of truss-plate rafters and the reliability-based code philosophy must be included. As well, structural research needs must be addressed, such as materials and fastener performance data, system analysis programs, serviceability and strength criteria, load models, reliability assessment procedures, and code development. This engineering-related research is imperative to the marketing of wood products. In other words, the first step to successfully marketing wood products is to ensure that the products and associated design procedures are accepted by building officials. As the report states, "expanding structural use of wood in nonresidential construction can proceed only if codes and standards bodies provide acceptance of wood in nonresidential applications *(31)*."

This basic sentiment is also expressed in a report by *Goodman (1987)*. He states that wood products can effectively compete in the nonresidential sector, especially with the advent of design tools that have been developed by past research and the increased use of reliability-based design methods. He states that penetration of this market will require the wood industry to "implement changes to provide materials and components which offer tight control over variability in strength and stiffness. Design code changes will be required and special attention in recognizing the differences in the behaviour of wood structures as opposed to those of other competitive materials will be imperative *(16)*."

Walters (1987), in a presentation on the importance of customer service, discusses the fact that nonresidential construction is a multifaceted activity which usually involves many participants in the decision making process, including an owner, architect, engineer, contractor, subcontractors, and material suppliers. Furthermore, nonresidential structures are generally larger, more complex, and highly regulated. As such, customer service (on the wood products suppliers part) for this market is much more complicated and demanding than in a commodity-based market, such as the residential sector. The concept of customer service becomes more paramount when one realizes that nonresidential projects (and the associated building materials) usually have to be sold twice: once to the specifier (the architect and structural engineer) and again to the owner, developer, contractor, or framer. Each of these buyers must agree to the building material at hand, and each has different needs which require different sets of services *(36)*.

Customer service for the first group of buyers, the specifiers, can essentially be equated with education. They need to be educated in the use and design of wood in nonresidential applications; they need to gain familiarity with wood as a building material. Along with design considerations, they must be assisted with economic analyses (for pricing buildings) and the familiarization of the vast array of wood products that exist in the marketplace. It is essential to remember that architects and engineers are the professionals that make the initial choice of building materials. Thus, they are the most influential party involved and, as a result, need to be serviced. *Walters (1987)* states that, "it is also important that their role and function not be bypassed or usurped since they can be the strongest advocates and allies possible *(36)*."

The second group of buyers, the owner, developer or general contractor, require a set of customer services as well. This customer service package usually includes assistance in obtaining building permits, meeting fire and sound requirements, warranties, performance guarantees, and quality assurance. General contractors usually require assistance in material takeoffs, system optimization, technical guidance, and most importantly installation plans and details (including shop drawings). Furthermore, a coordinated effort amongst all of the suppliers and an efficient delivery system is needed *(36)*.

It is essential that these consumer service needs be addressed by the marketing and distribution systems of forest products producers and suppliers in order for wood products to penetrate the nonresidential market. Coordinated efforts by manufacturers, trade associations, accessory manufacturers, and local sales representatives are required for a system like this to fall into place. It is important to remember that customer service has a real value, in terms of the customers' perceptions. That is, consumer loyalty can be gained and greater returns can be demanded *(36)*.

Galligan and O'Hallornan (1987) discuss one of the above mentioned concerns, product performance and quality assurance, at length. They conclude that, in order for wood products to compete effectively in the nonresidential sector, standards procedures and quality control systems for all wood products, especially ones that have recently been introduced, are absolutely essential. Specifically, performance-based, rather than prescriptive, product standards must be developed and quality control programs, developed by industry associations, must link the notions of producer / consumer risk to anticipated end uses *(13)*.

The need for improved competitive cooperation among the proponents of wood use is stressed in *Lyons' (1987)* report. In other words, an industry-wide effort (including producers, associations, and research agencies) must be put in place to convince architects, engineers, and contractors that "wood systems are not only viable, but in most cases are preferable over concrete and steel *(23)*." Finally, the need for communication that encourages, rather than discourages, the use of wood in nonresidential construction, was stated. Communication to specifiers must be in a positive and understandable manner. One must make a concerted attempt to understand the needs of the customers and communicate to him/her in an understandable and simple manner, avoiding technical jargon at all costs *(23)*.

Gill (1987) agrees and states that the successful dissemination of literature, documentation, design aids, and explanatory material (prepared by industry-wide forest products associations) among architects and engineers (and to students, free of charge) is required to increase wood use in nonresidential construction. This would serve to educate them in the field of timber design and to awaken their interest in wooden structures *(14)*.

Likewise, *Lembersky (1987)* proposes that, in order to overcome the barriers and misconceptions about wood use in nonresidential construction, concerted marketing efforts must be put forth by the forest products companies. However, this must not be in a way in which forest products compete with one another. Rather, the forest products industry, as a whole, must compete with the steel and concrete industries. Industry level promotion must be long-term and aggressive. As well, education on wood usage in nonresidential construction among architects, builders, and owners (the specifiers and users of buildings) needs to be improved. Schools entrenched in routinely teaching steel and concrete engineering, while ignoring timber engineering, need to be addressed. An awareness of wood as a viable option needs to be instilled in specifiers of building materials, upon which an understanding of the specific facts of wood usage can be built (dispelling misconceptions about performance, rot, fire, etc.). Finally, companies, along with the above mentioned marketing orientation, must develop a product orientation. This requires a further understanding of the performance of wood products in the overall context of building performance and product development based on engineering, research, and end-use considerations. This represents a technology and market driven approach, as opposed to the more traditional manufacturing or raw material driven approach *(22)*.

Crowley (1993) states that the recent development of engineered wood products and reliability based design methods will help to make inroads into the nonresidential marketplace. However, this is just the beginning for the highly fragmented and unfocussed wood products industry. Like the steel and brick industries, he recommends that a *Council for Wood Building and Construction* be established, comprising of industry, university, association, and government members. Presently, over 85 wood associations exist, yet only one is devoted to the needs of the nonresidential sector. The new council will focus on the specifiers of structural materials in this market and, through increased research, promotion, education, and technical support, "create awareness, induce trial, and support repeat buying *(7)*" of wood products. Hopefully, these coordinated efforts will serve to stimulate long term growth and demand in the nonresidential sector, demonstrate the competitiveness of wood building systems, and support the development of new products and services. In so doing, the council will become known as the single resource centre for issues relating to wood use in nonresidential construction. *(7)*.

Crowley (1993) also recommends that strategic partnerships among companies be set up to improve market penetration in the nonresidential sector. There are over 1600 small to medium-sized forest products companies in North America and these types of alliances would allow for scale economies to emerge through more efficient "co-marketing" sales tactics and joint product development. These partnerships would also work on improving the market position of wood by setting up cohesive and unfragmented delivery channels with minimal vendors, providing complete "turnkey" structural systems, selling tested and proven high quality products that are stable, durable, and environmentally friendly, offering product service and engineering consultation, and ensuring that up to date and accurate product information and research results are readily available to the specifiers. Furthermore, engineered wood products suppliers must differentiate themselves from commodity producers by offering engineering expertise, connection design, shop drawings, delivery and installation, product compatibility with nonresidential specifications, and computer ordering. In short, producers must sell the benefits of wood products to the specifiers of structural materials. To do this, they, along with the aforementioned council, must first understand the building requirements and improve the awareness of wood use in the nonresidential sector *(7)*.

Finally, The *Canadian Wood Council (1989)*, in its 1989 Annual Report, states that in order for wood products to penetrate the nonresidential markets, industry-wide action must be taken on key groups of decision makers "who determine how a building will be designed and constructed and what materials will go into that construction *(3)*." Five key groups of decision makers, whose numbers are large in North America, have been identified: teachers, architects, engineers, builders, and regulatory officials. The tactics used to increase wood usage in the nonresidential sector must rely on increasing the awareness of these key groups, by "collecting information from them on their needs, by building up technical information so that it is superior to that provided by the competitors, by using actual examples of successful wood construction, by demonstrating the attributes and advantages of wood products, by working with educational institutions so that their curricula include teaching about wood, and by a sustained effort to attend to all the details of regulatory procedures so that the regulatory environment is kind towards wood *(6)*."

A Survey of the Relevant Marketing Research:

Very little has been done in the way of gauging the attitudes and perceptions of the specifiers of structural materials in nonresidential construction using marketing research methods. However, two notable exceptions, both commissioned by the *Canadian Wood Council*, do exist. The first is a telephone survey conducted by the *IBI Group (1988)* of Toronto *(18)*. The second consists of focus group sessions and mail surveys and was conducted by *Optima Consultants (1989)* of Ottawa *(28, 29)*. Both of these marketing research undertakings will be discussed in turn.

The *IBI Group (1988)* conducted a telephone survey of 97 selected architects across Canada. A smaller number of contractors, insurance companies, owners / developers (five, five, and two, respectively) were also contacted. The purpose of this endeavour was to measure the attitudes of architects (as the key decision makers) with regards to lumber and wood products use in non-single family dwellings, and commercial, industrial, and institutional buildings of four storeys or less, and in so doing, hopefully identify the market barriers and constraints to increased wood use *(18)*.

The results of the analysis show that there are many perceived barriers to the use of wood products in this context. For example, product limitations, fire considerations, and the availability of tradespeople were frequently mentioned drawbacks to the use of wood. However, wood was also commended for its ease of use and lower costs. Potential methods to overcome these drawbacks were also elicited from the respondents. Their solutions included increased education, as well as improving product quality and availability, technological advances, providing more information, and improving the economics of using wood. An environment that would be conducive to an increase in the use of wood would include better technical information, better availability of materials, and materials which cost less. Finally, the survey also found that, while Ontario and Quebec had high construction volumes for buildings four storey or less, they had the lowest percentage of wood design. Provinces with high proportions of wood design included Saskatchewan, Manitoba, and Newfoundland *(18)*.

There were also three recommendations in the report prepared by the *IBI Group (1988)*. The first involved the transfer of information (communication efforts), in the form of promotional materials, information packages, and case studies, to architects in Ontario and Quebec. The second stressed the need for technical research, especially with regards to product limitations (fire hazard). Finally, the third (and perhaps most important) recommendation involved examining the concerns of the respondents in an attempt to determine whether they are true facts or false perceptions in reality *(18)*.

The research conducted by *Optima Consultants (1989)* was in two stages: the first consisting of qualitative focus group sessions with architects (eight), engineers (seven), and engineering educators (six), and the second consisting of quantitative mail-out surveys to 620 architects across Canada (with a 21% response rate or 129 architects). The purpose of the focus group sessions was to examine ways in which wood products usage could be increased, especially in the construction of low-rise commercial, industrial, and institutional buildings. This study hoped to identify the barriers which are responsible for the low level of wood use in this context, identify ways in which wood use could be increased in this context, assess the usefulness of the *Canadian Wood Council's* communication efforts, and find ways of ensuring that design students were exposed to wood construction and design. The purpose of the mail-out surveys was simply to assess the usefulness, effectiveness, and reception of the *Canadian Wood Council's* communications efforts among building professionals *(28, 29)*.

The results of the focus group sessions were, to say the least, numerous. Factors impeding the entry of wood into this market included the fact that many specifiers believe wood to be at its full market potential already, building and fire codes which place restrictions on wood use in larger buildings, strength and quality variations in wood, moisture problems and wood shrinkage, lower profit margins for engineers on wood buildings, numerous calculations involved in timber design, the lack of readily available resistance tables, the complexity of, and extra calculation work required for, timber connections, the lack of metrification in wood products, the lack of coordinated marketing and technical information available to specifiers, and environmental concerns associated with placing a higher demand on wood *(29)*.

Suggestions for increasing the use of wood in this sector included the production and distribution of technical information (specifically on safety performance and fire separation), design tables, and software, improved marketing (regular sales visits, selling of wood as an interconnected system, aggressive marketing of engineered wood products), metrification in the wood products industry, the creation of one, unified manual for wood (similar to steel), the standardization of timber connections, improved education in wood usage, research into the strength properties of wood, and the advocacy of combined materials use *(29)*.

In terms of education, it was acknowledged that wood design is generally not taught in most universities. Engineers and some educators noted a need for such timber engineering programs, however many educators felt that a timber design course should not be required in engineering curricula as wood is not seen as being as important in structural engineering as steel or concrete is. Despite this sentiment, the need for a good, dedicated Canadian wood design text book was noted *(29)*.

The remainder of this survey was dedicated to communication efforts, on the part of the *Canadian Wood Council*, to the specifiers of structural materials. Such items as *Wood Post*, data files, the *Limited States Design of Wood Structures* book, case studies, and the *Woods* software design program, were discussed at length. The panelists generally viewed these efforts favourably, depending on the specifiers in question. In other cases, certain groups found little practical use in some of these efforts but thought that other groups of specifiers could better utilize them *(29)*.

The results of the mail-out survey contained a number of key findings that were, by their nature, intrinsically tied to the findings from the focus group sessions on the *Canadian Wood Council's* communication efforts. It was also determined that 46% of the architects surveyed claimed to design nonresidential structures solely, while 25% stated that they design both residential and nonresidential structures, bringing the total of architects involved in nonresidential construction to 71% *(28)*.

Respondents were also asked to comment on the *Wood Construction Data Files*, the *Fire Protective Design Data Files*, *Wood Post*, and the *CWC Calendar*. Generally, responses were favourable (there was interest and familiarity) to all categories and architects noted improvement in the quality and distribution of the communication efforts *(28)*.

As well, additional information with regards to wood design was collected in this survey. For instance, architects stated that, in order to help them design in wood, they would require more technical information and data, a list of related publications, and information on wood protection, the characteristics of wood, and different wood applications *(28)*.

Finally, information with regards to the relative position of the forest products industry compared to steel and concrete was ascertained. In terms of advertising, the wood industry was considered to be superior to the steel industry. However, the steel industry was superior in the areas of office visits, seminars, and handling technical inquiries. Both industries were considered to be on par in the area of exhibits and tradeshows. A comparison with the concrete industry showed the wood products industry in a better light. Only in the area of seminars was the wood industry considered to be inferior. The concrete and wood industries were considered to be equal in the area of office visits. However, in every other area, the forest products industry was considered to be superior *(28)*.

A Comment on Methodology:

Though several studies have been cited in this report, very few of the authors have actually conducted genuine market research (i.e., scientific and inferable to the population) into the use of wood in nonresidential construction. In fact, most of the literature cited here (*Crowley (1993)*, *Howatson (1987)*, and *Jacques (1988)*, to name but a few) is mere commentary based on available census data, construction data, and research on the part of a few key individuals, including *Reid (1977), Spelter (1987), and Anderson (1987)*.

Unfortunately, in the case of *Reid's (1977)* work, the insistence on the use of tables makes interpretation difficult and arduous. As well, there appear to be problems with the research methodology used here. Apart from the mention of the research firm which collected the data, the dates at which collection took place, and the source of the data (*F. W. Dodge Division, McGraw-Hill Information Systems Co.*), very little information is given with regards to the procedures used in obtaining the data and the validity of the source. Thus, data is spurious, at best, and must be approached with caution. Furthermore, the information collected here is out of date and does not include Canadian consumption.

Unfortunately, like *Reid's (1977)* work, data from *Spelter et al. (1987)* is somewhat outdated and does not extend into Canada. Furthermore, the sampling methods (particularly the use of the bootstrap method to obtain relative standard errors) and the conversion factors (based on *F. W. Dodge* contract awards) used to characterize the nonresidential construction industry are questionable and confusing, to say the least. In fact, by admission of the author, a portion of construction activity is missed (though this was said to be taken into account). The surveys with specifiers of materials in nonresidential construction, which took the form of telephone questionnaires (350) and personal interviews (253) seem to be statistically valid (although the sample sizes are small considering the vast size of the groups in question). What is more striking here is the fact that the opportunity to do real marketing research was missed. In other words, while an adequate job of determining what the specifics of the problem at hand were (namely the lack of wood usage in the nonresidential sector), little was achieved in ascertaining why these problems are occurring and what can be done to prevent them. Despite these drawbacks, however, this is probably the most extensive survey of the nonresidential construction sector ever conducted and should, duly, be commended. Much can be learned from the methods of sampling and the information collected in this study.

Anderson (1987) uses similar methods (wood use factors applied to 1985 *F. W. Dodge* activity levels which are subsequently adjusted to Census totals) to obtain estimates for wood usage in the United States nonresidential construction market for 1985. As well, he often cites *Spelter's (1987)* 1982 data to substantiate his claims. Finally, commentary on the specifiers of building materials in nonresidential construction is based solely on *Spelter's* 1982 survey results. Thus, the problems stated above apply here, as well.

Correct marketing research procedures were, conversely, used in the *IBI Group (1988)* and *Optima Consultants (1989)* reports prepared for the *Canadian Wood Council*. Generally, all of the market surveys conducted here are valid. However, the sample population used in the *IBI Group* attitudinal survey is small and restricted to Canada. Thus, findings are few and not far-reaching and should be interpreted with caution. The *Optima Consultants* report on focus group sessions is extremely helpful in setting directions for future research needs in the area of attitudes and perceptions of specifiers in nonresidential construction. However, very few, if any conclusions can be drawn because of the qualitative nature of the data collection methods (focus group sessions). Conversely, the *Optima Consultants* report on communication efforts is thorough, quantitative, statistically valid, and conducive to drawing conclusions. However, the subject matter, by limiting itself to the communication efforts of the *Canadian Wood Council*, does not deal with the important topic of attitudes and perceptions of the specifiers of construction materials in nonresidential construction.

Summary of the Literature:

It can be seen from the literature that the North American nonresidential market is vast indeed; comparable in size to the residential market, according to some estimates. Unlike the residential sector, though, the nonresidential market is stable and exhibiting a slow but positive growth. The majority of nonresidential construction activity is small to medium-sized (less than 4 storeys in height and 100,000 square feet in area) and, as such, could viably be built of wood according to most building and fire codes. However, steel and concrete continue to dominate this market. The market share for wood products is small and in decline.

The North American nonresidential market remains relatively untapped by the forest products industry and, as such, represents an immense opportunity. In fact, the potential exists to increase wood's market share two or three times by eroding the shares of steel and concrete. This is especially true given the advent of specialty engineered wood products and reliability-based design methods. Some regions, such as Southern United States and Eastern Canada, show tremendous promise for growth. Mercantile and institutional buildings have also been identified as segments where wood use could be drastically increased.

To understand why wood use is low in a nonresidential context, one must speak to those directly involved in the specification of structural materials. There is relative agreement in the literature as to who the main specifiers of structural materials are: namely, architects, structural engineers, and to a lesser extent owners, building contractors, developers and other involved parties. However, there is disagreement as to how the specification of materials is apportioned between them. A survey of the relevant research seems to indicate that architects are thought of as the main specifiers with structural engineers acting as primary consultants. The remaining parties involved act in a more incidental manner, though their role in the specification of materials should not be discounted.

Most of the literature reviewed here centred around determining why the aforementioned parties specify wood so infrequently in the nonresidential sector and what can be done to overcome this reality. Many of the sentiments expressed were perceptions and do not necessarily represent the truth. Some of the most commonly stated concerns and issues included the following:

- Wood is thought of as a warm and aesthetically pleasing material, whose main use should be as decoration and trim and not engineered, structural applications where long spans are required. Conversely, wood is well suited to smaller buildings where strength of members is not an issue.
- Wood is a combustible material and there is a perception that it does not meet structural or fire resistance requirements for nonresidential buildings. When fire-resistive construction is possible, insurance rates become prohibitive.
- Building codes for nonresidential wood construction are thought of as complex and variable, while design manuals lack consistency.
- Wood structures are seen as temporary, unsafe, and non-substantial. They lack the durability of steel and concrete structures. They are "high-maintenance" compared to steel and concrete buildings. Pest and rot damage contributes to this argument, as well.
- Wood is thought of as a highly variable material, lacking in uniformity and quality. A prevalence of warped and crooked lumber and smaller diameter, second-growth timber with less clear wood and more juvenile wood does nothing to dispel these notions.
- Wood may be perceived as the "environmentally unfriendly" building alternative because of negative press surrounding harvesting and forest management practices and the declining resource base.
- There does not seem to be one specific delivery system in place, whereby engineering, component manufacture, and site erection are included in one "turnkey" package. Traditional chains of distribution are thought of as insufficient in the highly fragmented and unfocussed forest products industry.

- The forest products industry has done a poor job of marketing its goods to the specifiers of building materials, who are consequently untrained and unfamiliar with the vast array of engineered wood products that exist in the marketplace. As a result, misconceptions and fear pervade throughout the industry.

- Wood systems, despite a lower cost per piece, are seen as more costly than steel and concrete systems. This is due, in part, to contingencies that inexperienced contractors add on, insurance cost penalties, the cost of building in fire resistance, and the lack of "turnkey" structures.

- There is a strong steel and concrete tradition in the nonresidential sector due to well established and long-term relationships between specifiers, manufacturers, developers, and bankers. No such infrastructure is in place for the forest products industry.

- Timber engineering courses are scarcely taught at the university level. By far, steel and concrete use dominate design curricula across North America (in both architecture and engineering schools). As well, there seems to be a lack of continued education in issues of wood use. As a result, only a select group of designers and firms have any knowledge of timber design in a nonresidential context.

The solution to these problems then, according to most of the literature, is to educate the specifiers on the usage of wood as a structural material. A two-pronged approach to remedying this problem is generally offered. Improving (or even offering) timber design courses at the scholastic level will serve to spark the interest of many young designers. This should be accomplished by ongoing efforts on the part of industry-wide associations, research organizations, teaching institutions, and societies. As well, easy to read resource materials and design seminars must be made available to students.

Continuing education, conversely, can be accomplished simply by stepping up company-specific and industry-wide marketing efforts. Companies must offer quality assurances, consumer services, and one-source supply as well as personal sales calls, product brochures, information packages, and seminars. Engineered wood producers must differentiate themselves from commodity producers by offering more expertise and services in the design and installation of wood structures. Most importantly, the fragmented forest products industry as a whole must make a concerted and focused effort to alleviate any fears that specifiers may have concerning the use of wood, and convince them that wood is a viable option in many cases over its major competitors, steel and concrete. This can be accomplished by aggressively pursuing the specifiers of building materials, gauging their attitudes and perceptions, finding out their wants and needs, providing them with technical and product information and designs, and showing them demonstration buildings.

Other ways in which barriers to wood use in the nonresidential sector can be overcome include maintaining ongoing forest products research, especially in the areas of material strength, reliability assessment procedures, and fire resistance. Furthermore, companies must set up co-marketing alliances and product orientations whereby products are developed and sold (perhaps jointly) with engineering, research, and end-use considerations in mind. Lastly, cohesive and unfragmented delivery channels with minimal vendors must be set up to more efficiently serve the needs of the specifiers.

Finally, it should be stated that, with two notable exceptions, the absence of valid marketing research on the topic of wood use in the nonresidential sector is conspicuous, to say the least. Most of the literature cited here is nothing more than a restatement of available census and construction data. While this is commendable, the opportunity to scientifically determine why wood is not being specified more frequently and what can be done to overcome this reality has been missed in most cases. That is, the attitudes and perceptions of specifiers as they pertain to wood use were not considered, for the most part. It is obvious that, in order to correctly assess the market environment for wood products in the North American nonresidential sector, extensive marketing research must be performed on the specifiers of structural materials -- namely, the architects and structural engineers.

CHAPTER 2

PRELIMINARY RESEARCH

Preliminary research and the literature review made up Phase I (qualitative research) of this study; the purpose of which was three-fold. First, it was to determine what, if any, research had been done in this field. Second, it was to gather information and feedback from the actual specifiers of building materials and related professionals. Third, it was to obtain industry input on the types of results that would be of most use to them. Thus, along with the literature review, exhaustive ethnographic research and a meeting / survey of an industry advisory panel was undertaken. In so doing, a direction was set for Phase II (data collection and analyses) of this research undertaking: a comprehensive review of a significant number of specifiers of building materials in nonresidential construction in North America.

Ethnographic Research:

In late 1990, approximately seventy in-depth interviews were conducted with architects, structural engineers, contractors, and developers, as well as various related professionals such as academics, forest products industry personnel, fire experts, insurance agents, and lawyers. The topics of discussion revolved around the specification of building materials in nonresidential construction, with special attention to the use of wood products.

The idea behind this ethnographic research was to talk directly to the specifiers of building materials in nonresidential construction and, in so doing, learn who specifies building materials, what their attitudes and perceptions are, and what views have they to offer pertaining to the research at hand. The exploratory and qualitative nature of this preliminary research precludes any conclusive scientific results. However, several interesting trends (for each professional group) emerged as a result of these exhaustive discussions[1].

Architects considered themselves to be the main specifiers of structural materials in nonresidential construction. It is the structural engineer's job to aid them in the realization of their designs, by ensuring the structural integrity of

[1]These findings are too varied and numerous to recount here in detail. As such, the interested reader is directed to:

"A Preliminary Analysis of the Specifiers of Building Materials in Nonresidential Construction", by Robert A. Kozak, Donald W. Beckman, and David H. Cohen, November, 1991.

the building. The role of contractors and developers is seen as advisory by architects. Conversely, engineers feel that their role in the specification of building materials is equally important as the architects', especially when the engineer acts as the prime consultant. However, they do say that material specification is typically initiated by the architect. Finally, contractors and developers differentiate between two types of construction. "Standard construction" involves the developer bringing ideas forth to the architect, who subsequently specifies the construction materials (under the developer's approval). "Fast track construction" involves more of a team approach between architects, structural engineers, contractors, and developers. As well, the often ignored needs of the client are seen as being influential to contractors and developers.

Wood is generally not thought of as a viable alternative to steel and concrete in nonresidential construction by all four professional groups. Though some positive reactions to wood use in this manner were elicited, namely its warmth, beauty, non-corrosiveness and flexibility, perceptions were, for the most part, negative. Common complaints included prohibitive building and fire codes, higher costs associated with wood, material variability, a lack of durability, a lack of education and experience using wood, a highly litigious atmosphere which precludes the use of untested products like wood, the need for complicated timber connections, the need for additional drawings and calculations, a simplicity to wood which is associated with residential construction, inferior marketing by the forest products industry, and client preferences for steel and concrete. Architects seemed most favourably disposed to the use of wood in a nonresidential context, followed by structural engineers, and, lastly, contractors and developers. This is seen to be directly related to the amount of work that is required from each of the professional groups if wood were to be used widely in this application.

Various recommendations came to light as a result of conducting these interviews. It was seen that, despite the fact that the specification of building materials is generally a collective decision by several parties, architects are likely the most influential decision-makers, followed by structural engineers and then, lastly, contractors and developers (who act in an advisory capacity). Thus, it was recommended that survey questionnaires be sent primarily to architects, the main specifiers of building materials. However, structural engineers were also to be surveyed to a lesser degree, say a 2:1 ratio. It was also recommended that contractors and developers be surveyed (locally), not for any scientific purposes, but rather to obtain any related input that would prove to be useful in this research endeavour. Unfortunately, a lack of time and funds did not permit this latter investigation to be undertaken.

In an attempt to better understand the specification of building materials in nonresidential construction, six areas were identified for inclusion in the survey questionnaire:

1. General attitudes towards structural materials (wood, steel, concrete, and masonry) with specific attention to engineered wood products.
2. An understanding of the design and material selection process.
3. The effectiveness of the various strategies used to market structural materials.
4. The effects of education (both in the school and on the job) on the selection of building materials.
5. The impact and importance of code restrictions (building and fire) on the use of wood and other building materials.
6. The effects of legal and insurance related constraints on the specification of building materials.

Each of these topics were incorporated into the survey questionnaire with the aim being to yield scientifically valid conclusions pertaining to the specification of building materials in the nonresidential market.

Meeting with Industry Advisory Panel:

Upon completion of the literature review and ethnographic research, a meeting of an industry advisory panel (consisting of project sponsors and committee members) took place. The overall purpose of this meeting, held on February 21st, 1992, was to obtain feedback on the research that had been done to date and to elicit suggestions regarding the future direction of Phase II of this research; a comprehensive survey of a significant number of specifiers in nonresidential construction. Specifically, information pertaining to what types of data should be collected and from whom (using a mail-out questionnaire format) was discussed. However, as expected, the conversation moved in many directions. Minutes from the meeting, seen in Appendix A, show that a wide range of topics were discussed, including education, specification of building materials, mail surveys, design tools, performance requirements, product and technology requirements, the need for technical knowledge, communication efforts, information dissemination, seminars, marketing efforts, cultural differences, industry-wide versus company-specific goals, environmental issues, and ownership of the research.

In an attempt to simplify the outcome of the meeting and quantify a focus for Phase II of this research, facsimile surveys were sent to all of the participants the following week (Appendix B). In it, they were given a list of the many topics that were brought up during the course of the meeting and asked to rank the three most essential and three most needless issues for use in the mail survey. Results were collated (Table 2.1) in such a way that as one moves down the list, issues become less and less essential.

Table 2.1: Industry Advisory Panel's Focus for the Mail Survey.

ESSENTIAL	Best means for educating architects and engineers about design using wood.
	Most suitable design tools to encourage switch to wood use.
	Most appropriate current promotional, service, and training methods (for all construction materials).
Somewhat Essential	Need and desire for technical information and knowledge about existing solid wood commodities.
	Process that firms use to choose structural materials for commercial construction.
	Factors affecting the installed cost of wood in industrial buildings, compared with competitor materials.
	Design philosophy and whether it is amenable to wood.
Neither Essential or Needless	Attitude towards wood in general.
	Impact of perceptions and realities of laws, codes, and insurance premiums as constraints on wood use.
	Existing and expected importance of environmental impact on construction and use of building materials.
	Market structure -- types of design firms; who within firm designs buildings suitable for wood.
Somewhat Needless	Familiarity and opinions towards specific engineered wood products, as well as commodity solid wood products.
	Product positioning (with concrete and steel) for specific uses.
	Market size in terms of dollars, square footage, and number of design firms.
NEEDLESS	Familiarity and opinions towards specific engineered products.

The resulting focus for the mail survey (Table 2.1) was extremely helpful in setting the direction of Phase II of this research endeavour. Specifically, questions to be posed to the specifiers of building materials in nonresidential construction (in the form of a survey questionnaire) were obtained and prioritized. As expected, the industry representatives were concerned with more immediate issues like the best means of education and promotion, the most effective design tools and technical information, and factors affecting building costs. These topics were extensively addressed in the mail survey. More esoteric issues, which emerged from the ethnographic research, were considered less essential. These include issues of market positioning, size and structure, as well as specifiers' attitudes toward and familiarity with building materials and their perceptions of building codes, laws and environmental issues. This is not to say that the latter issues were ignored in the mail survey. Rather, these topics were dealt with in a more peripheral manner.

CHAPTER 3

METHODS

Any scientifically valid research project must begin with rigid attention to issues of sampling and data collection. This is especially prevalent in a study of this magnitude, where the size of the population, the methods of sampling, and the cost of sampling prohibit re-sampling in the event of design error. Thus, methodology is absolutely critical and must be closely scrutinized. That said, the sampling and subsequent analyses of architects and structural engineers across North America was carried out in accordance with accepted scientific methods *(39)*. The sample frame, sample size, sampling procedure and design, and sampling instrument are presented here in detail. Primary data collection, entry, and analyses are also discussed.

Sample Frame:

The population under study consists of all architects and structural engineers in North America. It is recognized that many of these professionals are not involved in the specification of materials in nonresidential construction. However, an estimation of the proportion of design professionals that do not work in the area of nonresidential construction allowed for a better understanding of the marketplace to emerge. Furthermore, given that information was collected using a mail survey, inexperienced designers were asked to pass the survey along to someone else in their firm with more appropriate qualifications. It should be noted that individual designers were sampled rather than entire design firms, because it is believed that the personalization that comes with individual sampling ensures a higher response rate *(10)*.

The sample frame, from which design professionals were selected, came from various mailing lists. These lists were chosen, not only on the basis of size, but on which one(s) best represented the population in question. That is, while comprehensive lists were desirable, it was more important to obtain ones that closely approximated the population, geographically and demographically.

In Canada, the entire mailing list of architects and structural engineers used by the *Canadian Wood Council* was purchased through *York Mailings* in Ottawa. In the United States, mailing lists of registered architects / designers and structural engineers were purchased from the *American Institute of Architects* and the *American Society of Civil Engineers*, respectively. It should be noted that these three lists represented the most comprehensive catalogue of North American designers that could be found. In all, approximately 90,000 names were represented. In order to bring this number down to a workable level, the lists were amended to include only those architects and structural engineers that were registered as such. Each of the three lists were then sorted by address (by province in Canada, and by Zip Code in the United States) and systematically sampled using a random selection scheme (n^{th} name starting at a randomly generated location on the list) to ensure that the samples approximated the geographical makeup of designers across North America (see the following section). This varied slightly in the province of Quebec where, due to the language of the questionnaire, every effort was made to select designers that were English-speaking or bilingual.

Sample Size:

According to the 1991 Canadian census, there were nearly 12,000 architects and approximately 10,000 structural engineers working in Canada in that year (note that the latter figure is not known exactly as civil engineers have not been sub-divided). The 1988 United States census reported lower per capita rates of approximately 38,000 architects and 15,000 structural engineers. Thus, the sample frame sizes of the two populations under consideration (N_1 and N_2) are 50,000 and 25,000 for architects and structural engineers, respectively.

Unfortunately, due to budgetary constraints, coupled with the relatively high costs of sampling units using the mail questionnaire format, funding was the main consideration (and limiting factor) in determining the sample sizes (n_1 and n_2) for architects and structural engineers. At an average cost per sampling unit of $3.30 (the quoted price, including printing and mail-out), and a total budget of $20,000, no more than 6,000 surveys could be mailed out. Equally split among both professional groups, this meant 3,000 surveys each. At an architect to engineer ratio of 2:1 (as proposed in the ethnographic research), the number of surveys sent out became 4,000 and 2,000 for architects and engineers, respectively. It should be noted that these figures represent the number of surveys sent out and not the actual sample size, as non-response has not been taken into account at this point.

Admittedly, this was not a very scientific approach to determining sample size. However, it was useful in showing what limits existed. Furthermore, there were several problems associated with scientifically determining the sample sizes to be used for this study. First, in the case of simple random sampling, sample size determination assumes that an estimate of the precision or error around the mean, as well as its variability, is known. Not only were these estimates not known, but it was difficult to determine which of the many variables should be used as the basis for sample size estimation in a survey of this magnitude.

The second problem is that the method of stratified random sampling (geographically) was used to sample the units in this study (please see following section for further explanation). Here, determination of total sample size and subsequent strata sample sizes requires a knowledge of strata population sizes as well as an estimate of the per strata variations for the variable(s) under study. Although population strata sizes could be determined using census data and mailing lists, estimates for the variations of the variable(s) under study would be impossible to determine on a per stratum basis without the aid of an extensive and costly pilot test which samples all geographic strata. Using this type of information, sample sizes (total and strata) could easily be estimated, either equally, proportionally, or optimally. However, pilot testing of this nature was not considered to be feasible, given the budgetary constraints. Furthermore, the problems of error estimation and variable selection seen above applied here as well.

Nonetheless, sample size calculations for both professional groups were carried out in an attempt to determine whether or not financial limitations would hinder the scientific validity of the experiment. The sample size calculation for a simple random sample was used here (due to its relative ease) with the assumption that it approximated (or was slightly more than) the value that would be obtained in the stratified scenario. First, a variable under study had to be selected from the survey to base the sample size calculations on. The attitudinal variable of "agreement level" was selected due to its importance and prevalence in the survey. This variable usually took on the form of an approximate continuous five-point scale ranging from "strongly agree" to "strongly disagree". The variance of this parameter was crudely estimated by dividing the range of observations by 4, in the following manner:

$$S_y^2 = \left(\frac{Range}{4}\right)^2 = \left(\frac{5-1}{4}\right)^2 = 1.0$$

where: S_y^2 *= the variance of the observations.*

The significance level was set at $\alpha = 0.05$, while the error value was set to 0.15. This means that, for a 95% confidence interval, a precision of plus/minus 0.15 around any parameter estimate (for a confidence interval of 0.30) is considered acceptable, which seemed to be a reasonable assumption. The general equation for determining the sample size in a simple random sample, including the finite population correction (fpc) factor, was used as follows:

$$n = \frac{1}{\frac{E^2}{t^2_{0.05/2,30} S^2_y} + \frac{1}{N}}$$

where: $t = 2.042$, *the t-value at 30 degrees of freedom,* $\alpha = 0.05 / 2$;

$S_y^2 = 1.0$;

$E = 0.15$;

N = *population size for architects* (N_1) *and structural engineers* (N_2);

n = *sample size for architects* (n_1) *and structural engineers* (n_2).

The equation is computed at 30 degrees of freedom and is halted if sample size exceeds 30 or is reiterated until sample size convergence takes place. In both cases reiteration was not necessary. For a population of 50,000 architects (N_1), a sample of 185 (n_1) was required to achieve the desired precision, given our assumptions. For the 25,000 structural engineers (N_2), the sample size value was only marginally less, equaling 184 (n_2). This meant that approximately 370 completed surveys, or 6% of what is financially possible (6,000), needed to be returned to ensure statistical validity for the population as a whole, as well as for both professional groups. This proportion was well below that of the expected response rate which, though difficult to predict, would be expected to lie between 10% and 30%, for a return of between 600 and 1,800 surveys (given a total sample size of 6,000). Thus, even with stratification, where a smaller total sample size would be expected, over-sampling was foreseen at these levels. Though somewhat costly, this conservative method of sampling was advisable in the event that response rates were much lower than anticipated. In fact, this is how the research proceeded. The maximum allowable number of surveys (6,000, given our budgetary constraints) were sent out.

Based on the results of the ethnographic research, coupled with the differences seen in population sizes of the two professional groups, a 2:1 split in sample size between architects and structural engineers was employed. That is, both of these groups were over-sampled at n_1=3,986 for architects and n_2=1,822 to offset the possibility of very low returns and increase the precision of per strata parameter estimates (see Table 3.1). At this level of sampling, statistical validity and precision levels would still be upheld, assuming that the response rates exceeded 4.6% and 10.1% for architects and structural engineers, respectively. Furthermore, a 3:1 ratio between American and

Canadian designers was employed. The sample size in the United States was 4,308 while that of Canada was 1,500 (see Table 3.1)[2]. Like the breakdown of professional groups above, this distribution was considered valid because it approximated the actual proportions that exist in North America.

Sampling Procedure and Design:

As mentioned previously, the sample frame of architects and structural engineers across North America was first sorted by address, then selectively sampled. This effectively created a proportional allocation sampling scheme that is stratified or weighted geographically. That is, surveys (and thus sample sizes, assuming equal response rates across regions) were proportionally allocated according to the number of architects and structural engineers working in each strata. This can also be accomplished with the following equation:

$$n_i = n \times \frac{N_i}{N}$$

where: *n_i is the sample size from the i^{th} stratum;*
N_i is the population size of the i^{th} stratum;
n is the total sample size;
N is the total population size.

In other words, if one region contained 10% of the population (or sample frame membership), then 10% of the surveys were sent to randomly selected architects and engineers in that region. The rationale behind this stratified random sampling is three-fold. First, it ensures a geographically representative sample. Second, it allows for subgroup analyses and comparisons between and within strata, given a large enough total sample size (although conclusions pertaining to subgroups will be less precise than those inferred for the entire study population). Third, if stratification is justified, stratified random sampling is more precise than simple random sampling due to the fact that part of the total variation in a simple random sample is explained by the logical groupings of the stratified sample. It should also be noted that optimal allocation schemes, such as the *Neyman* and *Optimum* methods, were not considered here. These methods take strata variation into account and, as such, require information that was not readily available.

[2] Note that, due to a communication oversight with the American associations, the total sample size is 5,821, rather than 6,000. In Canada, the sample size remains at 1,500. However in the United States, the sample size was reduced to 4,321: 2,999 architects and 1,322 structural engineers (refer to Table 3.1).

The strata were based on twenty-one mutually exclusive geographical groups: the nine census regions in the United States (Pacific, Mountain, West North Central, East North Central, West South Central, East South Central, South Atlantic, New England, and Middle Atlantic) and the twelve Canadian census regions (ten provinces and two territories). This allowed for demographic and unrelated peripheral statistical information to be easily obtained for each stratum from the *United States Bureau of Census* and *Statistics Canada.* The distribution of sample units, by strata (census region), country, and professional group can be seen in Table 3.1, while a more detailed breakdown of the census regions and stratification can be seen in Appendix C. It should be noted that, with this scheme, the number of geographical regions was too large for meaningful results to emerge on a per stratum basis. That is, the

Table 3.1: Distribution of Sample Units by Stratum, Country, and Professional Group.

	Architects	**Structural Engineers**	**Total Proportion**
United States (4,321):	**2,999**	**1,322**	**74.23%**
Pacific	596	280	15.04%
Mountain	163	69	3.99%
West North Central	220	82	5.19%
East North Central	433	164	10.26%
West South Central	270	124	6.77%
East South Central	105	61	2.85%
South Atlantic	555	221	13.33%
New England	210	92	5.19%
Middle Atlantic	447	229	11.61%
Canada (1,500):	**1,000**	**500**	**25.77%**
British Columbia	140	66	3.54%
Alberta	88	57	2.49%
Saskatchewan	22	23	0.77%
Manitoba	37	17	0.93%
Ontario	357	170	9.06%
Quebec	296	116	7.08%
Newfoundland	7	9	0.27%
Nova Scotia	26	16	0.72%
Prince Edward Island	9	7	0.27%
New Brunswick	11	12	0.40%
Yukon	2	3	0.09%
Northwest Territories	5	4	0.15%
TOTAL (5,821):	**3,999**	**1,822**	**100.00%**

per stratum sample sizes were too small to estimate strata parameters with acceptable precision levels. As a result, census regions were collapsed together to form broader geographic groupings (in Canada, West / North, Central, and East / Maritimes; in the United States, West, Midwest, South, and Northeast) in an attempt to increase the statistical precision per sub-group.

Sampling Instrument:

The mail survey method of data collection is the most efficient and cost effective means of securing data from geographically diverse populations *(10)*. A reproduction of the mail-out survey can be seen in Appendix D (note that the last two pages varied slightly between architects and structural engineers). Its design was based closely on the system prescribed by the *Total Design Method (1978)*, whereby systematic or nonsampling error is minimized and response rate is maximized through proper mail survey design and implementation *(10)*.

Survey topics were largely based on what was seen to be lacking in the literature and by ideas generated in the ethnographic research as well as the industry advisory focus group. Questions were logically ordered without bias with broader, more general queries at the beginning of the survey, funneling down into more specific issues as the survey progressed, and ending with a personal information section. It should be noted that the first question of the survey acted as a filter question to those who did not work in the field of nonresidential construction. If this indeed was the case, the respondent was asked either to fill out the personal information section and send the survey back unanswered or to pass the survey onto someone more qualified to answer the questions. The remainder of the mail survey was divided into the following seven sections:

1. The **building design** section collected information on the types of buildings that are designed in the nonresidential sector and otherwise. The types of materials that are used for applications four storeys or less, and the extent of their use, were also determined[3];

2. The **building material use** section asked designers about their use and awareness of steel, concrete, masonry, and wood products. Their opinions of each of these structural materials was also elicited.

[3] Although this research purports to be concerned with nonresidential construction, the survey also collects data on low-rise multifamily dwelling units and commercial / residential combinations because of obvious similarities between these and nonresidential structures. For this reason, the term *buildings four storeys or less* more accurately reflects the information being collected here and is used extensively throughout the analysis.

3. The **wood use** section gave designers the opportunity to state the benefits and drawbacks to using wood in buildings four storeys or less. The use of wood, both in general and specific applications, was also sought;
4. The **education / promotion** section asked designers about their schooling, their on the job training, and their work experience. The types of structural materials that they most frequently learned about, as well as the most common and influential methods of information dissemination, were also determined;
5. The **design process and philosophy** section collected information on how the specification of structural materials is apportioned, the types of design methods that are used, and the importance of various considerations in material selection;
6. The **environmental issues** section ranked steel, concrete, masonry, and wood on a number of environmental dimensions that are common to *Life Cycle Analysis*; and
7. The **personal information** section collected demographic and psychographic information from designers in order to logically group them for marketing purposes. Information regarding their workplace environment was also elicited.

The questions asked in the survey took on many forms and measurement scales to facilitate varying types of statistical analyses (see the following section for further details). These included simple-dichotomy questions, determinant-choice questions, frequency-determination questions, checklist questions, open-ended questions, category scales, Likert scales, constant-sum scales, a modified semantic differential scale, and numerical scales. Generally, the scales were used to measure attitudes and perceptions (statistically), while the questions were used simply to ascertain facts and accumulate statistics (with counts and proportions). Finally, questions were designed in such a way that systematic error was minimized. That is, complexity and ambiguity were avoided, leading and loaded questions were not asked, no assumptions of the respondents were made, and there were no double-barreled questions. For further information on the survey questions, the reader is directed to the actual questionnaire in Appendix D.

Due to time constraints, full-scale pretesting of the survey did not take place. That said, peers, colleagues, and related professionals were asked to fill out the survey, comment on the clarity of the questions, and note the time it took to complete it. As a result, the final questionnaire seen in Appendix D, which is the product of countless revisions, is accurate, lucid, and readable. It is, however, far from concise. Though lengthy surveys are known to reduce response rates, it was felt that the amount of information obtained on a per respondent basis was well worth this cost.

The mail surveys were professionally printed in a 6" X 9" twenty page booklet form by *Benwell Atkins*, Vancouver. Their covers were colour-coded according to country of origin and professional group, and individually numbered from 0001 to 6000 to correspond with matching mailing labels. This allowed for the respondent to be easily identified and stricken from the mailing list when the second survey was sent out. Business Reply Mail information (bar codes, permit numbers, return addresses, etc.) was printed on the back cover of the surveys sent in the United States. This allowed the respondent to simply seal the survey and drop it in the mail.

In Canada, due to Canada Post regulations, a return envelope containing this information had to be sent along with the survey. All surveys were sent out in *University of British Columbia* business envelopes. In Canada, they were mailed out (first class) from the *Benwell Atkins* mailing house, with a *University of British Columbia* return address. In the United States, they were mailed out (bulk rate) from *Security Mailings* (Blaine, Washington) with a *Blaine Enterprises* (Blaine, Washington) post office box return address. Responses from the United States were picked up on a weekly basis.

Three cover letters, corresponding to the three mail-outs, were printed on *University of British Columbia* letterhead and included in the mail-out packages. The first letter explained the project at hand and its importance. It asked respondents to participate, explained how they were selected, gave instructions, and assured them of complete confidentiality. Finally, it closed with an offer to answer any questions that they may have had and a note of thanks. The second letter reiterated the purpose and importance of the project. It served as a reminder to those who had forgotten to fill the survey out and a thanks to those that already had. The third letter was very similar to the first letter, except with a slightly more intense and desperate tone. For each mail-out, there were slight variations depending on professional group and country of origin (see Appendix E).

Packages were mailed out using a three-point contact system. This scheme, which is acknowledged to maximize response rates *(10)*, occurred as follows:

1. *Monday, February 28th, 1994:*

   First mail-out to all 6,000 samples in a large-format business envelope. Package included survey and the first cover letter (and return envelope in Canada).

2. *Monday, March 14th, 1994:*

   Second mail-out to all sample units in a small-format business envelope. Package included the second cover letter (a reminder) and no survey.

3. *Monday, March 28th, 1994:*

   Third mail-out to those sample units that did not yet respond in large-format, business envelope. Package included copy of survey and the third cover letter (and return envelope in Canada).

Responses began to arrive as of March 28th, 1994. The cut-off date, where surveys were no longer accepted, was set at ten weeks after the initial mail-out or May 9th, 1994. As soon as surveys arrived, they were dated and coded according to degree of completion (fully, partially, or not at all). Data was then systematically entered, one section at a time, into an *Excel for Windows V. 5.0* spreadsheet for further analyses.

Notes on Data Analyses:

A discussion of data analyses must begin with a restatement of what exactly is to be measured in this study. In this case, this is not an uncomplicated task, for it is easy to get lost amidst the vast array of variables being collected in the survey. It is, however, known that the study purports to analyze the North American specifiers of building materials in nonresidential construction. Specifically, the attitudes and perceptions of two professional design groups, architects and structural engineers, are being gauged on issues pertaining to the specification of building materials in nonresidential construction. In so doing, it is hoped that a better understanding of material specification (especially in the case of wood products) will be obtained. This information can then be used as a starting point for the forest products industry in its attempt to penetrate this yet relatively untapped nonresidential market.

The issue of "attitudes and perceptions", two interchangeable terms, must also be addressed. In the field of psychology, an attitude is defined as "an enduring disposition to consistently respond in a given manner to various aspects of the world *(39)*." It is composed of three components: affective, cognitive, and behavioural. The affective component refers to one's feelings or emotions toward an object. The cognitive component refers to one's awareness of and knowledge about an object. Finally, the behavioural component reflects a predisposition to action *(39)*. Each of these components, as they pertain to architects and structural engineers, was thoroughly analyzed in this study. The rationale is that to change one's attitudes with regards to the specification of structural material in nonresidential construction (in this case, to the use of wood products), one must first have a complete understanding of the many attitudes that exist, both positive and negative. Only then can marketing strategies be properly implemented and subsequent managerial action enacted.

It should also be stated that attitudes, because they are hypothetical constructs, cannot be measured directly. Rather, indirect means to some stimulus, such as verbal expression or overt behaviour must be measured. Attitudes are then inferred based on these observations, assuming that they are valid measures *(39)*. One way of eliciting responses from which attitudinal information can be obtained is with a mail survey. Specifically, questions or stimuli are designed such that all of the components of attitudes can be measured indirectly using inference. In other words, a designer may have a negative attitude towards wood products. However, this information can only be inferred from questions which ask how he/she feels towards wood in structural applications. His/her attitude cannot be measured directly. Thus, it is important that valid attitudinal measures using a system of scales be used in mail surveys.

This is precisely what the survey in this study has attempted to do. Various scales were employed to measure the three components of attitudes in as many ways as possible. Nonmetric nominal scales were used in categorical and fixed-alternative style questions, like simple-dichotomy questions, determinant-choice questions, frequency-determination questions, and checklist questions. Nonmetric ordinal scales were used in ranking and constant-sum questions. However, generally speaking, direct or underlying metric interval scales were used throughout the survey. These took the form of category scale questions, Likert scale questions, modified semantic differential scale questions, numerical scale questions, behavioural differential scales, and underlying metric multichotomous questions. These latter scales were primarily used for attitudinal measurement.

The types of scales used in a survey define what types of statistical analyses may be performed on the data. For instance, nominal data, because it is simply used for classification purposes, can only be tallied and proportioned according to a priori defined groups. Ordinal scale data can be used for counts, percentile-ranks, and median calculations. As such, analyses on data obtained using these two types of scales is limited. Fortunately, most of the mail survey was designed to incorporate interval scales. With true interval scales, simple mathematics can easily be applied, and means and standard deviations can be calculated. Thus, most statistical techniques may be performed on interval data.

Various statistical techniques were explored for use in this study. These included, but were not limited to, well known univariate techniques like analysis of variance and two-tailed tests for differences in means, and lesser known multivariate techniques, such as multiple discriminant analysis, cluster analysis, simple factor analysis, and principle components analysis. As well, means, standard deviations, modes, proportions, and tallies were used throughout the study to measure a diverse range of subjects. These techniques were used in tandem to summarize and compare aggregate statistics and logically profile segments of design professionals; all of which, ultimately, will hopefully serve to facilitate the development of specifically tailored marketing strategies. Finally, it should be noted that two software packages were extensively used in the analysis of data: *Excel for Windows V. 5.0* and *SPSS for Windows V. 6.0.*

CHAPTER 4

RESULTS I - SUMMARY OF THE FINDINGS

Results are reported in two sections. The first section (Results I) is a concise summary of all of the findings. Response rates, personal information, and each of the sections in the survey are individually aggregated and reported on in turn (in each case, the question and the section of the survey from which the information was collected are clearly indicated in the subheadings). Tallies, proportions, and means are used extensively throughout the summary with little by way of any statistical analyses. However, wherever applicable, various statistical tools have been used to underscore the results (especially analysis of variance and Bonferroni's multiple comparison method). No attempt at group segmentation or stratification, either by point of origin, profession, or any other appropriate utilitarian variable, was made here (this is seen in the Results II section of the report).

It should be noted most of the results apply, not only to nonresidential structures, but to multifamily low-rise residential buildings and commercial / residential combinations, as well. In some cases, single family dwelling units (detached homes and duplexes) are also included in the analysis. For this reason, the more precise nomenclature of "buildings four storeys or less" is used throughout. As well, the terms "respondents", "designers", and "specifiers" are used interchangeably to refer to architects and structural engineers.

Response Rate:

Of the 5,808 surveys sent out, 978 were returned. The breakdown of total responses by country and professional group is seen in Table 4.1. It should also be noted that 44 late responses, which came in after the cut-off date, were also received (15 from Canada and 29 from the United States).

Table 4.1: Breakdown of Responses by Country and Professional Group.

	Architects	Structural Engineers
Canada	152	146
United States	442	238

The calculation of response rate requires a knowledge of the number of sample units that were nonreachable. In other words, the number of designers that did not receive the survey, either due to death or relocation since the time of compiling the mailing lists, must be determined. In Canada, mail that does not reach its destination is returned to the sender. This is not the case in the United States, however. Thus, to estimate the total number of nonreachables, the number of nonreachables in the United States must be inferred from the number of Canadian nonreachables. In Canada, this figure was 264 or 17.60% of all designers. Extrapolating this rate to the sample units in the United States gives a figure of 758, for a total of 1,022 nonreachables.

Response rate was calculated using the following equation:

$$total\ response\ rate = \frac{returns + late\ returns}{sample\ size - nonreachables} \times 100\% \quad = \frac{978 + 44}{5{,}808 - 1{,}022} \times 100\% \quad = 21.35\%$$

Thus, **21.35%** of the North American designers that could be reached responded to the survey. This is well within acceptable response rates for population inferences from mail questionnaires, especially for a survey of this magnitude (in general, in order to collect voluminous amounts of information from mail-out surveys, response rates must be traded off) *(5, 20)*. Of these, 553 were completed while the remainder, 425, were only partially completed (personal information only) or not attempted at all. In other words, 56.54% of the designers that responded felt qualified to design buildings four storeys or less, while 43.46% did not.

Respondents who did not attempt to complete any of the survey did so for a variety of reasons. Many communicated and cited, among other reasons, a lack of experience / qualifications in nonresidential design, a lack of interest / time, illness / retirement, and inapplicability. Most of these respondents should have, at the least, filled out the *Personal Information* section as they were asked to. However, they did not for some reason.

The majority of those that partially completed the survey by filling out the *Personal Information* section did so primarily because they were instructed to by the first question. This question served to filter out designers for whom the survey was inapplicable (43.46%). Generally speaking, these respondents had little or no experience with designing buildings four storeys or less. Rather, their workloads were devoted entirely to buildings five storeys or more (14 respondents), single family dwelling units and/or duplexes (14 respondents), nonbuilding structures (84 respondents), or two or more of the above (16 respondents). Those that did no design work in the previous year (33 respondents) or did not feel qualified to answer the questions for some reason (71 respondents) were asked to act accordingly, as well. Designers, for whom any one of these scenarios was applicable, were asked to find another qualified individual to complete the survey. Those that were unable to do so were asked to go directly to and fill out the *Personal Information* section[4].

Finally, it should be noted that some of the partially completed and incomplete surveys remain an enigma. That is, no reason or information was given to account for these designers not wanting to participate. However, given the enormity of the survey, this is not at all surprising.

Revising the response rate calculation to take only the completed surveys into account yields the following:

$$revised\ response\ rate = \frac{returns + late\ returns}{sample\ size - nonreachables} \times 100\% \quad = \frac{553 + 44}{5{,}808 - 1{,}022} \times 100\% \quad = 12.47\%$$

Alternatively, the response rate calculation can be corrected to include only those respondents who felt qualified to design buildings four storeys or less, as follows:

$$corrected\ response\ rate = \frac{returns + late\ returns}{(sample\ size - nonreachables) \times \%\ qualifed} \times 100\%$$

$$= \frac{553 + 44}{(5{,}808 - 1{,}022) \times 56.54\%} \times 100\% \quad = 22.06\%$$

That is, **12.47%** of the North American designers that could be reached, or **22.06%** of all *qualified* North American designers, answered the survey completely; still acceptable proportions given the length and complexity of the questionnaire. Ultimately, sample sizes employed in this study varied between 500 and 553 in most cases, depending on the extent to which each question was answered.

Based on degree of completion, the breakdown of responses (excluding late responses) by country, professional group, week returned, and mail-out can be seen in Table 4.2. Wherever pertinent, response rates, calculated without

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[4] The above respondents (23.72% in total) were unable to pass the survey on to anyone else, while 5.26%, in fact, did so. This means that at least 29% of those sample units reached were, for one reason or another, unable / unqualified to complete the survey. This proportion may be somewhat higher due to the fact that some of the surveys were returned blank and there is no way of determining whether these respondents were unable, unqualified, or unwilling to complete it.

correction factors, are also shown in parentheses. Note that, even in the *completely answered* category, response rates exceed those obtained by the sample size calculations.

Table 4.2: Breakdown of Responses by Country, Professional Group, Week Returned, and Mail-out.

	Total Responses	Completely Answered	Personal Information Only (as requested)	Not Answered
Country:				
Canada	298 (25.32%)	156 (13.83%)	49	93
United States	680 (19.97%)	397 (10.37%)	197	86
Professional Group:				
Architects	594 (18.91%)	392 (12.74%)	98	104
Structural Engineers	384(26.63%)	161 (11.89%)	148	75
Week Returned:				
1	8	4	2	2
2	84	47	11	26
3	88	52	15	21
4	65	34	15	16
5	157	95	29	33
6	121	68	30	23
7	221	124	68	29
8	112	57	41	14
9	76	46	25	5
10	46	26	10	10
Mail-out:				
First	464	353	104	7
Second	402	198	141	63
Personal Communication	112	2	1	109
TOTAL:	**978 (21.35%)**	**553 (12.47%)**	**246**	**179**

Response rates in Canada were seen to be higher than those in the United States. This makes sense, given the survey's point of origin. On the whole, structural engineers responded much more favourably to the survey than did architects. However, the rate of completed questionnaires is lower for the structural engineer group. This is due, in part, to the fact that a large proportion of the structural engineers surveyed designed nonbuilding structures exclusively. As such, they were asked to fill out the *Personal Information* section of the survey only. Finally, most of the surveys were returned between weeks 5 and 8 in a normally distributed manner, while the majority of the surveys returned were the first ones that were sent out.

Personal Information (Section VII):

Personal information was collected from all respondents in *Section VII* of the survey. Specifically, facts germane to architects and structural engineers, such as their demographic characteristics and data pertaining to their places of work, were obtained. Each is summarized in turn.

Demographic Breakdown (Questions 1 - 4):

Basic demographic information, such as gender, age, ethnicity, and place of residence, was collected from the respondents in the first part of *Section VII (Personal Information)* of the survey. Results, which are seen in Tables 4.3 and 4.4, are divided into two sections to reflect the fact that respondents who were not qualified to answer the survey were asked to complete the *Personal Information* portion of the survey anyway. Thus, the first column shows the demographic breakdown of respondents who completed the survey in its entirety. The second column merges these results with data obtained from the partially completed surveys.

From Table 4.3, it can be seen that an overwhelming majority of respondents were male and Caucasian. The age distributions were slightly skewed towards younger designers, with the majority of respondents lying somewhere between 31 and 50 years of age. The modes for both groups occurred in the 36 to 40 year class, while the mean ages were 45.95 and 46.45 years for the first and second columns, respectively.

Table 4.4 shows the breakdown of respondents' places of residence by census region. In the United States, most of the returns came from the Pacific, East North Central, South Atlantic, and Middle Atlantic regions. The majority of Canadian returns came from Ontario, Quebec, British Columbia, and Alberta. By comparing Table 4.4 to the distribution of sample units seen in Table 3.1, it is easy to see that the distribution of responses is very similar indeed; both on a per region and a per country basis. In other words, because the distribution of sample units is known to be a valid representation of the population, it is safe to say that the distribution of responses also approximates it well. This further substantiates the argument that results obtained here can be accurately inferred onto the population as a whole.

Table 4.3: Some Demographic Characteristics of Respondents.

	Completed Surveys	Completed and Partially Completed Surveys
Gender:		
Male	93.97%	92.32%
Female	6.03%	7.68%
Age:		
20 or less years	0.19%	0.13%
21 - 25 years	0.57%	1.71%
26 - 30 years	3.43%	4.61%
31 - 35 years	15.25%	13.70%
36 - 40 years	20.00%	18.71%
41 - 45 years	17.53%	16.47%
46 - 50 years	13.14%	12.52%
51 - 55 years	8.38%	8.04%
56 - 60 years	8.19%	8.17%
61 - 65 years	5.90%	6.46%
66 - 70 years	4.38%	5.27%
71 - 75 years	1.71%	2.50%
76 - 80 years	0.57%	0.79%
more than 80 years	0.76%	0.92%
Ethnicity:		
Caucasian	89.15%	89.18%
African-American	0.39%	0.40%
Native American	1.55%	1.60%
Asian	5.04%	5.87%
Hispanic	1.55%	1.20%
Other	2.32%	1.74%

Table 4.4: Residential Breakdown of Respondents by Census Region.

	Completed Surveys	Completed and Partially Completed Surveys
United States:	**72.53%**	**74.84%**
Pacific	15.75%	15.80%
Mountain	4.58%	4.17%
West North Central	5.31%	6.70%
East North Central	12.64%	11.89%
West South Central	5.13%	6.70%
East South Central	3.48%	2.78%
South Atlantic	10.26%	11.51%
New England	5.49%	5.81%
Middle Atlantic	9.89%	9.48%
Canada:	**27.47%**	**25.16%**
British Columbia	4.94%	4.55%
Alberta	4.40%	3.79%
Saskatchewan	1.10%	1.14%
Manitoba	0.73%	0.88%
Ontario	9.16%	7.59%
Quebec	4.76%	4.80%
Newfoundland	0.37%	0.51%
Nova Scotia	0.92%	1.01%
Prince Edward Island	0.00%	0.00%
New Brunswick	0.18%	0.25%
Yukon	0.18%	0.13%
Northwest Territories	0.73%	0.51%

Workplace Environment (Questions 5 - 16):

Information pertaining to the workplace environments of respondents was also obtained. Since this information was collected in *Section VII (Personal Information)* of the survey, data from the partially completed surveys could have been incorporated. However, because many of these surveys were from respondents who were neither architects nor structural engineers, this information was excluded.

Respondents were asked about their career spans in the design profession. Table 4.5 lists the results by the length of time they have been actively practicing and the length of time they have been at their present place of work. On average, designers have been in practice for 18.71 years and at their present place of work for 11.25 years. A comparison of the two distributions shows the breakdown of *length of time at present place of work* to be completely skewed towards a shorter time frame (more than 60% of the respondents have been with their present employer firm for less than ten years). This result, coupled with the means, would seem to indicate that there is a great deal of movement within the design professions.

Table 4.5: Distribution of Years as a Practicing Designer and at Present Place of Work.

Years:	Practicing	At Present Place of Work
0 - 5 years	9.85%	34.86%
6 - 10 years	16.60%	27.09%
11 - 15 years	21.24%	13.55%
16 - 20 years	17.18%	9.76%
21 - 25 years	10.23%	4.78%
26 - 30 years	9.46%	3.59%
31 - 35 years	6.95%	3.78%
36 - 40 years	5.21%	1.79%
41 - 45 years	1.93%	0.40%
46 - 50 years	1.16%	0.20%
more than 50 years	0.19%	0.20%

Respondents were also asked to comment on the size of their workplaces, both in terms of number of employees and amount of business done. Table 4.6 shows distributions of various parties at work. Total employees refers to everyone working in the firm. Primary designers refers to designers in the respondents' professional group (architects for architects, engineers for engineers). Finally, secondary designers refers to designers in the opposite grouping (engineers for architects, architects for engineers). There are an average of 247.85, 17.43, and 3.82, employees in each group, respectively. Approximately 60% of the respondents' employment is in small to medium-sized firms with less than twenty employees and five primary designers. Large firms (more than 100 employees) account for only 15% of the respondents' employment. One quarter of the respondents surveyed work alone (which seems to be in agreement with the fact that 40.61% are self-employed), while there are generally no more than thirty primary designers in any one given firm. Finally, three quarters of those surveyed state that there is no secondary designer employed in their firm, which is to say that the majority of communication that takes place between architects and structural engineers involves two or more companies. Companies that do employ a secondary designer usually have only one or two.

Table 4.6: Distribution of Primary Designers, Secondary Designers, and Employees.

Number of Employees:	Total Employees	Primary Designers	Secondary Designers
0	3.53%	3.12%	75.04%
1	9.61%	25.34%	8.64%
2	4.31%	14.04%	3.14%
3	4.71%	10.33%	1.57%
4	5.29%	6.63%	1.77%
5	4.31%	3.90%	1.38%
6 - 10	13.93%	12.67%	3.54%
11 - 20	14.90%	11.11%	2.55%
21 - 30	6.67%	4.09%	0.59%
31 - 40	4.31%	1.75%	0.20%
41 - 50	3.92%	1.95%	0.20%
51 - 100	9.61%	2.92%	0.59%
101 - 200	6.08%	0.98%	0.59%
201 - 500	4.31%	0.98%	0.20%
more than 500	4.51%	0.19%	0.00%

These findings are confirmed by the results in Table 4.7, which show that approximately 60% of the firms surveyed are small to medium-sized (billing less than $2,000,000 a year), while only 13% bill more than $10,000,000. The data also indicates that, while a significant portion of billings can be attributed to buildings four storeys or less, very little business comes from wood buildings four storeys or less.

Respondents were also asked to state how many employees at their firms *design* buildings four storeys or less (in general and out of wood) and how many *specialize in designing* wood buildings four storeys or less. The mean number of employees that design buildings four storeys or less is 10.44. An average of 3.60 employees design buildings four storeys or less using wood as the main structural component, while only 1.48 employees specialize in this type of structure. The distributions seen in Table 4.8 confirm these findings. Approximately 95% of all firms surveyed have at least one employee on staff (80% having less than ten) who designs buildings four storeys or less. In marked contrast, almost 60% of the firms surveyed do not have a designer on staff devoted to timber design.

Table 4.7: Distribution of Billings per Year.

Billings per Year:	**Total**	**Buildings 4 Storeys or Less**	**Wood Buildings 4 Storeys or Less**
under $100,000	15.83%	18.93%	50.14%
$100,000 - $500,000	24.05%	26.79%	22.37%
$500,001 - $1,000,000	9.28%	9.24%	5.93%
$1,000,001 - $2,000,000	10.13%	10.16%	2.96%
$2,000,001 - $5,000,000	9.49%	9.93%	0.81%
$5,000,001 - $10,000,000	8.86%	6.70%	2.16%
over $10,000,000	13.29%	6.70%	0.81%
do not know	9.07%	11.55%	14.82%

Table 4.8: Distribution of Designers by Type of Building Designed.

Number of Employees:	**Design Buildings 4 Storeys or Less**	**Design Buildings 4 Storeys or Less Using Wood**	**Specialize in Wood Buildings 4 Storeys or Less**
0	4.10%	25.64%	57.95%
1	25.91%	25.87%	21.38%
2	14.69%	16.86%	8.08%
3	13.39%	10.16%	4.51%
4	5.18%	4.62%	2.38%
5	4.10%	3.23%	1.43%
6 - 10	13.39%	7.16%	2.85%
11 - 20	8.86%	4.62%	0.47%
21 - 30	2.81%	0.46%	0.00%
31 - 40	1.30%	0.46%	0.24%
41 - 50	1.73%	0.46%	0.47%
more than 500	4.54%	0.46%	0.24%

Most of the remaining firms sampled have only one or two. However, 75% of the firms surveyed do have at least one employee on staff (in most cases, less than three) who occasionally designs with wood.

Finally, respondents were asked to state the types of buildings that they and their place of work were well known for designing. Ultimately, there is little difference between what individuals and firms are notable for. Schools are the most frequently cited structures, followed closely by detached homes. Offices, industrial buildings, and stores are also often mentioned. Public buildings, religious structures, and multifamily dwelling units are seen to be moderately popular. The remaining building types, while mentioned, do not rank highly in this regard.

Building Design (Section I):

Section I of the survey dealt with issues pertaining to building design. Specifically, respondents were queried on the types of buildings that they design, the materials that they use, and their preferences in these regards.

Design Workloads (Questions 2 & 3):

Figure 4.1 summarizes time spent on all facets of design. On average, buildings four storeys or less account for 79.90% of the design workload. The remainder is fairly evenly split between buildings five storeys or more, nonbuilding structures, and other related endeavours like remodeling, renovation, interior design, and planning. Figure 4.2 further breaks down the category of buildings four storeys or less. On average, for these types of structures, 67.14% of the design workload is devoted to nonresidential buildings (offices, warehouses, stores, hospitals, schools, public buildings, etc.), while 9.48% and 4.22% are devoted to multifamily dwelling units and commercial / residential combinations, respectively. Single family dwelling units account for 18.15% of the workload, while other activities (as above) make up the remaining 2.01%. It should be noted that this study is focusing on nonresidential buildings, multifamily dwelling units, and commercial / residential combinations (totaling 80.84%) that are four storeys or less (totaling 79.90%). Simple multiplication can be used to show that these structures account for 64.59% of all buildings that are designed.

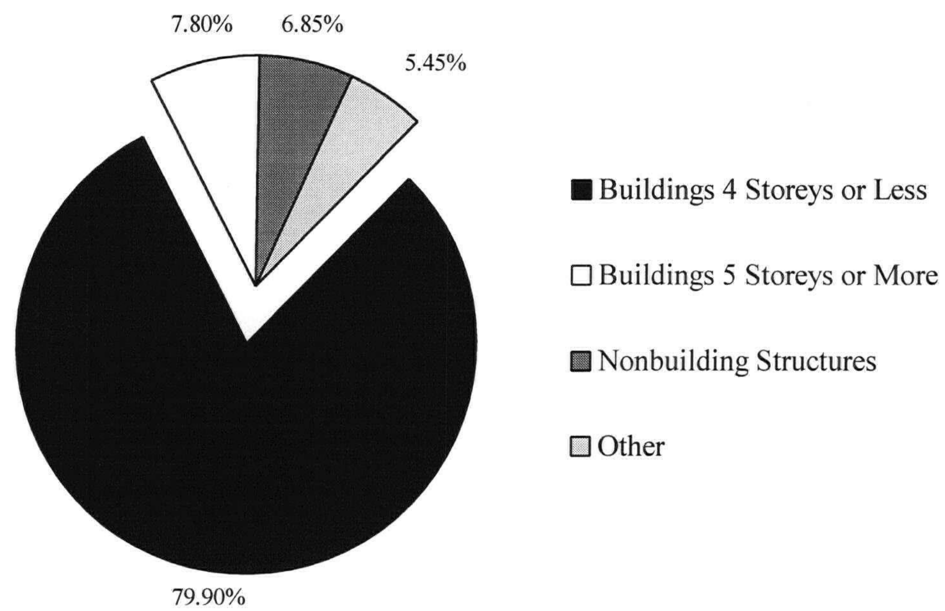

Figure 4.1: Proportion of Design Workload (All Building Types).

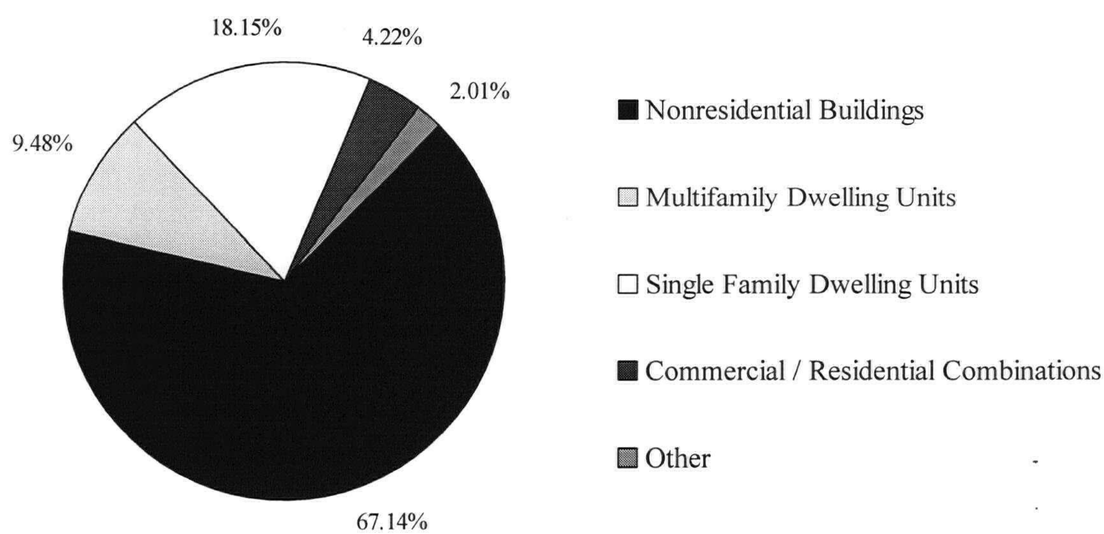

Figure 4.2: Proportion of Design Workload (Buildings 4 Storeys or Less).

Structural Material Use (Question 4):

Respondents were then questioned on structural material use in buildings four storeys or less. Specifically, they were asked to state the proportion of buildings that they have designed in the past, and the number of buildings that they designed in 1993, that have used wood, steel, concrete, masonry, another material, or a combination as the primary structural component(s). Means were computed and are plotted in Figures 4.3 and 4.4. For both sets of data, one way-analyses of variance ($\alpha = 0.05$) were performed to test for significant differences between means[5]. In both cases, there were significant differences and Bonferroni's method, a conservative statistical technique used to detect differences in means, was employed to determine which of the materials' use levels varied.

On average, the market position for wood in the nonresidential sector appears to be favourable. According to the past use levels, wood buildings have had 33.36% of the market share, followed closely by steel buildings at 29.36%. In absolute terms, this translates into an average of 9.78 wood structures and 3.69 steel structures built per specifier in 1993. In terms of 1993 usage, there are significant differences between wood and steel, while for past use levels, no such differences exist. This may mean that, while wood may be widely used in numerous, smaller projects, approximately the same amount of steel is used in fewer, larger projects. Conversely, it may be indicative of the fact that respondents can probably more accurately assess the number of buildings designed in the previous year than they can the proportion of buildings designed in the past. Regardless, the 1993 averages are likely more valid than the past results, given that they are more up to date.

The past shares for concrete, masonry, and combination structures vary between 12% and 13% for averages of 1.55, 1.95, and 1.41 buildings designed per specifier in 1993, respectively (in each case, they are not significantly different from one another, although their usage levels are significantly less than those of steel and wood). The combination category refers to buildings in which two or more materials are used as the main structural components. Designers who indicated that they design these types of buildings were asked to list the structural

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[5] Note that, for each analysis of variance, the *other materials* category was removed because of its infrequent mentions. When left in the analyses, its variances were considerably lower than those of wood, steel, concrete, masonry, and combinations thereof. This is a violation of the assumptions of analysis of variance and can be corrected with logarithmic transformations. However, due to the obvious nature of the problem, it was decided simply to exclude it. For the sake of completeness, it should be noted that the *other materials* category includes a few mentions of aluminum as an alternative to the more common structural materials. However, the number of buildings designed out of aluminum is trivial and is not considered an issue at present.

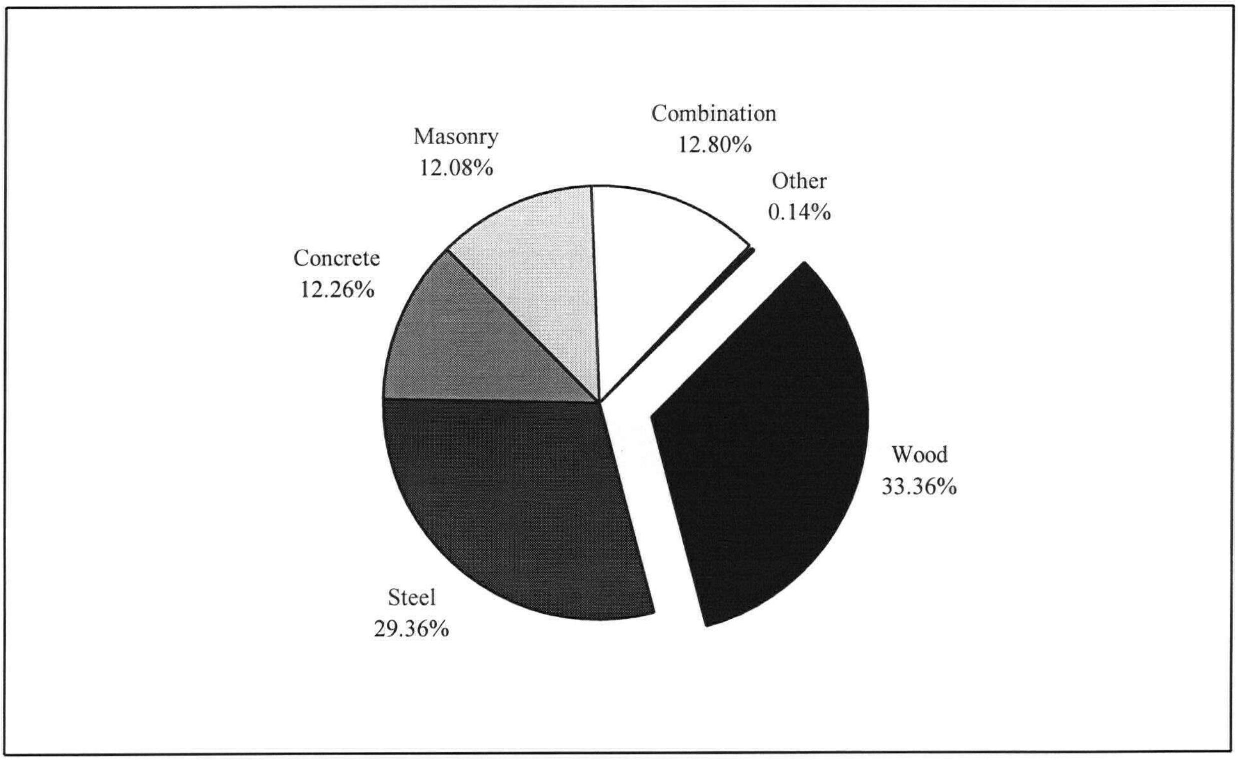

Figure 4.3: Proportion of Structural Material Use in the Past (Buildings 4 Storeys or Less).

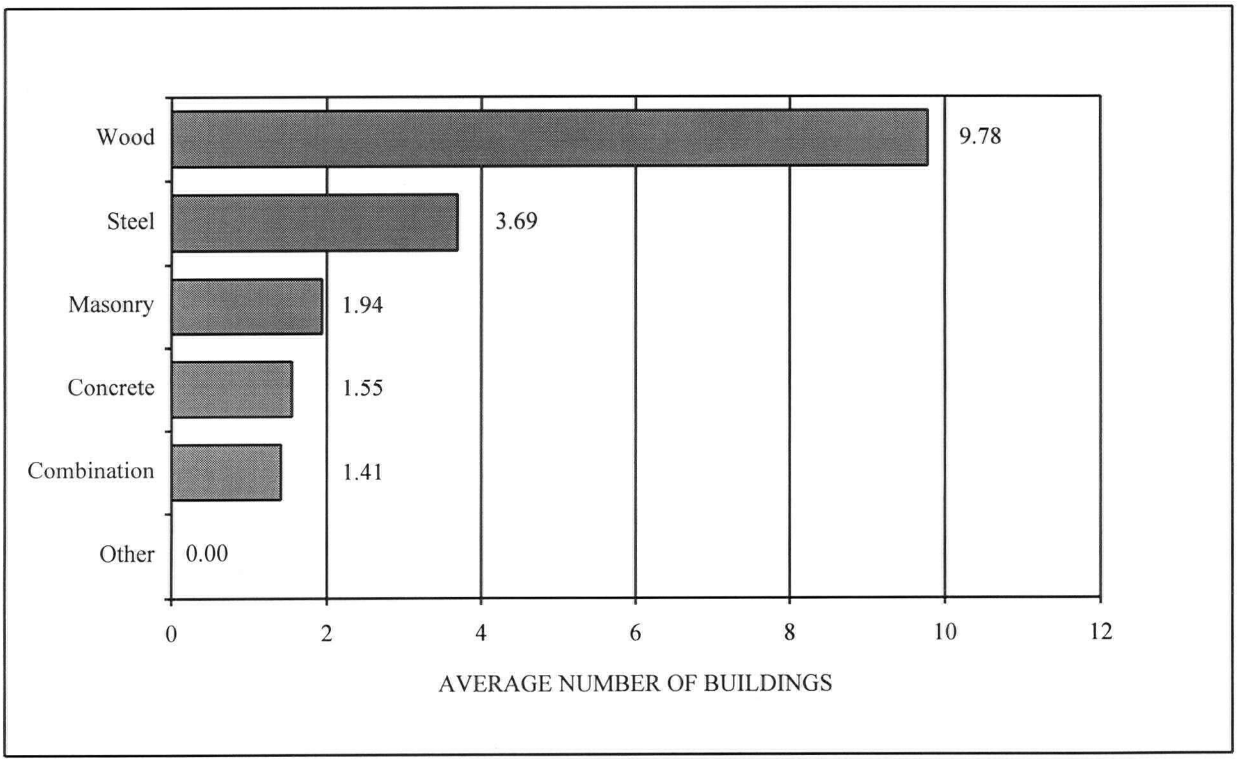

Figure 4.4: Average Number of Buildings Designed in 1993 by Structural Material (Buildings 4 Storeys or Less).

materials that they typically use in tandem. Steel and masonry are the most cited materials at 30.74% and 29.39%. Wood and concrete account for 21.62% and 17.91%, respectively. Some of the more popular material combinations include masonry and wood, steel and concrete, and masonry and steel.

Along with material use in buildings four storeys or less, respondents were asked to rank structural materials in order of preference. Results can be seen in Figures 4.5 and 4.6. In Figure 4.5, adjusted rank scores for each material were obtained by weighting the ranks (three for the first preference, two for the second, and one for the third), and summing the results. Though the scores are statistically meaningless (as an analysis of differences in means would be), they do serve to show the order and magnitude of material preference. Steel ranks the highest, followed closely wood. Concrete and masonry rank somewhat lower, though they are roughly equally preferred. Combinations and other materials do not rank highly at all.

These results are confirmed by Figure 4.6 which summarizes the structural material preference ranks[6]. The columns in the graph show the number of times each material is ranked first, second, or third. Steel and wood ranks first 35.18% and 33.00% of the time. Concrete and masonry do not fare as well at 14.23% and 11.86%, respectively. Combinations and other materials rank first less than 6% of the time. Steel, concrete, and masonry all rank second at between 24% and 26% of the time, while wood was somewhat lower at 20.65%. However, all four materials rank third comparably at between 23% and 25% of the time. Again, combinations and other materials are of little consequence in the second and third place rankings.

Buildings Designed (Question 5 & 6):

Next, information was obtained from respondents about the types of buildings that they have designed both in the past and in 1993. As well, they were asked to rank these buildings in order of preference. Results, summarized by building end use, height, and area, can be seen in Figures 4.7 to 4.12.

Figures 4.7 and 4.8 show the proportion and preference of buildings designed by end use, respectively. Industrial buildings, offices, detached homes, and schools are the most widely designed types of buildings; each accounting

[6] The fact that there is agreement between responses is indicative of the fact there is internal validity within the questionnaire and a high degree of reliability for each of the questions. For a further explanation, please refer to the *Summary and Discussion* section.

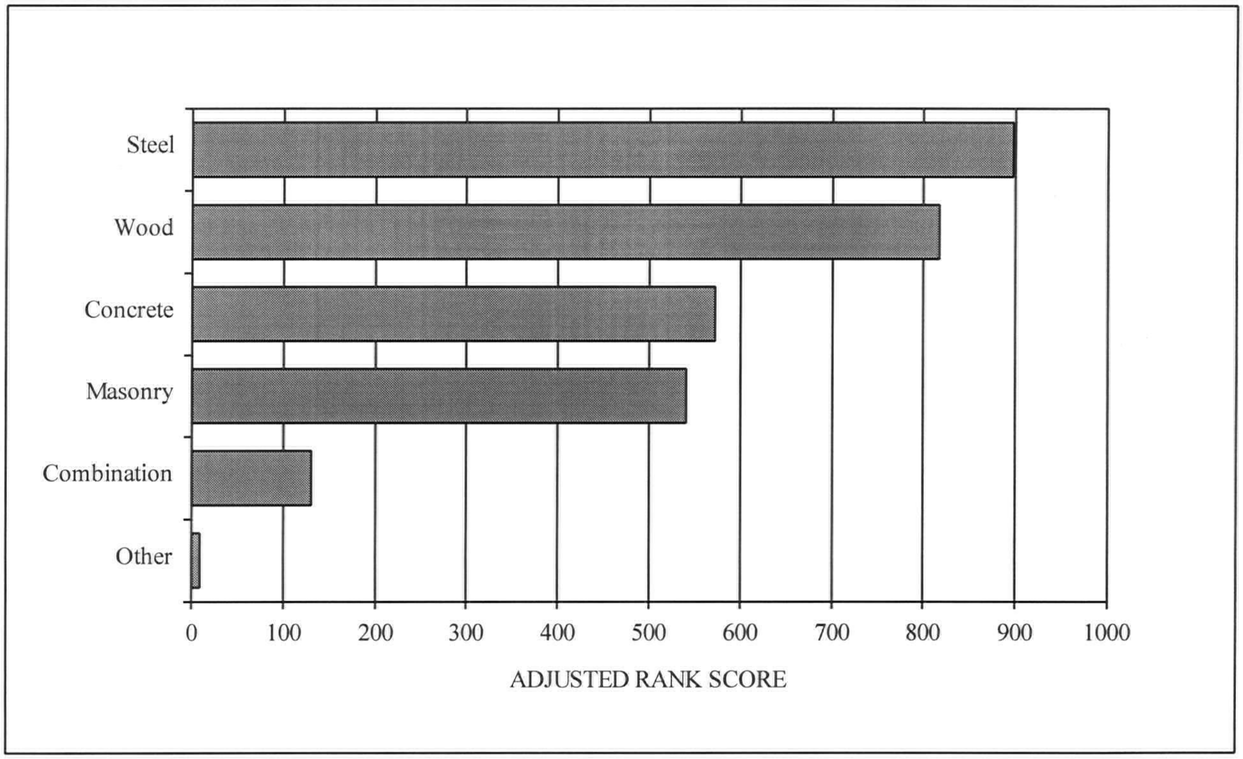

Figure 4.5: Adjusted Rank Score Preference for Structural Materials (Buildings 4 Storeys or Less).

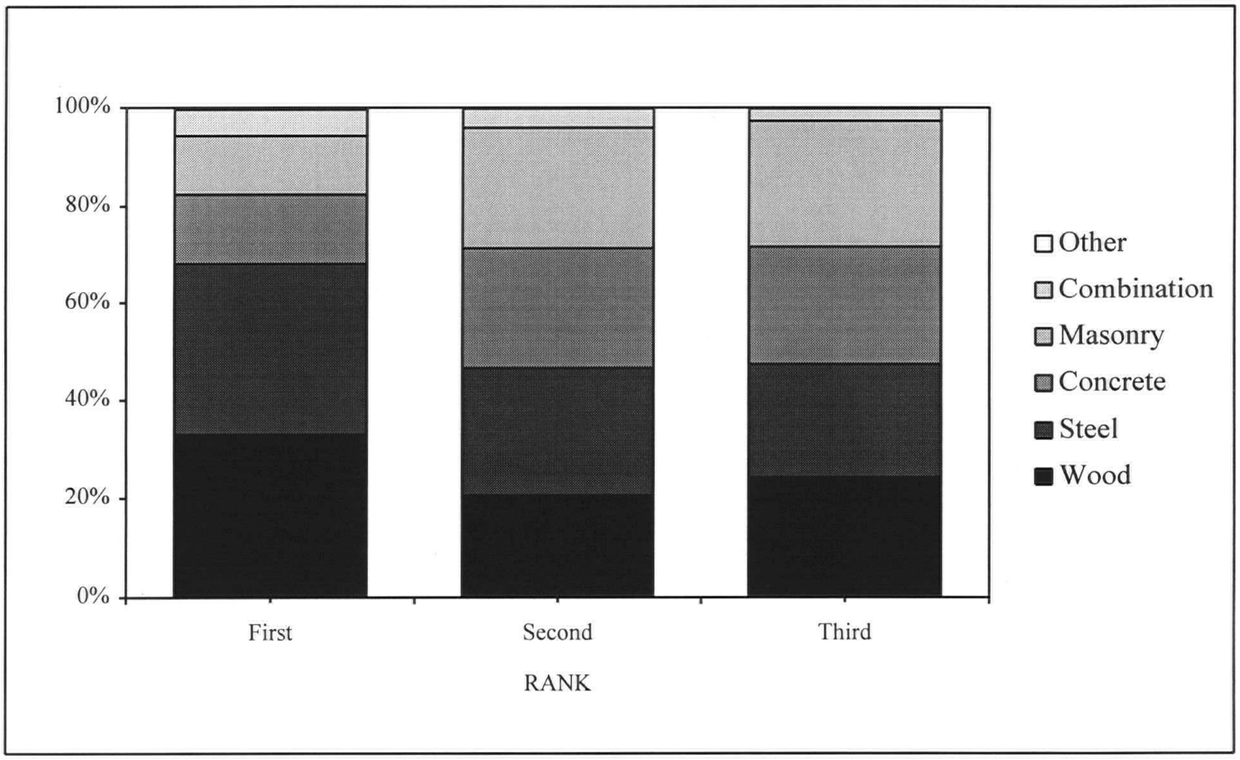

Figure 4.6: Rank Summary of Structural Material Preference (Buildings 4 Storeys or Less).

for more than 10% of the total. These are followed by public buildings, commercial buildings, multifamily residences, and hospitals, at between 5% and 10%, and religious buildings in the 3% to 4% range. The remainder, including restaurants, hotels / motels, seniors' residences, other buildings, recreational buildings, commercial / residential combinations, entertainment facilities, and farm structures, all fall below 3% of the design total. As expected, there is little variation between the proportion of buildings designed in the past and those designed in 1993. In fact, with few exceptions, the differences are below 1%. This said, residential home design is 5% higher in 1993 than it is in the past. Public building design is about 1% higher. Conversely, office and store design are down by between 1% and 2% in 1993.

Using the weighted adjusted rank score method (as above), designers' building preferences by end use are graphed in Figure 4.8. In terms of design preference, offices are, by far, the most popular type of building. This is followed by schools, detached homes, industrial buildings, and public buildings. Commercial buildings, multifamily residences, and religious buildings are moderately preferred. The remaining buildings do not rank well in terms of preference. It is interesting to note that the preference ratings and the proportions designed are very similar. One exception is hospitals, which ranks moderately in terms of proportion designed, but is not at all highly preferred.

Figures 4.9 and 4.10 show the proportion and preference of buildings designed by building height, respectively. At approximately 45% of the total, one storey buildings are the most frequently designed structures, followed by two storey buildings at just below 30%. Three storey buildings account for just over 10% of the design total, while four storey buildings (the least designed in this category) and buildings five storeys or more make up less than 10%. Again, with the exception of one storey buildings, there is little variation (less than 2%) between the proportion of buildings designed in the past and those designed in 1993. There is, however, a 4% increase in the amount of one storey buildings designed in 1993. This is likely related to the increase in residential homes seen previously.

Despite the fact that one storey buildings are the most frequently designed structures, they are not the most preferred. One storey buildings fall closely behind two storey buildings. These are followed, in order of preference, by three storey buildings, buildings five storeys or more, and four storey buildings. It should be noted that the preference rating for buildings five storeys or more does not necessarily reflect on the design population as a whole as many respondents who partake in such building were filtered out of the sample population.

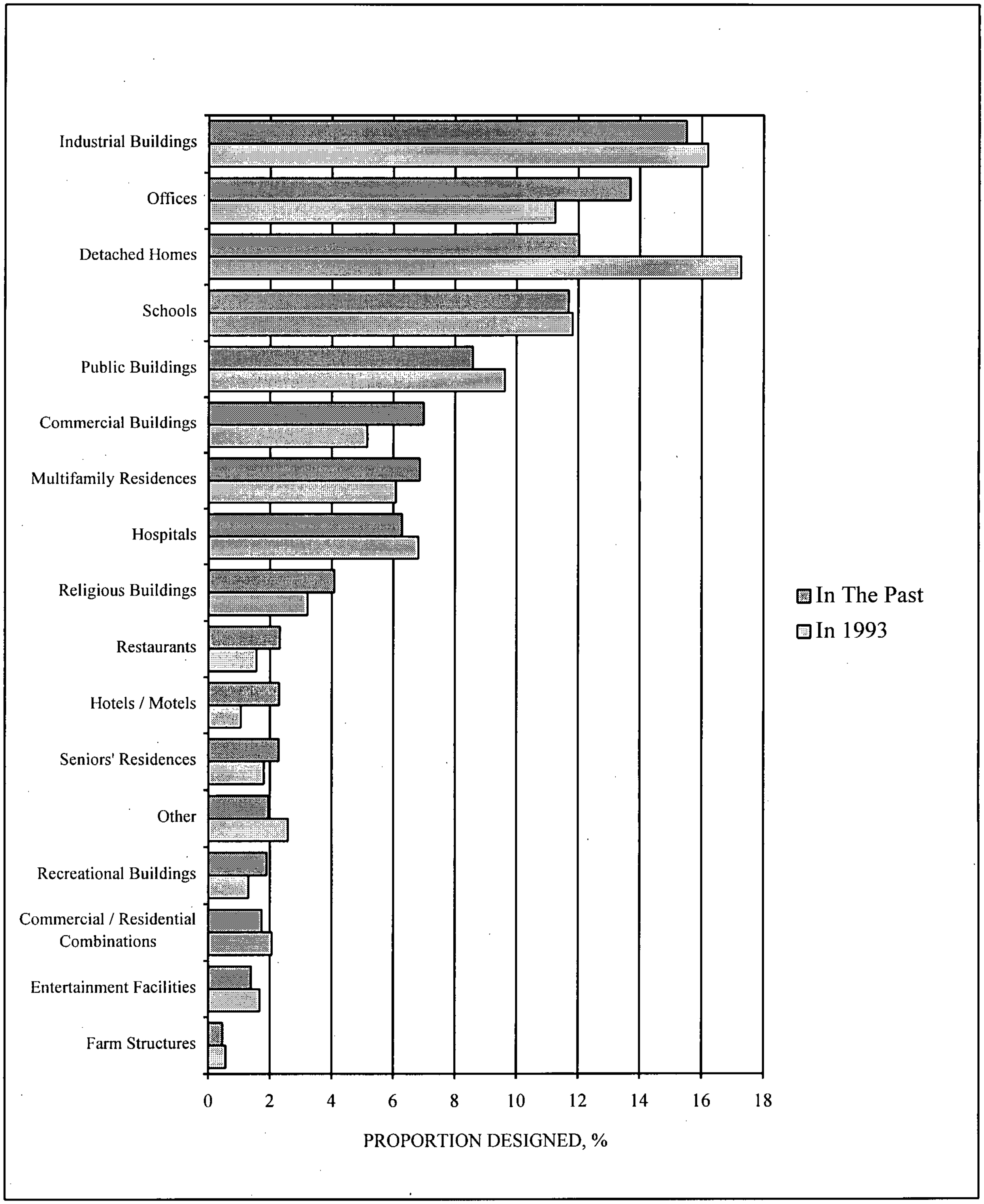

Figure 4.7: Proportion of Buildings Designed by End Use.

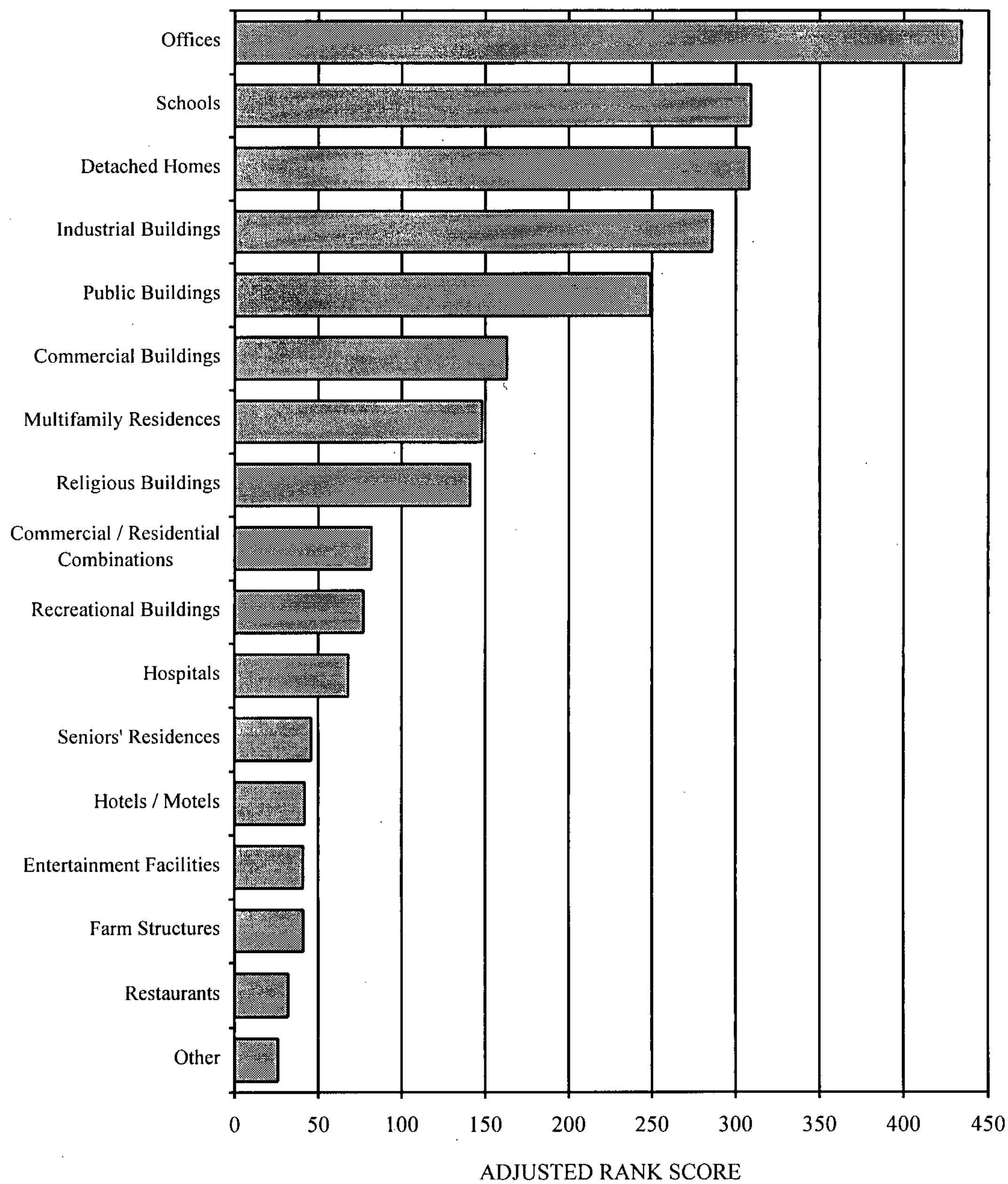

Figure 4.8: Preference of Buildings Designed by End Use.

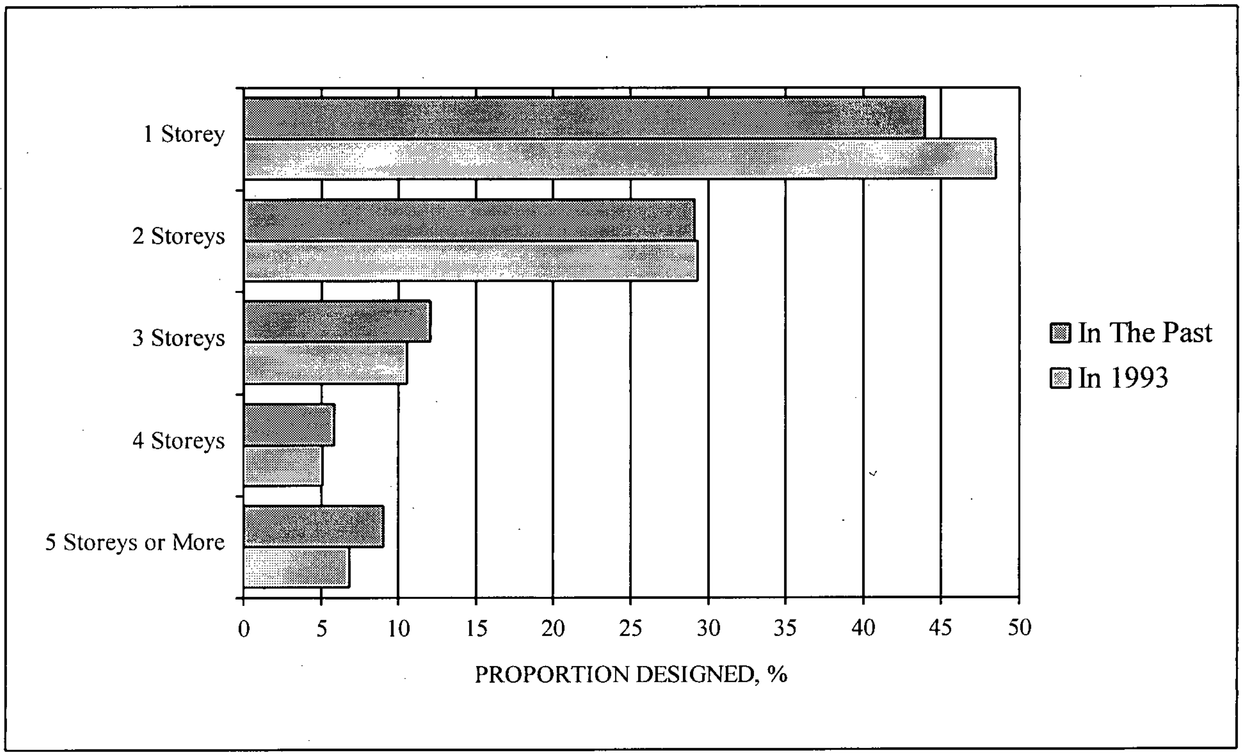

Figure 4.9: Proportion of Buildings Designed by Height.

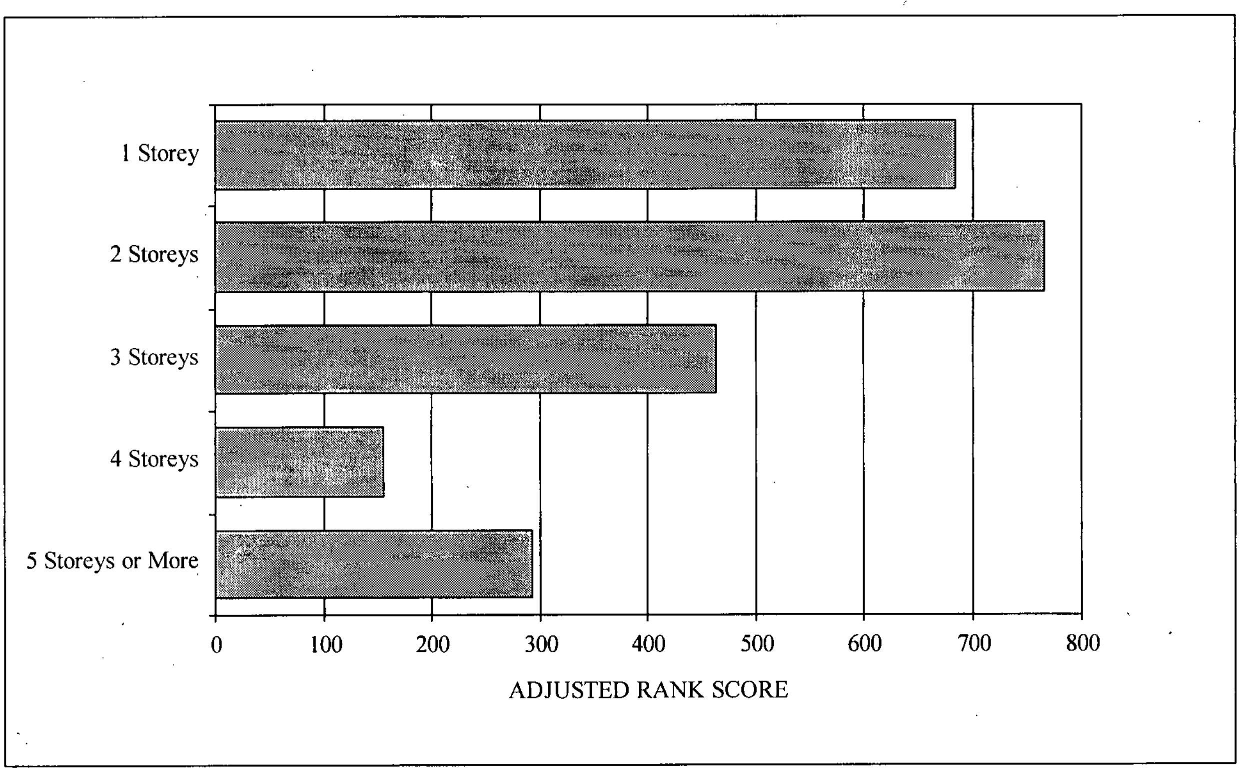

Figure 4.10: Preference of Buildings Designed by Height.

Finally, Figures 4.11 and 4.12 show the proportion and preference of buildings designed by building area, respectively. By far, at more than 70% of the buildings designed, structures with floor areas of less than 10,000 square metres are the most abundant. Structures with floor areas between 10,000 and 50,000 square metres account for about 15% of the design total, while those greater than 50,000 square metres make up about 10%. In each case, there is less than 3% variation between the amount designed in the past and in 1993. In terms of design preference, buildings with floor areas of less than 10,000 square metres rank first, followed by mid-sized buildings, and lastly, buildings with floor areas exceeding 50,000 square metres.

Frequency of Structural Material Use by Building Type (Question 7):

The last part of *Section I* of the survey asked respondents to state how frequently their designs (excluding single family dwelling units) incorporate steel, concrete, wood, masonry, a combination, or another material as the major structural component. First, they were instructed to check off the types of buildings that they design in each of three categories: end use, building height, and building area. Next, they were asked to state how frequently they use the structural materials listed for each application that they selected. A five-point scale measured frequency of material use as follows: *1, always use this material; 2, very often use this material; 3, sometimes use this material; 4, rarely use this material; and 5, never use this material.* Because of the underlying metric nature of these scales, means were computed and plotted for each building category. These are seen in Figures 4.13 through 4.15, which show frequency of material use by end use, building height, and building area, respectively. Buildings are listed in order of wood use. That is, buildings use less and less wood as one moves to the right of the plot. Note also that, in each case, *other* materials can largely be ignored as their use is negligible in all of the applications.

Based on Figure 4.13, it can be seen that, on average, wood use is highest in low-rise multifamily residences, where it is *very often* utilized. This is followed by farm structures, religious buildings, seniors' residences, restaurants, and commercial / residential combinations, where wood is *often* used. Offices, hotels / motels, recreational buildings, commercial buildings, and entertainment facilities *sometimes* use wood, on average. Finally, schools, public buildings, and industrial buildings *rarely* use wood, while hospitals almost *never* do. The use of steel, concrete, and masonry seem to be inversely proportional to the use of wood products. That is, in general, where wood usage is low, the use of alternative structural materials is high. This is especially true in the case of steel which seems to be used *very often*, on average, in most applications. Concrete and masonry seem to loosely follow the patterns of

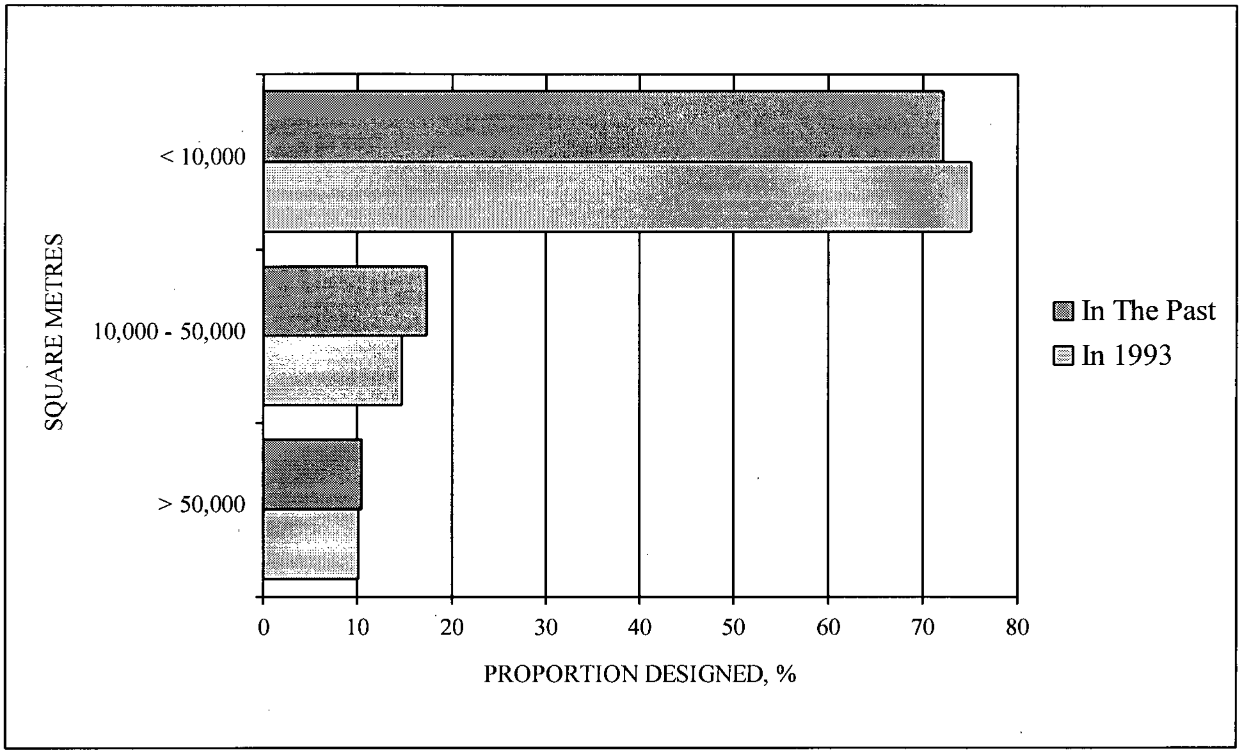

Figure 4.11: Proportion of Buildings Designed by Area.

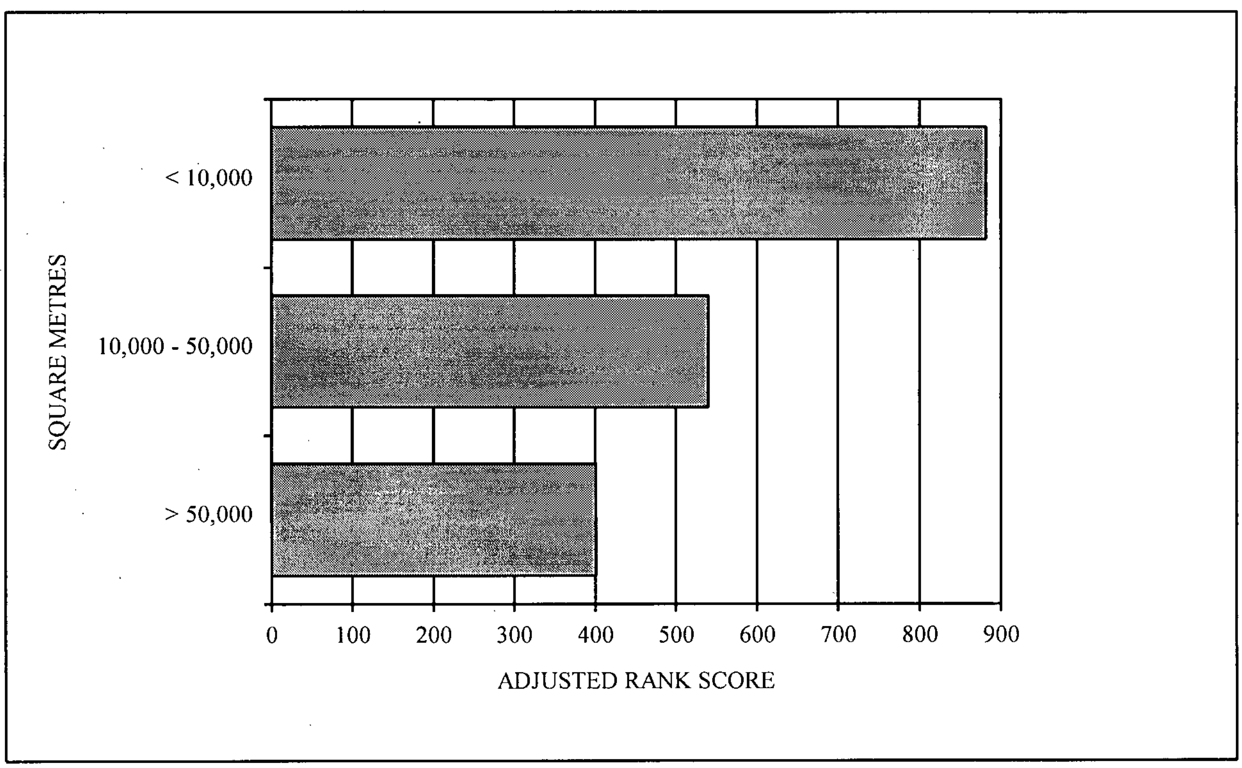

Figure 4.12: Preference of Buildings Designed by Area.

steel, with slightly lower usage levels, averaging from *sometimes* to *often* in most cases. Material combinations are *often* used in most cases, as well.

As expected, there is a downward trend of wood use as building height increases (Figure 4.14). Wood, on average, is used *often* in one storey applications. This holds true for material combinations as well. Steel and masonry are *sometimes* used, though not as frequently, while concrete is used even less. At two storeys, all of the materials cluster together at averages between *sometimes* and *often*. Wood and masonry begin losing their shares to steel and concrete. However, at this point, only steel and material combinations are used more frequently than wood. Concrete and masonry are still used less often. At three storeys, materials begin diverging in terms of frequency of use, with wood and masonry losing much more of their shares, material combinations remaining stable, and steel and concrete gaining tremendously. At this point, steel is used *very often*, while concrete and material combinations are *often* used, on average. Masonry use exceeds wood use, both of which are only *sometimes* used. At four storeys, the picture for wood is bleak, *rarely* being used in this application. Conversely, steel and concrete are *very often* used. Material combinations are *sometimes* used, with masonry being used even less so. That said, it should be reiterated that, almost 70% of the buildings designed are two storeys or less in height (Figure 4.9).

The same trends in wood use are prevalent in the category of building area. As area increases, the frequency of wood use falls. At less than 10,000 square metres, material use is difficult to differentiate, averaging between *sometimes* and *often* for all materials. At between 10,000 and 50,000 square metres, the picture begins to clear up. Wood has lost its share and is used only *rarely*, while masonry is used *sometimes*. Material combinations remain stable and are *often* used. Concrete and steel have again gained, and are *often* and *very often* used, respectively. Buildings greater than 50,000 square metres almost *never* use wood structurally. Material combinations are *sometimes* used, with masonry being used even less. Steel is almost *always* used, while concrete is *very often* used in these applications. Again, it should be restated that, by far, the majority of buildings designed are less than 10,000 square metres in size (Figure 4.11).

It is recognized that an analysis of variance could have been performed on these means, to determine whether or not frequency of structural material use varied significantly between and within applications. However, due to the large number of variables, coupled with the fact that the large sample sizes would ensure statistical differences in most cases, an analysis of this sort was not included. That said, some very important trends have been noted. For

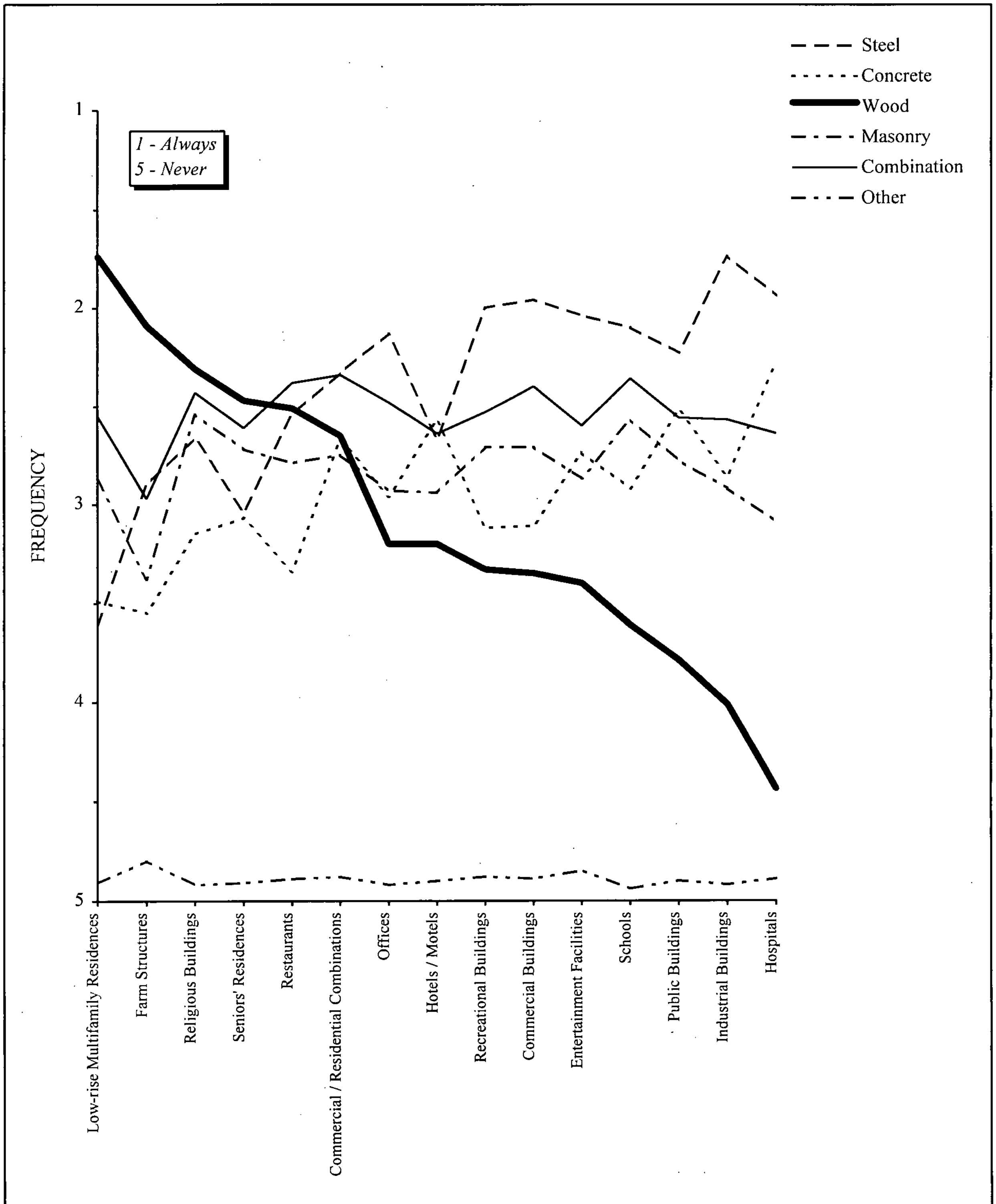

Figure 4.13: Frequency of Structural Material Use by Building End Use (Buildings Four Storeys or Less).

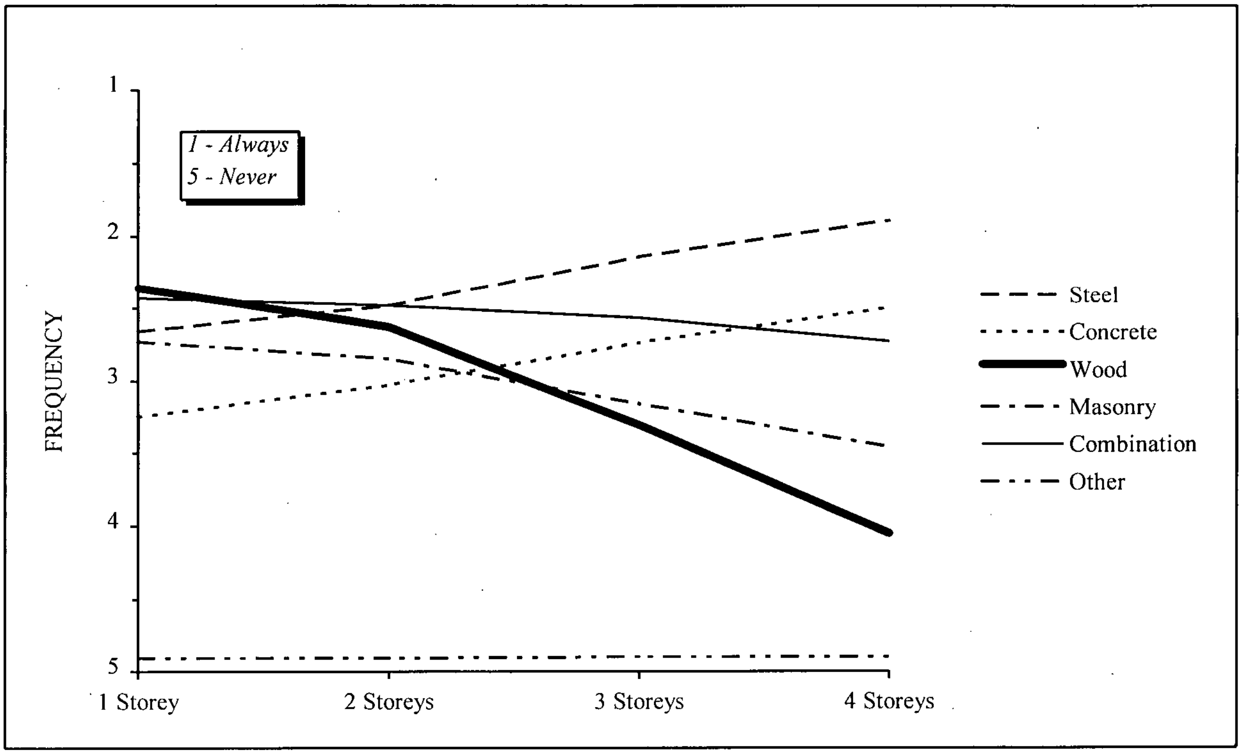

Figure 4.14: Frequency of Structural Material Use by Building Height (Buildings Four Storeys or Less).

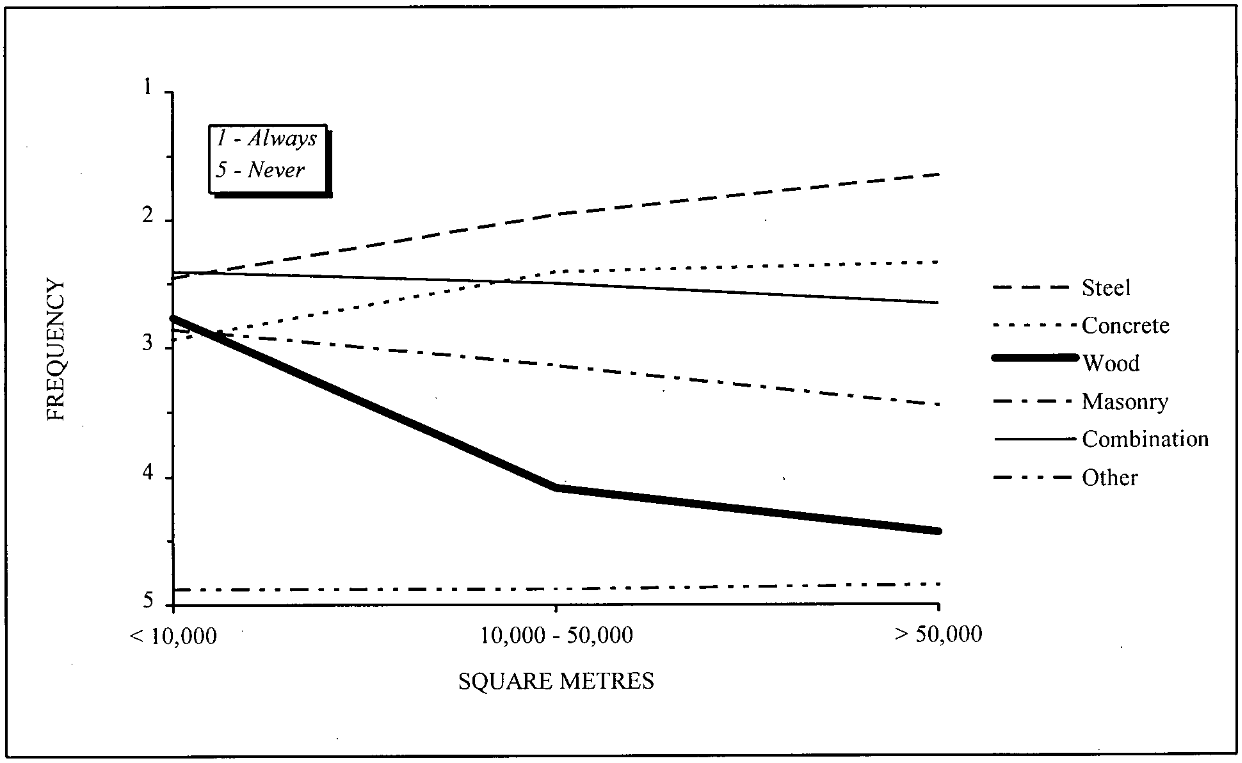

Figure 4.15: Frequency of Structural Material Use by Building Area (Buildings Four Storeys or Less).

instance, it is very obvious that the larger the building (in height or floor area), the less frequent wood use is. Furthermore, its share is being lost to steel and concrete (although primarily steel). This is mitigated somewhat by the fact that material combinations (which very often include the use of wood products) do not seem to be as dependent on building size. Rather, they remain relatively constant (decreasing marginally) as building size increases. These results are validated by those obtained in the end use analysis, where it can be seen that wood is losing its share to concrete, masonry, and especially steel. Again, larger buildings (hospitals, industrial buildings, public buildings, and schools) seem less likely to use wood than smaller buildings. Furthermore, institutional buildings (schools, hospitals, some public buildings) use little wood. On the other hand, many commercial structures (stores, hotels / motels, and offices) sometimes use wood, while residential buildings (low-rise multifamily residences, seniors' residences, and commercial / residential buildings) seem to use it frequently. This holds true for farm structures, religious buildings, and restaurants, as well.

Building Material Use (Section II):

Section II was designed to obtain information on material use (both structural and non-structural) in buildings four storeys or less. More precisely, respondents were asked to rate building materials, describe how they are used in various applications, and indicate their levels of awareness towards specific products.

Product Attributes (Question 1):

The first question asked designers to rate wood, steel, concrete, and masonry on a number of qualitative dimensions. In an attempt to ascertain the varying perceptions that designers have toward structural materials, several positive statements regarding structural materials were made and respondents were asked to state which of the materials best and least fulfilled the quality described. Materials which *best fulfilled the quality described* were given a score of *1*, while materials which *least fulfilled the quality described* were given a score of *-1*. The remaining materials were considered neutral and given a score of *0*. Means for the structural materials on every qualitative dimension were computed and are summarized in Table 4.9 (note that qualitative statements are ordered such that as one moves down the list, there is less and less agreement in the case of wood products). This numerical classification scheme has resulted in a continuum being devised, whereby positive numbers represent agreement, on average, with the statement being made and negative numbers (in parentheses) represent disagreement. Furthermore, as means

Table 4.9: Fulfillment of Quality Described by Structural Material.

	Wood	Steel	Concrete	Masonry
material is warm and inviting	.94	(.48)	(.38)	.22
material is simple to install	.79	.13	(.36)	.18
material is attractive in appearance	.77	(.07)	.05	.48
material is inexpensive to install	.76	(.08)	(.34)	.06
tradespeople are readily available	.70	.22	.20	.35
building costs are low	.62	.06	(.30)	.08
material is adaptable	.60	.28	.26	(.02)
material is simple to design with	.60	.41	(.04)	.15
material is easy to obtain	.57	.22	.50	.42
material is readily available	.54	.23	.54	.43
material is inexpensive	.47	(.10)	(.17)	.06
material has good value for the money	.42	.47	.25	.43
material is competitively priced	.37	.42	.18	.33
building codes are easy to understand	.29	.31	.26	.22
material is environmentally friendly	.29	(.10)	.23	.40
material is safe	.16	.57	.72	.39
fire codes are easy to understand	.02	.14	.56	.38
supply of material is consistent	.01	.46	.45	.37
material is strong	(.04)	.85	.55	.15
material is easy to maintain	(.28)	.12	.56	.47
material is durable	(.30)	.53	.69	.40
material is uniform	(.32)	.85	.02	.21
material is long-lasting	(.32)	.57	.68	.44
material is priced consistently	(.33)	.41	.32	.33
material is of consistent quality	(.35)	.92	(.08)	.12
material is fire resistant	(.61)	(.10)	.88	.52
material is non-combustible	(.73)	.37	.86	.51

approach the two polar extremes (*1, -1*), the level of agreement / disagreement for that structural material increases in magnitude. Some of the highlights of this query are as follows.

Wood products have several perceived strengths. Above all, they are considered to be warm and inviting and attractive in appearance. As well, wood buildings are simple and inexpensive to install and tradespeople are readily available. To a lesser degree, wood is thought of as adaptable, simple to design with, easy to obtain, and readily available. The major weakness that wood products have is that they are thought of as combustible and lacking in fire resistance.

Steel's major strengths lie in the fact that it is considered to be a strong and uniform material of consistent quality. It is also long-lasting, safe, and durable. Its major weakness is that, unlike wood, it is not thought of as a warm and inviting material, nor is it heralded as particularly attractive.

Concrete is advantageous primarily because, unlike wood, it is thought of as a non-combustible and fire resistive material. Furthermore, it is perceived as being long-lasting, durable, strong, safe, and easy to maintain. It is readily available, easy to obtain, and fire codes are easily understood when it is used. Like steel, concrete is not considered to be warm and inviting. As well, it is one of the more difficult and expensive materials to install.

Masonry does not score extremely high or low on most of the dimensions. That said, its greatest strength is in its fire-resistivity and non-combustibility. Its biggest weakness is its lack of adaptability. However, for the most part, masonry scored positively.

Some very notable trends in this data should be pointed out as well. While wood receives nine negative mentions, concrete receives seven, steel six, and masonry only one. That is, of the four structural materials, wood has the highest proportion of negative perceptions. Furthermore, several of the scores for wood seem more extreme than for the other structural materials. In other words, designers seemed tremendously excited and/or discouraged about many aspects of wood products. This is not as obvious in the cases of steel and concrete, where some high, positive scores were coupled with a few low, negative scores. It was certainly not the case with masonry, where relatively low, positive scores were obtained in most instances. Designers seem genuinely uninterested in masonry, on the whole; it is a dependable and unexciting material. Conversely, steel and concrete have a substantial number of benefits, which greatly outweigh their drawbacks.

Again, analyses of variance was not undertaken due to the sheer magnitude of the variables. That said, countless comparisons can still be made from this data by a careful observation of trends. A few notable ones are mentioned here. In some instances, many of the structural materials seem to do equally well. In others, one or two materials are clearly either at an advantage or a disadvantage. For example, wood, concrete, and masonry (and steel to a lesser extent) are all relatively easy to obtain and readily available. Wood, steel and masonry (and concrete to a lesser extent) each have fairly good value and are competitively priced. Building codes are equally difficult to understand for each material (though not impossibly so), while fire codes are easier to understand for concrete and masonry. In terms of appearance and building / material costs, wood and masonry have the clear advantage over steel and concrete. Compared to other materials, wood has a clear disadvantage with regards to safety, durability, strength, longevity, price / supply consistency, and fire resistance. Wood and concrete do not fare well in the categories of uniformity and quality. Steel is thought of as non-combustible, although not fire resistant. Concrete and masonry are thought of as more difficult to design with than wood and steel. Finally, the use of masonry, wood, and concrete is thought of as relatively benign in terms of environmental impact, while steel is thought of as environmentally unfriendly.

Use of Building Materials by Application (Question 2):

Next, designers were asked to list, by application, the materials that they generally use in buildings four storeys or less. To account for material combinations and varying methods of design, respondents were not restricted and were able to list as many materials as were germane. Applications, in order of wood use, included interior trim / detail, interior partitions, roof systems, floor systems, exterior wall systems, and exterior cladding. Note that two non-structural applications were included (interior trim / detail and exterior cladding), as well as one which may or may not be structural, depending on the nature of the design (interior partitions). Response breakdowns, by application, are seen in Figure 4.16.

Wood use is high in the non-structural interior trim / and detail category. In fact, 84.47% of the responses indicated that they use wood in this application. The remainder is fairly evenly split between steel, masonry, and other materials, including plastics, aluminum, vinyl, glass, and gypsum board / drywall. At 43.29% of the responses, wood still has the advantage in the interior partition category. However, steel (33.48%) and masonry (17.15%) account for a sizable portion of the material use in this application. Other materials (primarily gypsum board /

drywall) make up less than 5% of the responses while the share for concrete is negligible. At 55.25% of the responses, steel use is highest in the roof systems category. Wood use is still substantial (37.81%), while concrete is infrequently used (6.50%). Masonry and other materials are negligible in this application. At 26.89% of the responses, even less wood is used in the category of floor systems. Here, concrete seems to be the dominant material of choice (39.28%), with steel capturing the remaining share (33.46%). Again, masonry and other materials are negligible in this application. Masonry has the highest proportion of responses, at 43.34%, in the exterior wall systems category. This is followed by wood (26.26%), steel (18.34%), and concrete (11.31%). Other materials are hardly used at all in this application. Again, masonry use, at 45.81%, is seen to be high in the non-structural exterior cladding category. This is followed by wood (21.95%), steel (18.52%), and concrete (7.00%). Other materials, including vinyl, aluminum, and stucco, account for 6.72% of the responses in this application. Finally, by tallying the total responses, it can be seen that the overall picture for wood products is favourable. Ignoring applications, wood accounted for the majority of responses (37.79%). Steel was second (27.93%), followed by masonry (19.42%), concrete (12.11%), and other materials (2.76%).

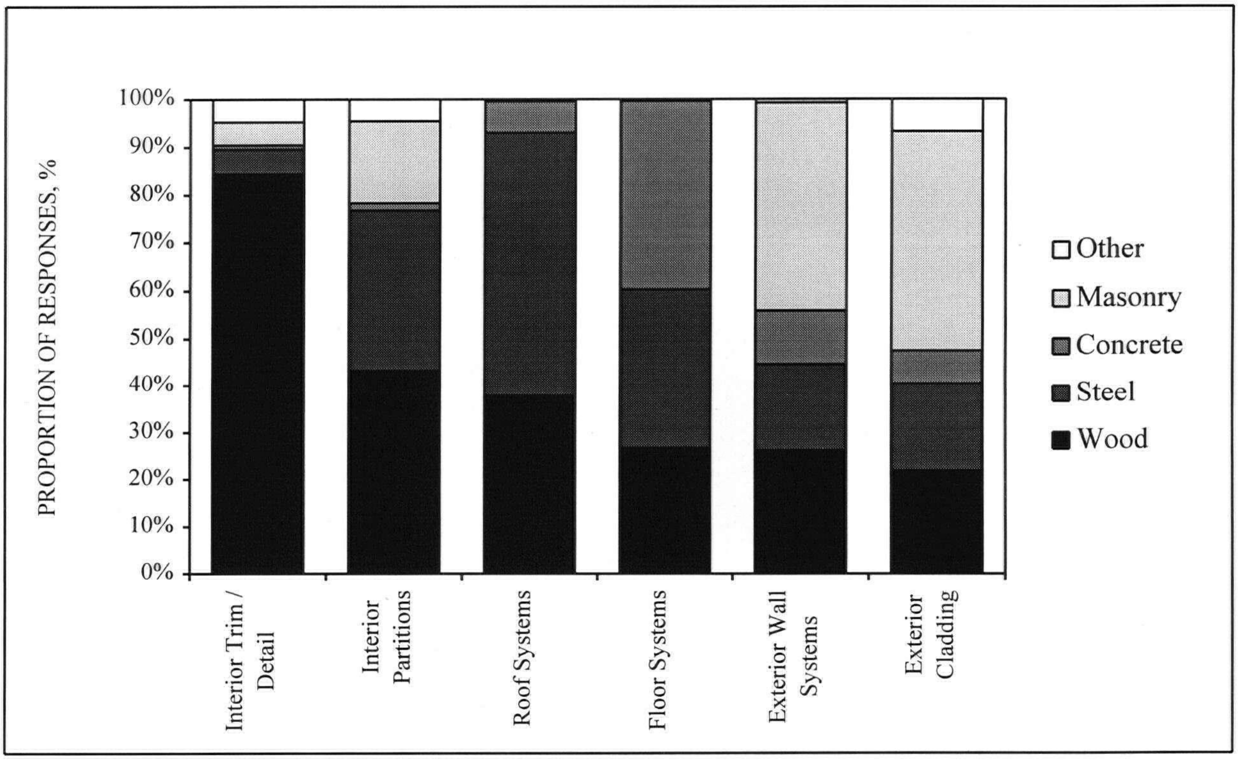

Figure 4.16: Breakdown of Material Use by Application (Buildings 4 Storeys or Less).

Familiarity with Building Materials (Question 3):

The latter part of *Section II* asked respondents to state how knowledgeable and experienced they were with a vast array of wood products, both structural and non-structural, as well as steel, concrete, and masonry products. For each product, two underlying four-point metric scales were used as follows: *1, not at all knowledgeable / experienced; 2, not very knowledgeable / experienced; 3, somewhat knowledgeable / experienced;* and *4, very knowledgeable / experienced.* Means of the awareness levels were computed and are plotted (in order of familiarity) in Figures 4.17 (structural wood products), 4.18 (non-structural wood products), and 4.19 (steel, concrete, and masonry products). As expected, experience levels are lower than knowledge levels for each product listed. In fact, the gap between knowledge and experience becomes wider and wider the less familiar designers are with the products.

In terms of structural wood products, designers seem very familiar with lumber studs and dimension lumber. In fact, experience and knowledge ratings were, on average, as high for these products as for any other. Pitched roof trusses also scored reasonably well. However, designers seemed only somewhat knowledgeable / experienced with floor trusses, timbers, glulam beams, and wood I-beams. Familiarity seems to decrease even more with parallel chord trusses, laminated veneer lumber, and composite lumber. Ultimately, designers' knowledge and experience of products like parallel strand lumber and stressed skin panels becomes minimal, scoring lower than any other product. Specifiers seem to more familiar with traditional, commodity-based products than reconstituted, engineered products

Likewise for non-structural wood products, plywood has a high knowledge and experience rating. On average, designers are also well acquainted with siding / plank decking and particleboard, to a lesser extent. However, oriented strand board, medium density fibreboard, and waferboard do not fare as well. Each of these product's average familiarity scores lie between somewhat and not very knowledgeable / experienced.

Without going into detail about the familiarity scores of each steel, concrete, and masonry product, some very important trends should be noted. Fully, eight of the products listed scored higher than *somewhat knowledgeable / experienced.* This is compared to three structural and two non-structural wood products. Furthermore, seven of these wood alternatives scored as high as *3.5* (between *somewhat* and *very knowledgeable / experienced*), compared to two structural and one non-structural wood products. Eleven of the thirteen wood alternatives scored at least a *3*

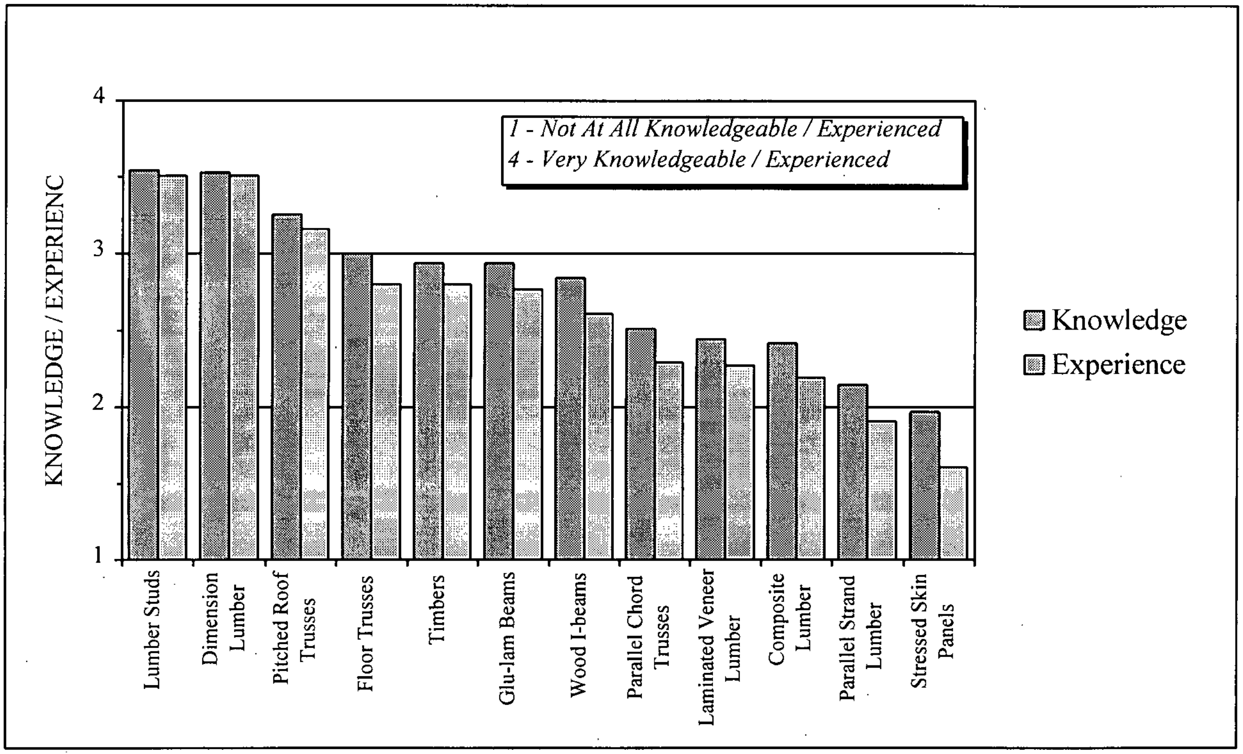

Figure 4.17: Knowledge/Experience of Structural Wood Products.

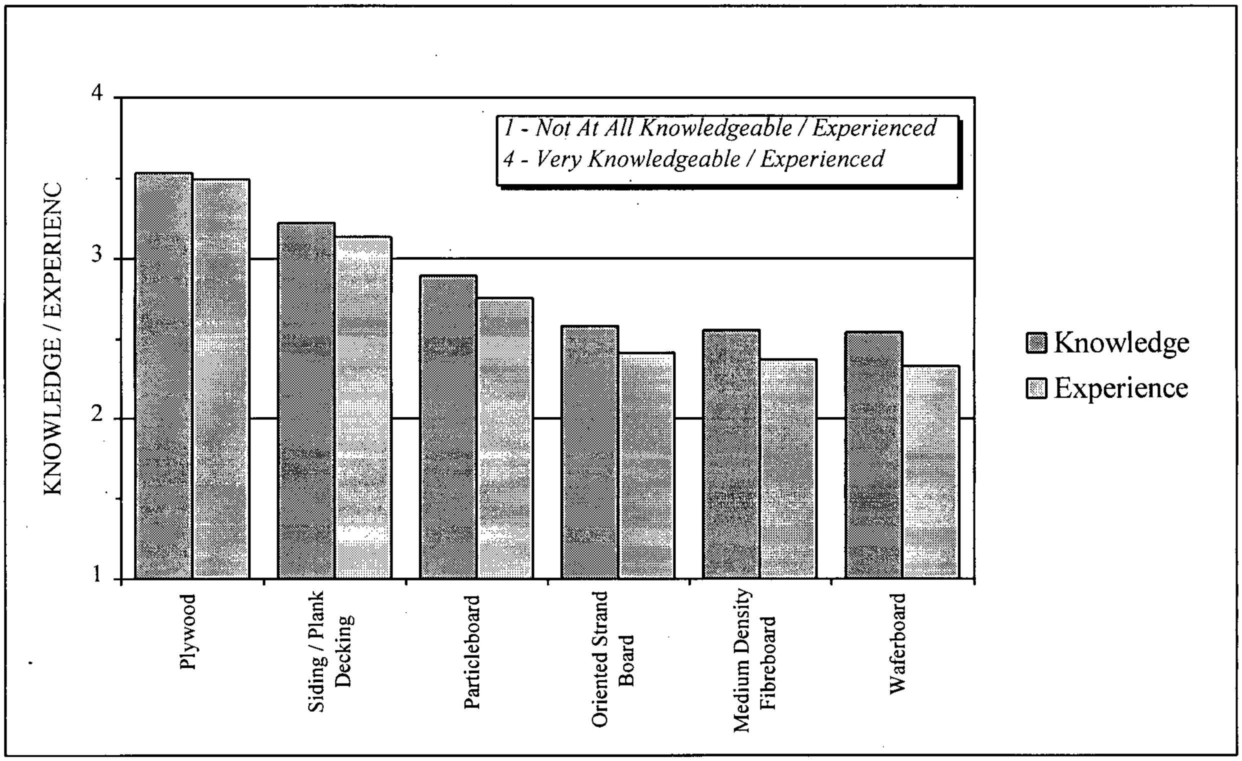

Figure 4.18: Knowledge/Experience of Non-structural Wood Products.

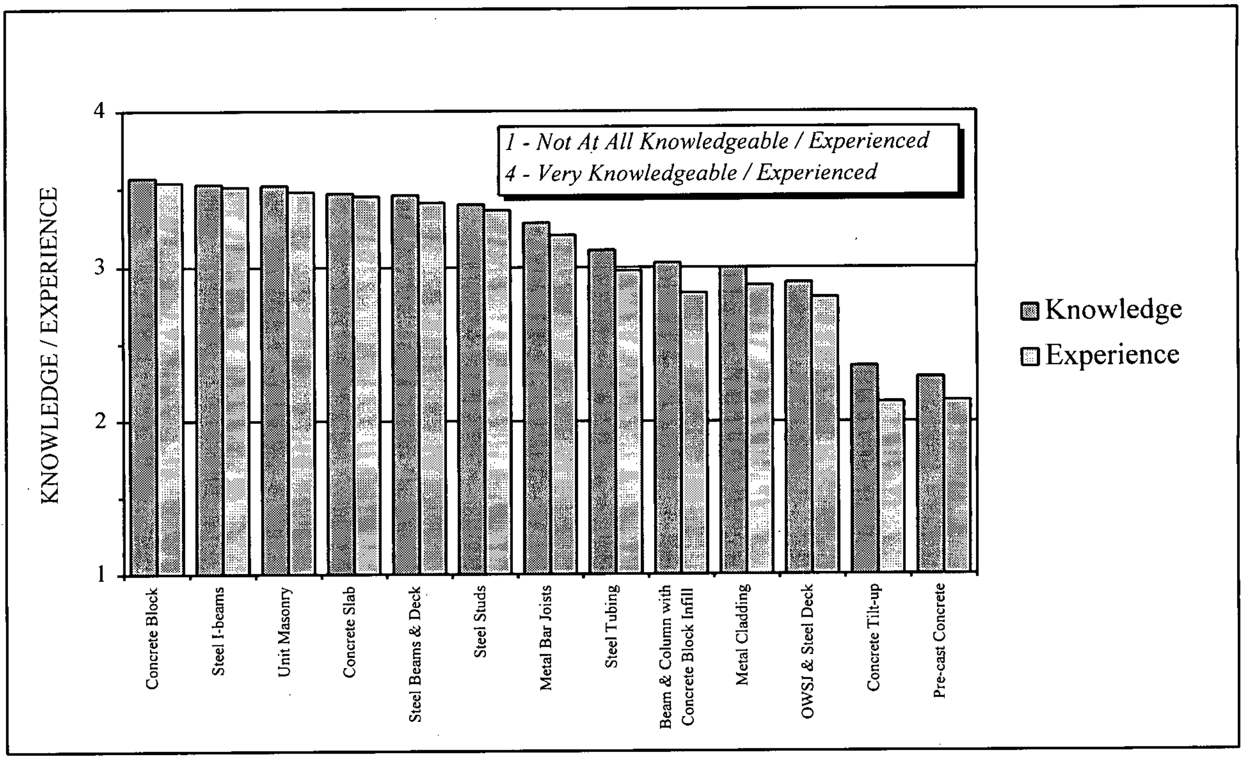

Figure 4.19: Knowledge/Experience of Other Building Materials (Steel, Concrete, Masonry).

(*somewhat knowledgeable / experienced*) on the familiarity rating (with only two concrete products scoring slightly below the neutral point, *2.5*), while only ten of the eighteen wood products fared as well. In short, designers seem much more familiar with steel, concrete, and masonry products, both in terms of knowledge and experience.

Wood Use (Section III):

Section III of the survey asked respondents about wood and how it pertains to designing buildings four storeys or less. Specifically, designers were queried on whether or not they design with wood, how favourable they are to wood used in certain applications, and what they perceive wood's strengths and drawbacks to be.

Wood Use (Questions 1 - 4):

Overall, the market situation for wood used in small to medium-sized buildings appears to be favourable. Fully, 84.33% of the respondents feel that they are qualified to design buildings four storeys or less using wood as the main structural component, while 15.67% do not. However, only 62.02% say that they presently design buildings four storeys or less in wood, while 37.98% do not. Somewhat fewer respondents, 49.12%, like to see wood used as a structural material in these applications, while 13.70% do not and the remaining 37.18% do only sometimes. Despite these promising results, there should be some cause for concern in the wood products industry. More to the point, improving the market position for wood used in buildings four storeys or less may prove difficult. Only 8.86% of the respondents intend on using more wood in future designs, while 18.70% intend on using less. The remaining 72.44% have no intention of changing their usage levels one way or the other.

Favourability to Wood Use (Question 5):

Respondents were also asked to rate various types of buildings according to how favourable they were to the use of wood as a structural material in those applications. A five-point underlying metric scale measuring favourability to wood use was again incorporated as follows: *2, very favourable; 1, favourable; 0, neutral; -1, not favourable;* and *-2, not at all favourable.* Means were computed for each application so that continuums of favourability could be devised. These continuums, arranged from most to least favourable, can be seen in Figures 4.20 (by end use), 4.21 (by building height), and 4.22 (by building area).

Results obtained here agree with those obtained in the *frequency of material use* question (again, an example of the reliability and validity of the survey). For the most part, designers are favourable to wood use in buildings that they, in reality, already design with wood. For example, respondents are most favourable to wood use in low-rise multifamily residences, farm structures, religious buildings, and seniors' residences. They are also, on average, slightly favourable to restaurants, commercial / residential combinations, offices, and recreational buildings being built with wood. Designers are least favourable to wood use in hospitals and, to a lesser extent, industrial buildings, public buildings, and schools. Commercial buildings, hotels / motels, and entertainment facilities did not fare particularly well in this regard either. Again, the trend seems to be that wood use is not viewed as favourable in larger commercial, industrial, and institutional spaces. It is, however, favoured in smaller residential and specialty buildings.

These findings are verified by Figures 4.21 and 4.22, which show favourability to wood use decreasing as building size increases. Designers seem very favourable to wood use in one storey buildings and, to a lesser degree, two storey buildings. Wood use in three storey structures is looked upon only slightly favourably (close to neutral), on average, while at four storeys, the limit has been surpassed. Designers are not favourable to wood use in this application. A similar trend is observed in an analysis of floor area. On average, wood use is favoured at less than 10,000 square metres, only slightly so at between 10,000 and 50,000 square metres, and not especially at more than 50,000 square metres.

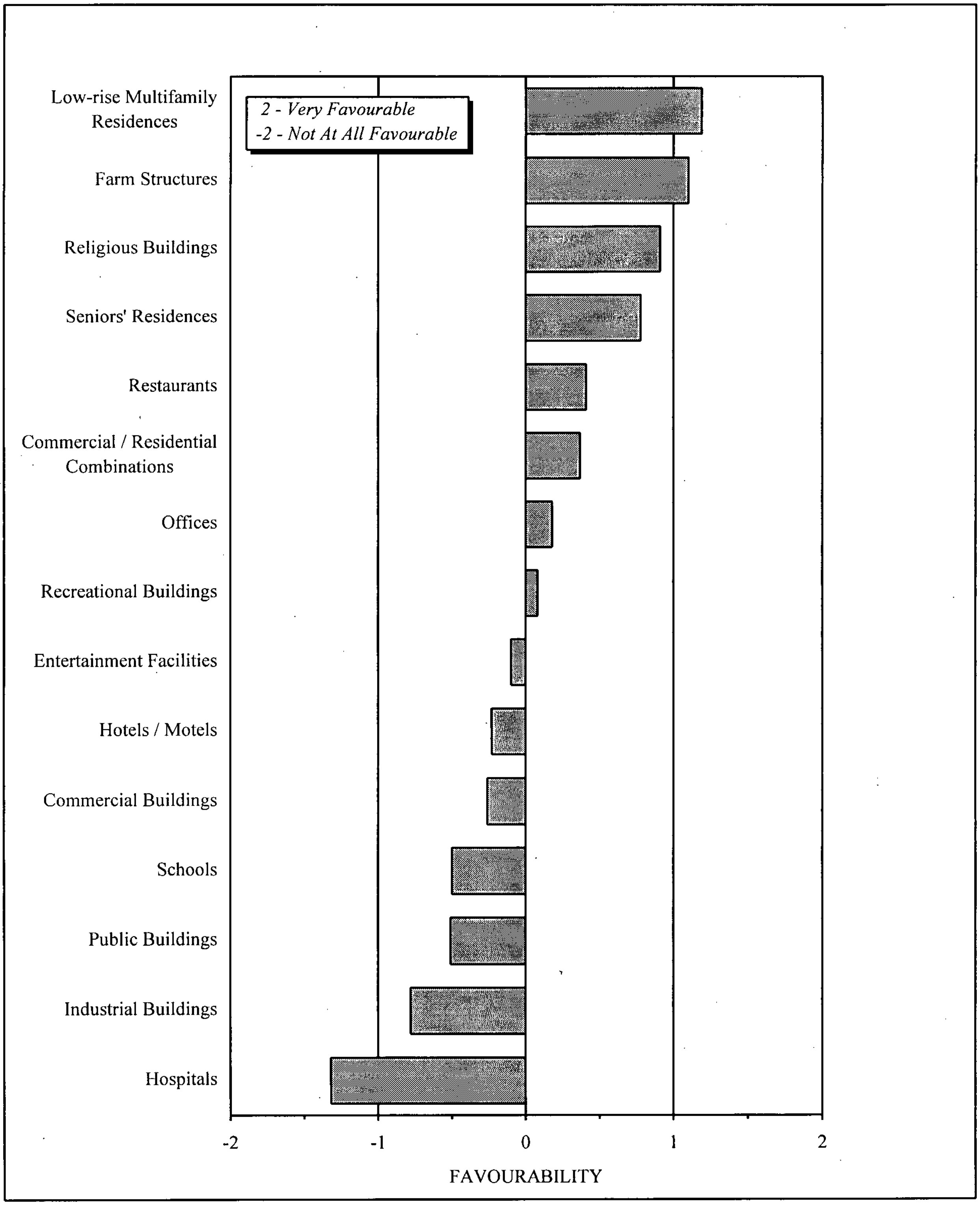

Figure 4.20: Favourability to Wood Use by End Use (Buildings 4 Storeys or Less).

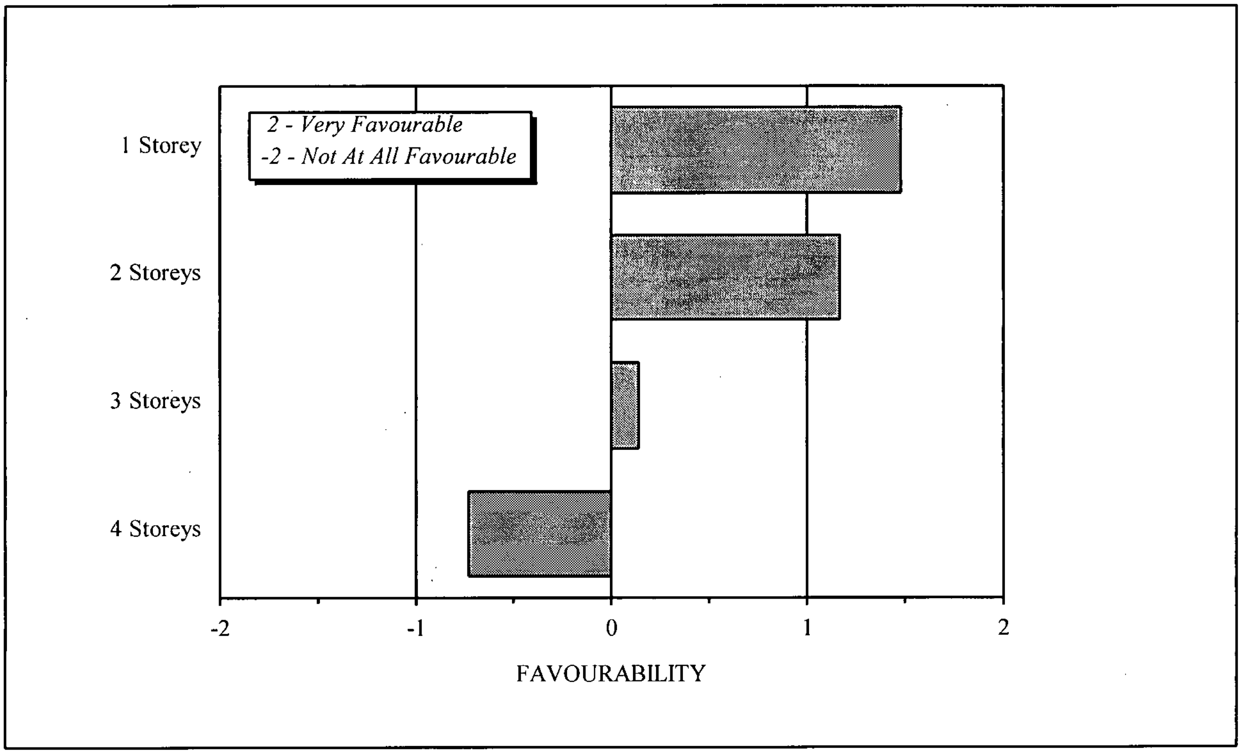

Figure 4.21: Favourability to Wood Use by Building Height (Buildings 4 Storeys or Less).

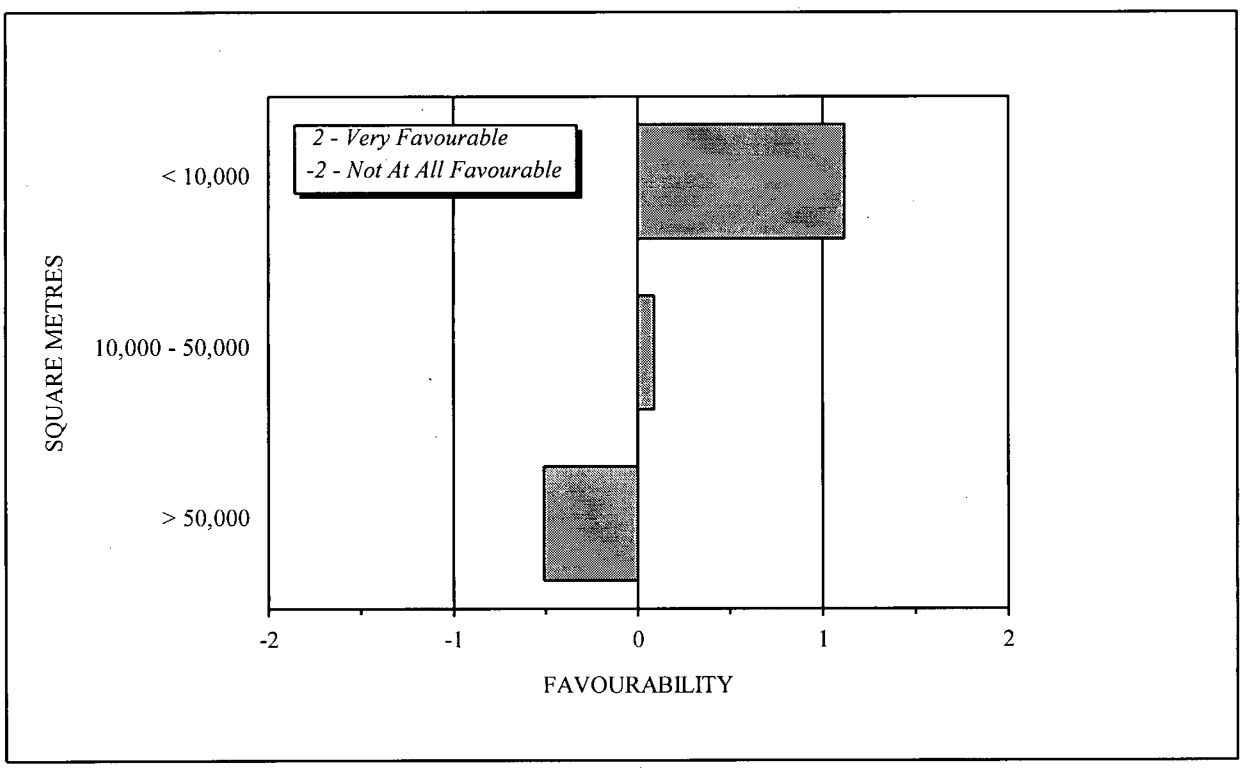

Figure 4.22: Favourability to Wood Use by Building Area (Buildings 4 Storeys or Less).

Attitudes and Perceptions of Wood Use (Questions 6 - 8):

Next, specifiers were asked to indicate their levels of agreement on a number of qualitative statements pertaining to wood, buildings four storeys or less made of wood, and timber design. A five point *Likert* scale was utilized to measure agreement levels for each statement as follows: *1, strongly disagree; 2, disagree; 3, no opinion; 4, agree;* and *5, strongly agree.* Results are graphically represented in Figures 4.23 to 4.24 which show the proportion of responses in each agreement category.

The results from questions pertaining to buildings four storeys or less made primarily out of wood are seen in Figure 4.23. At least 75% of the respondents agree or strongly agree that these types of structures are easy to build, comfortable, and attractive, with disagreement levels at below 10% in each case. Between 60% and 70% of the designers believe them to be functional, inexpensive to build, and well insulated, with less than 15% disagreeing. However, less than 35% of the respondents think of wood buildings as long-lasting, well lit, and sound-proof, with very little strong agreement and up to 35% disagreement. The proportion of respondents with no opinion ranged from 12% to 35%, with the exception of the lighting category, where over 60% had no opinion. This is probably due to the fact that structural material choice has little bearing on how well a building is lit.

Issues of designing with wood as a structural material are explored in Figure 4.24. Almost 75% of the respondents either agree or strongly agree that designing with wood is simple. Less than 15% disagree with this statement, while the remainder have no opinion. Approximately 60% of the respondent feel that wood design is gratifying, with little disagreement at less than 5%. However, only 40% think that this type of design is not time consuming, with over 20% stating that it is. It should also be noted that in the latter two categories, a significant proportion of respondents (approximately 35%) had no opinion.

Basic questions surrounding the use of wood are summarized in Figure 4.25. Approximately 50% of the respondents agree or strongly agree that, with wood, design calculations are simple, building codes are easy to understand, and design of connections between members is not difficult. In each case, there is less than 30% disagreement. Over 40% agree that rot and pest damage is not overwhelming with wood, while less than 20% disagree, and the remainder (over 40%) have no opinion. Slightly less than 40% of the respondents agree that fire codes are simple to understand when wood is used, with almost an equal amount (approximately 35%) disagreeing. Lastly, only 25% of the designers agree that fire protection is easily built in to buildings that use wood, with

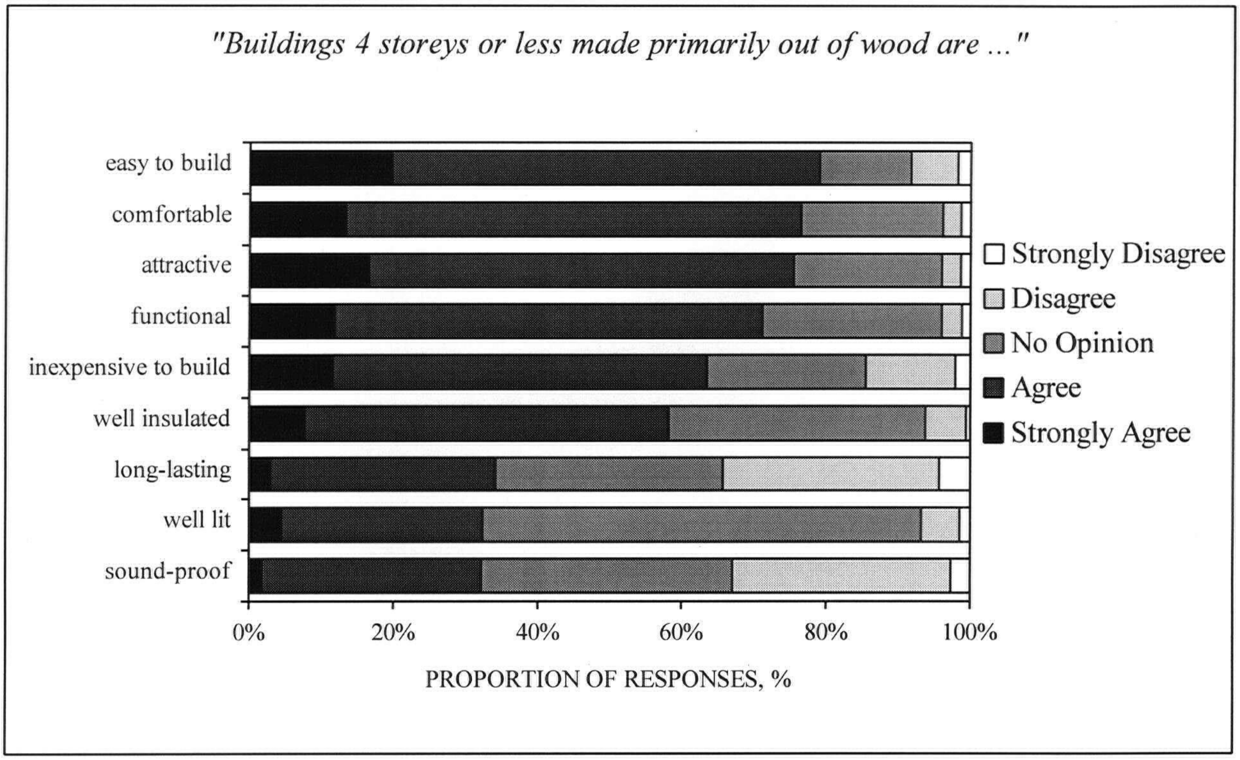

Figure 4.23: Level of Agreement.

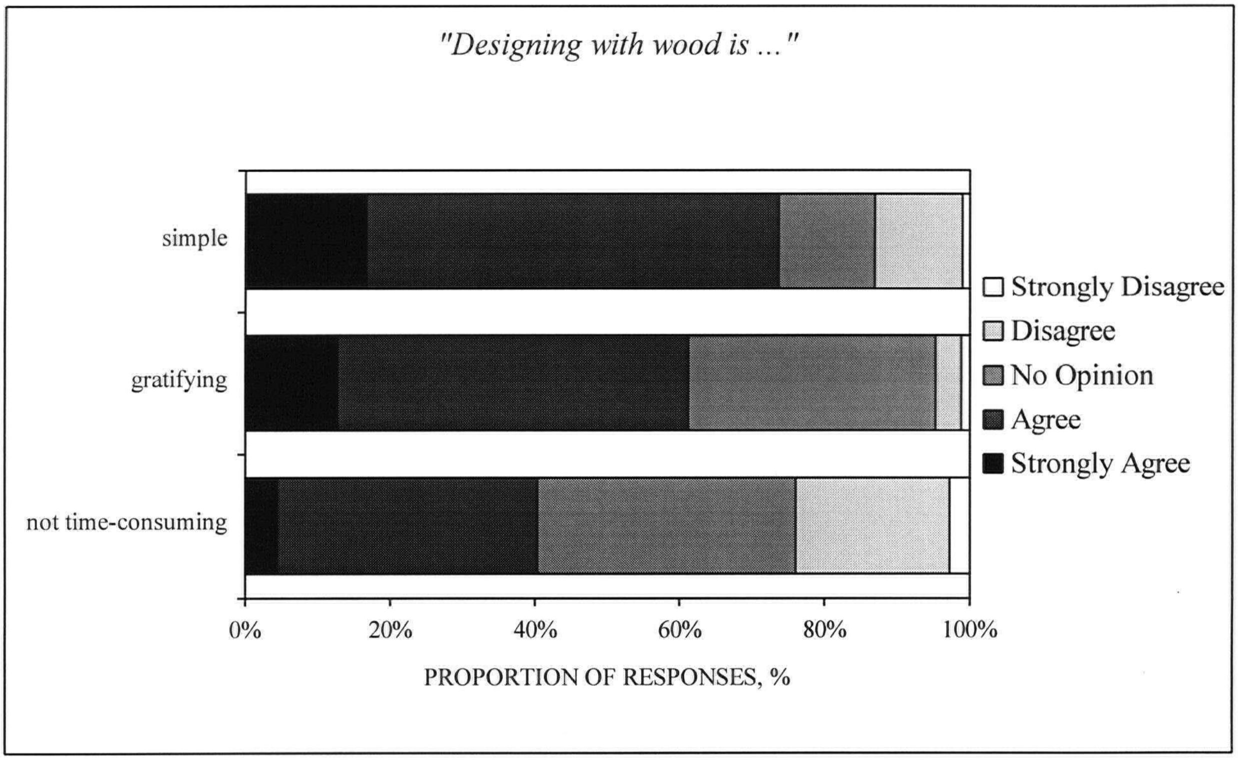

Figure 4.24: Level of Agreement.

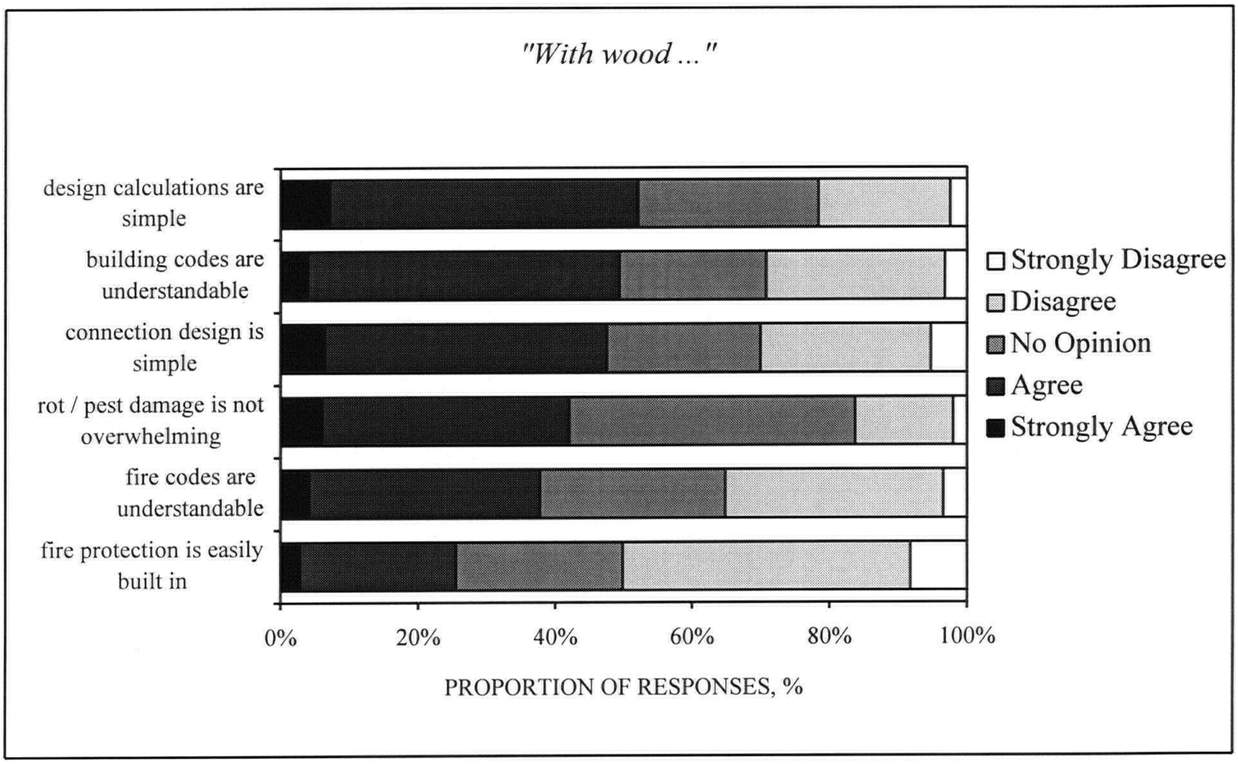

Figure 4.25: Level of Agreement.

disagreement levels exceeding 50%. It should be noted that, with the exception of rot and pest damage, the proportion of respondents who had no opinion ranged between 21% and 28%. The high proportion of respondents having no opinion about rot and pest damage may be the result of this factor being of little concern in several regions. Also, relatively speaking, there is a small proportion of respondents (less than 8%, and compared to 20% in some cases) who strongly agree with these statements. However, as above, strong levels of disagreement are uncommon.

Respondents were also asked to compare wood products to alternative structural materials, like steel, concrete, and masonry, on a number of dimensions. The breakdown of responses is seen in Table 4.10 and, again, shows the relative position of wood to be favourable. For the most part, wood products are seen as being less costly in terms of material expenses, building installation, labour, and total building costs. Design costs for wood buildings are generally the same or less than for other structural materials, while finishing costs are seen to be more, less, or equal. Generally speaking, wood buildings require the same, or sometimes fewer, number of designers, specifiers, and structural engineers. The number of contracting crews and construction workers / tradespeople required to build wood structures is either the same or less than for any other type of building. Lastly, the availability of skilled tradespeople seems to be the same or greater in wood construction.

Respondents were also asked simple True and False questions about wood, the results of which can be seen in Table 4.11. Again, most designers reacted positively to wood use. The majority of respondents feel that wood withstands loads well (dead loads, seismic loads, wind loads, and especially live loads). Respondents generally agree that when wood is used, it fulfills the architectural requirements of buildings well in terms of space, function, light, and structure. They also state that, for the most part, design errors and omissions, building failures, and lawsuits which arise as a result of events such as these, do not occur more frequently when wood is used structurally. The downside for many respondents is that, when wood is used structurally, building insurance and, to a lesser degree, liability insurance are expensive. Both are relatively easy to obtain, with building insurance being slightly more difficult than liability insurance. However, a significant portion of designers state that they do find it difficult to secure insurance policies when wood is used structurally.

Table 4.10: A Comparison of Wood to Other Structural Materials (Breakdown of Responses).

	More	The Same	Less
...the material cost is	14.35%	14.14%	71.52%
...the design cost is	12.16%	50.93%	36.91%
...the cost of installation is	7.13%	17.82%	75.05%
...labour costs are	10.57%	19.87%	69.56%
...finishing costs are	25.47%	36.21%	38.32%
...the total building cost is	8.69%	20.76%	70.55%
...the number of designers required is	4.18%	66.74%	29.08%
...the number of specifiers required is	3.35%	70.92%	25.73%
...the number of contracting crews required is	7.46%	42.43%	50.11%
...the number of construction workers/tradespeople required is	11.86%	43.22%	44.92%
...the number of structural engineers is	1.68%	69.96%	28.36%
...the availability of skilled tradespeople is	39.16%	41.68%	19.16%

Table 4.11: True or False (Breakdown of Responses).

	True	False
Wood withstands dead loads well.	79.14%	20.86%
Wood withstands live loads well.	85.39%	14.61%
Wood withstands seismic (earthquake) loads well.	79.28%	20.72%
Wood withstands wind loads well.	80.04%	19.96%
When wood is used structurally, building insurance is easy to obtain.	59.81%	40.19%
When wood is used structurally, building insurance is inexpensive.	26.55%	73.45%
When wood is used structurally, liability insurance is easy to obtain.	68.95%	31.05%
When wood is used structurally, liability insurance is inexpensive.	44.84%	55.16%
Building failures are more common with wood than with other materials.	15.95%	84.05%
Design errors and omissions are more common with wood than with other materials	16.59%	83.41%
Wood fulfills the space requirements of buildings well.	82.81%	17.19%
Wood fulfills the functional requirements of buildings well.	85.00%	15.00%
Wood fulfills the light requirements of buildings well.	82.06%	17.94%
Wood fulfills the structural requirements of buildings well.	78.70%	21.30%
When wood is used structurally, lawsuits and litigation occur more frequently than usual as a result of building failures, errors and omissions, etc.	15.09%	84.91%

Likelihood of Wood Use by Application (Question 9):

Next, respondents were asked about the likelihood of their using wood products in specific building applications, both structural and non-structural. Results are seen in Figure 4.26. Over 95% of the respondents surveyed are either likely or very likely to use wood non-structurally for interior trim and detail. Over 80% are likely to use wood in interior partitions (which may or may not be structural), while only 50% would use wood for exterior cladding (which is non-structural). Figures for structural wood use are high as well, with over a 75% likelihood of use in roof systems. Over 65% of the respondents also state that they would either likely or very likely use wood for exterior wall systems and floor systems. Thus, the situation for wood in the small to medium-sized construction sector again appears to be good, both for structural and non-structural products.

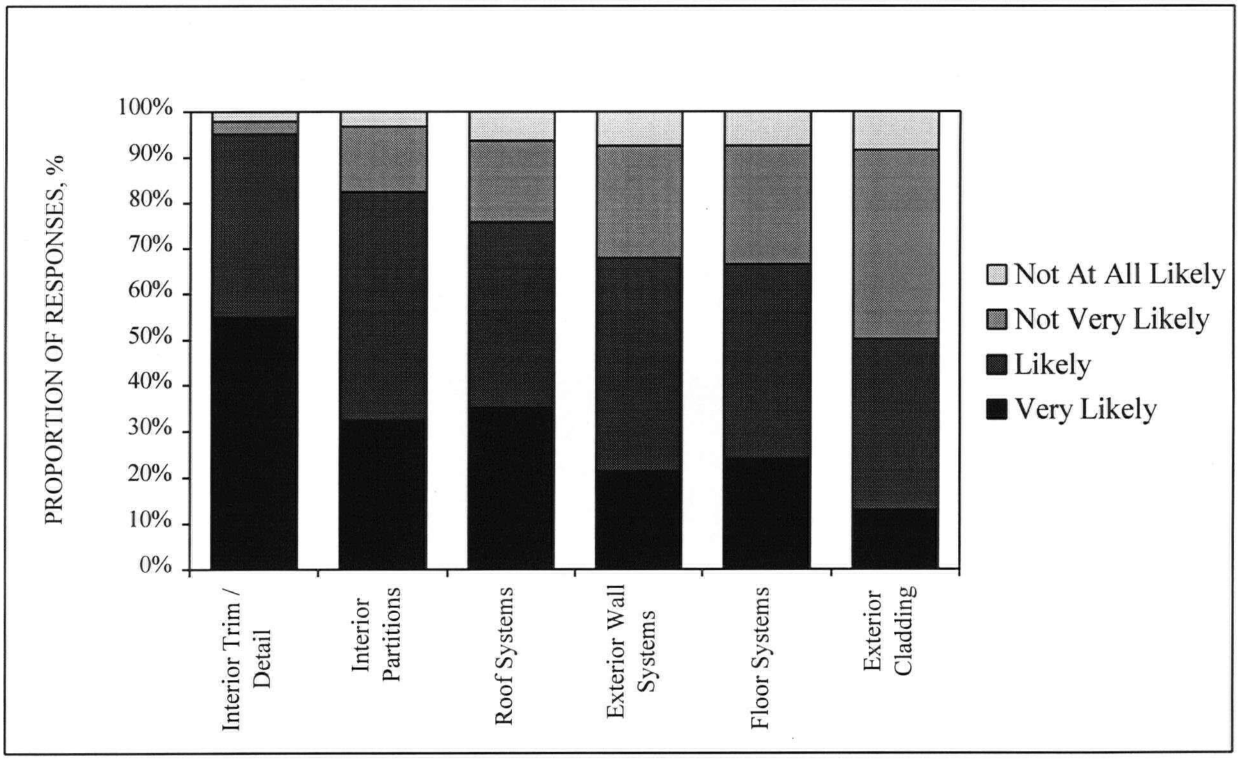

Figure 4.26: Likelihood of Wood Use by Application (Buildings 4 Storeys or Less).

Drawbacks to Wood Use (Question 10):

Finally, the latter part of *Section III* asked designers to choose (from a list) the three greatest drawbacks to wood use in buildings four storeys or less. Results, in Figure 4.27, show quite clearly that the greatest concern is that wood burns, followed by the fact that it deteriorates and rots. Several respondents also mentioned the fact that wood is a variable material and that it shrinks and swells. Some stated that it is not durable and strong, and even fewer said it was costly and difficult to design with. Many additional drawbacks (seen in the other category) were mentioned, including span limitations, building and fire code restrictions, environmental impact, and maintenance problems. Finally, specifiers were asked whether or not they would like to learn how some of these drawbacks could be overcome: 60.25% said that they would, 8.28% said that they would not, and 31.47% said that they already knew how to.

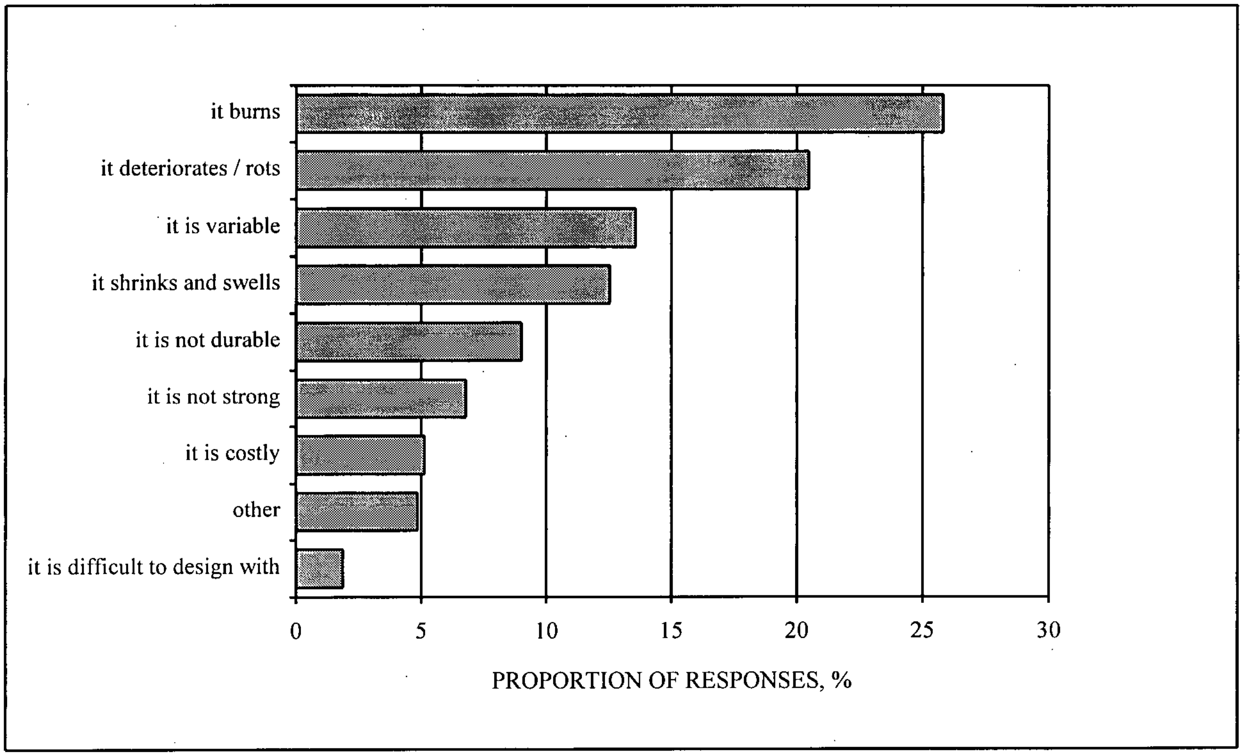

Figure 4.27: Drawbacks to Wood Use (Buildings 4 Storeys or Less).

Education / Promotion (Section IV):

Section IV of the survey asked specifiers how they learn about structural materials, both at school and on the job. The first part of the section dealt with issues of education. Specifically, information pertaining to their educational backgrounds and orientations, as well as the structural materials that were most commonly taught, was obtained. The latter part of the section asked about the effectiveness and occurrence of various promotional methods that they are exposed to on the job.

Place of Formal Education (Question 3, Section VII):

One question seen in the *Personal Information* section is included here, as well. Specifiers were asked where they received their formal design education. The breakdown of respondents who completed the survey in its entirety is seen in Table 4.12. Results are fairly consistent with those seen in the regional breakdown in Table 4.4. The majority of respondents in the United States received their formal design education in the Pacific, West North Central, East North Central, and Middle Atlantic regions, with the most popular region being East North Central. In Canada, most of the designers went to school in Ontario, with some in Quebec, Alberta, British Columbia, and

Manitoba. Still other designers received their formal education in other parts of the world, like Europe and Asia, both of which are mentioned more often than some regions in Canada.

Table 4.12: Breakdown of Respondents' Place of Formal Design Education.

United States:	**70.58%**
Pacific	10.77%
Mountain	5.96%
West North Central	7.88%
East North Central	16.35%
West South Central	4.81%
East South Central	3.46%
South Atlantic	6.15%
New England	4.62%
Middle Atlantic	10.58%
Canada:	**24.04%**
British Columbia	2.88%
Alberta	3.27%
Saskatchewan	1.15%
Manitoba	2.50%
Ontario	8.09%
Quebec	4.62%
Newfoundland	0.19%
Nova Scotia	1.15%
Prince Edward Island	0.00%
New Brunswick	0.19%
Yukon	0.00%
Northwest Territories	0.00%
Other:	**5.38%**
Africa	0.58%
Asia	1.15%
Continental Europe	1.54%
United Kingdom	1.92%
South America	0.19%

Educational Background (Question 1 & 2):

Respondents were asked about their educational backgrounds in the field of design. By far, the most popular response, at 54.91%, is university training, with 21.42% at the post-graduate level. Continuing education and on the job / apprenticeship training account for 17.55% and 15.28% of the responses, respectively. Colleges and technical / trade schools make up only 6.70% and 3.30% of the responses. The remaining responses (2.26%) are split between no formal program or another form of training like art school, construction experience, or peers. Designers were then asked to describe the orientation of their design education. The most popular response, at 36.37%, was a technical orientation. Slightly fewer respondents, at 30.17% and 24.56%, state that the focus of their design education was practical and artistic. Only 7.16% and 1.74% claim to have been exposed to a scientific and business orientation, respectively.

Learning About Structural Materials (Questions 3 - 6):

Next, specifiers were asked to comment on the process of learning about structural materials, both at school and on the job. Not surprisingly, 61.39% of the respondents stated that their design education has had an impact on the structural materials that they specify in their work today. However, just 15.79% claimed that they exclusively specify only those materials that they learned about at school. This is substantiated by the fact that 75.51% of the respondents stated that most of what they have learned with regards to design concepts has been on the job, while only 24.49% said that it was at school. Fully, 98.43% of the respondents stated that most of what they have learned with regards to product information has been on the job, while only 1.57% said that it was at school. All of these results seem to indicate that, while the role of education should not be diminished (this is where structural material use and the design process is first taught, after all), designers learn more during the course of their professional careers.

That said, education is still a fundamental part of how a designer learns to use structural materials. With that in mind, specifiers were asked to estimate the proportion of the time spent learning about structural materials that is devoted specifically to wood, steel, concrete, masonry, and other materials. Mean proportions were computed and results are seen in Figure 4.28. A one-way analysis of variance ($\alpha = 0.05$) and Bonferroni's test of differences revealed that the amount of time spent learning about structural materials significantly differed in each case. On average, steel and concrete are, by far, the most commonly taught structural materials at 32.86% and 29.82%, respectively. Wood's average share of teaching time is somewhat less at 22.48%, while masonry falls even further behind at 13.25%. Other materials, like plastics, aluminum, composites, and tensile canvas, account for 1.58% of this apportionment.

These results are in agreement with those seen in Figure 4.29. Here, respondents were asked to rate three methods of acquiring knowledge about wood, steel, concrete, and masonry: their education, their on the job training, and their work experience. A four point underlying metric scale was used to measure effectiveness of learning, as follows: *1, no knowledge of material gained; 2, little knowledge of material gained; 3, some knowledge of material gained;* and *4, much knowledge of material gained.* Means of *knowledge gained* were computed and are plotted in Figure 4.29 by structural material. Here, a two-factor analysis of variance ($\alpha = 0.05$) was performed. Initial results indicated that a highly significant interaction was taking place between the two factors: structural materials and methods of acquiring knowledge. Upon further examination of Figure 4.29, it was thought that most of the interaction was occurring in the education category (lines were not parallel for this factor). As a result, the education category was removed and the analysis re-run. As expected, there was no interaction in this model. This indicates that there is no relationship between structural materials and on the job training / work experience in terms of knowledge gained. To verify this, Bonferroni's test was subsequently performed on the means. In fact, there were no significant differences between knowledge of material gained in either of these two categories. That is, knowledge of each of the structural materials is acquired in equal measures at work (at a level slightly higher than *some knowledge gained*, on average).

This is not true in the case of education. Here, the method of acquiring knowledge does have a bearing on the extent to which each material is learned about. In fact, the results seen above (Figure 4.28) are verified. Bonferroni's test was again employed to indicate that knowledge gained at school was significantly different for each material. On average, steel is the material most learned about at school, followed by concrete, wood, and, lastly, masonry. Steel and concrete cluster somewhat above *some knowledge gained*, while wood and masonry fall below this level.

The upward trend for all of the structural materials (concrete being the exception, in one case) should also be noted. As above, it seems that most learning with respect to materials is done on the job. In general, knowledge gained is

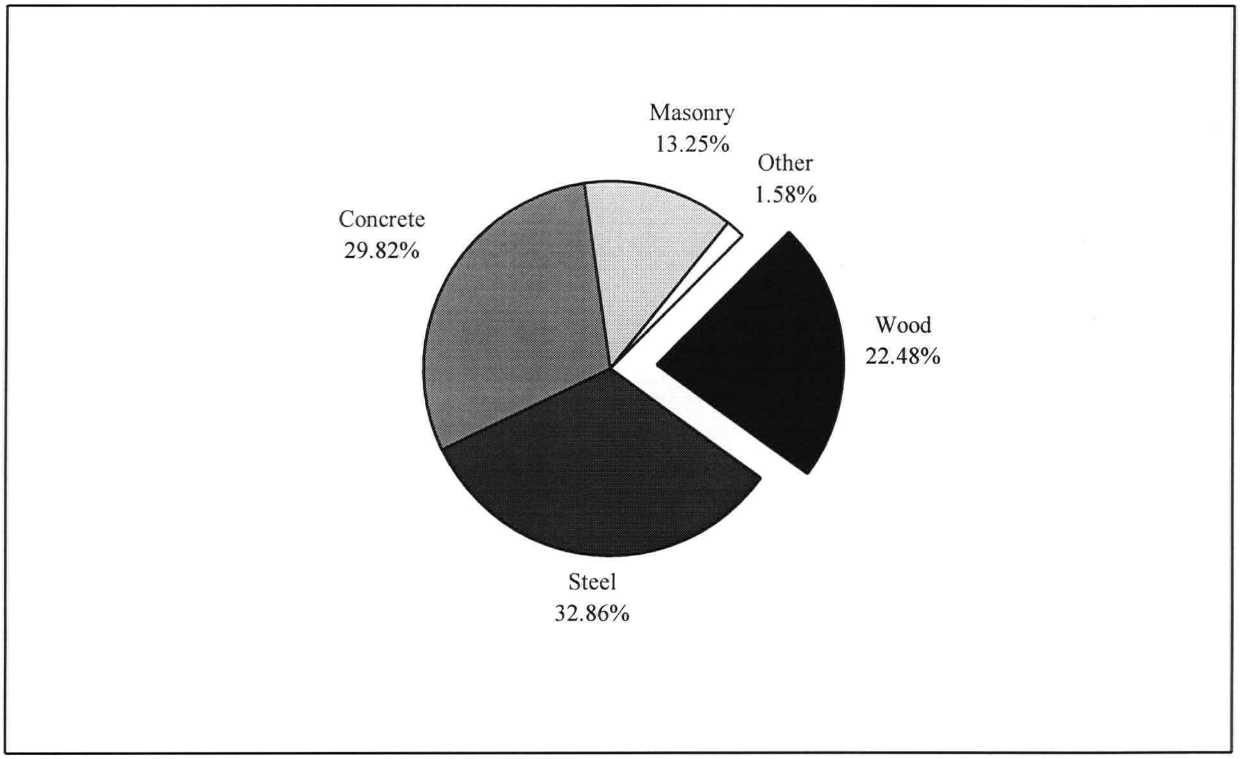

Figure 4.28: Proportion of Time Spent Learning About Structural Materials.

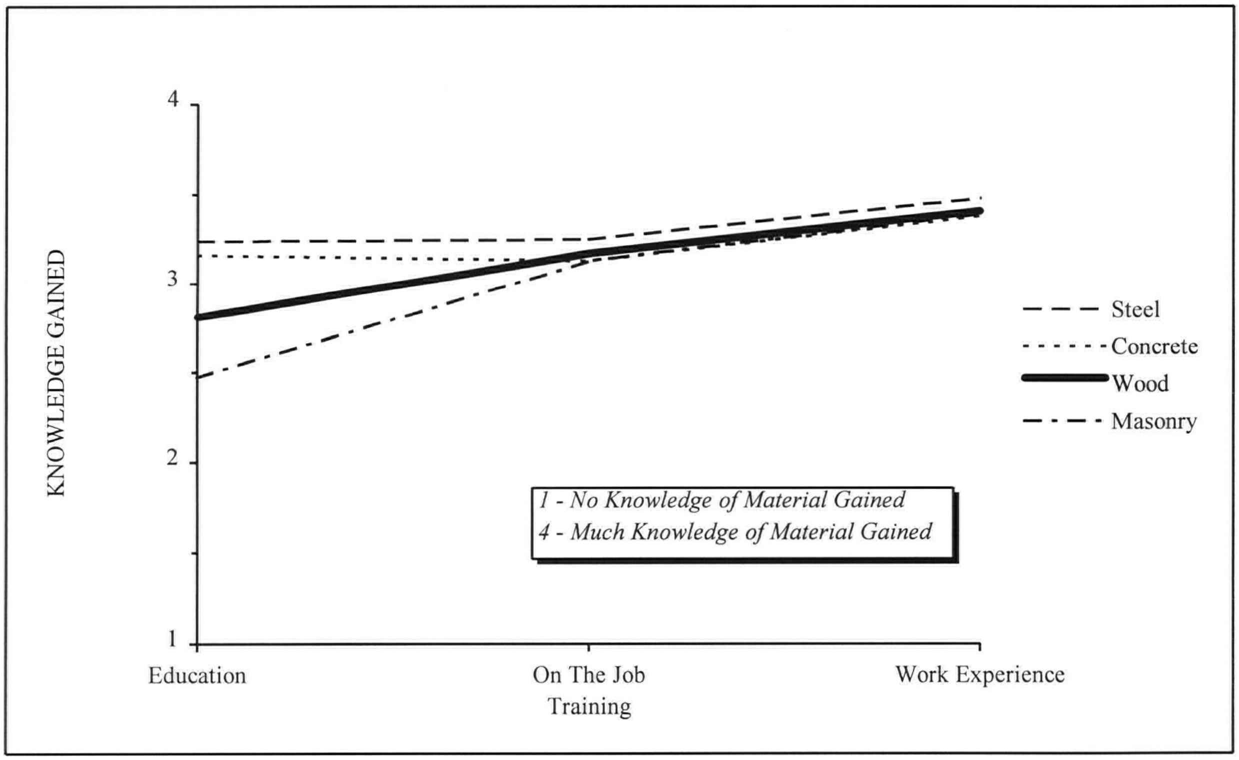

Figure 4.29: Effectiveness of Various Methods in Acquiring Knowledge about Structural Materials.

lowest at school, increasing with on the job training, and maximizing with work experience. Once again, Bonferroni's test was used to show that each method of acquiring knowledge was significantly different.

Promotional Methods (Questions 7 & 8):

Given the importance of learning about products, systems, and services on the job, respondents were asked about various promotional methods of obtaining information at work. The most common, influential, and used methods are seen in Figure 4.30 by proportion of responses. Methods which resulted in the respondent exploring and using a new material are seen in Figure 4.31. The most common forms of obtaining product information on the job are by reading materials (e.g., trade magazines and journals), manuals / data files (e.g., design manuals and codes), and corporate (company-specific) promotion (e.g., product manuals and advertising). These are followed by word of mouth (e.g., peers and co-workers), personal promotion (e.g., sales calls and technical support), association (industry-wide) promotion (e.g., newsletters and mailouts), and continuing education (e.g., courses and seminars). Physical examples (e.g., demonstration buildings and tradeshows), proactive marketing (e.g., design submission and project costing), computerized information (e.g., on-line data bases and design software), and other miscellaneous methods (e.g., consultants and travel) are seen to be relatively uncommon methods of learning about new products, systems, and services.

The methods of obtaining information on the job that specifiers use correspond closely to how popular they are. For example, the most common methods, reading materials and manuals / data files, are also the most utilized. Two notable exceptions are continuing education and physical examples, where use is much higher than occurrence. These results were verified by asking designers which of the methods of obtaining product information were most influential. Here, manuals / data files are thought of as being the most influential, followed by reading materials. Word of mouth and physical examples are also seen as relatively effective means of educating specifiers about structural materials. These are followed by continuing education, personal promotion, and, to a lesser extent, corporate promotion. In comparison, association promotion, proactive marketing, computerized information, and other methods are seen as not being very influential. Two paradoxical trends should be noted here. First, corporate and association promotion, while relatively common, do not appear to be very influential to many specifiers. Conversely, relatively uncommon methods of obtaining product information, like word of mouth, continuing education, and physical examples, are seen as being influential.

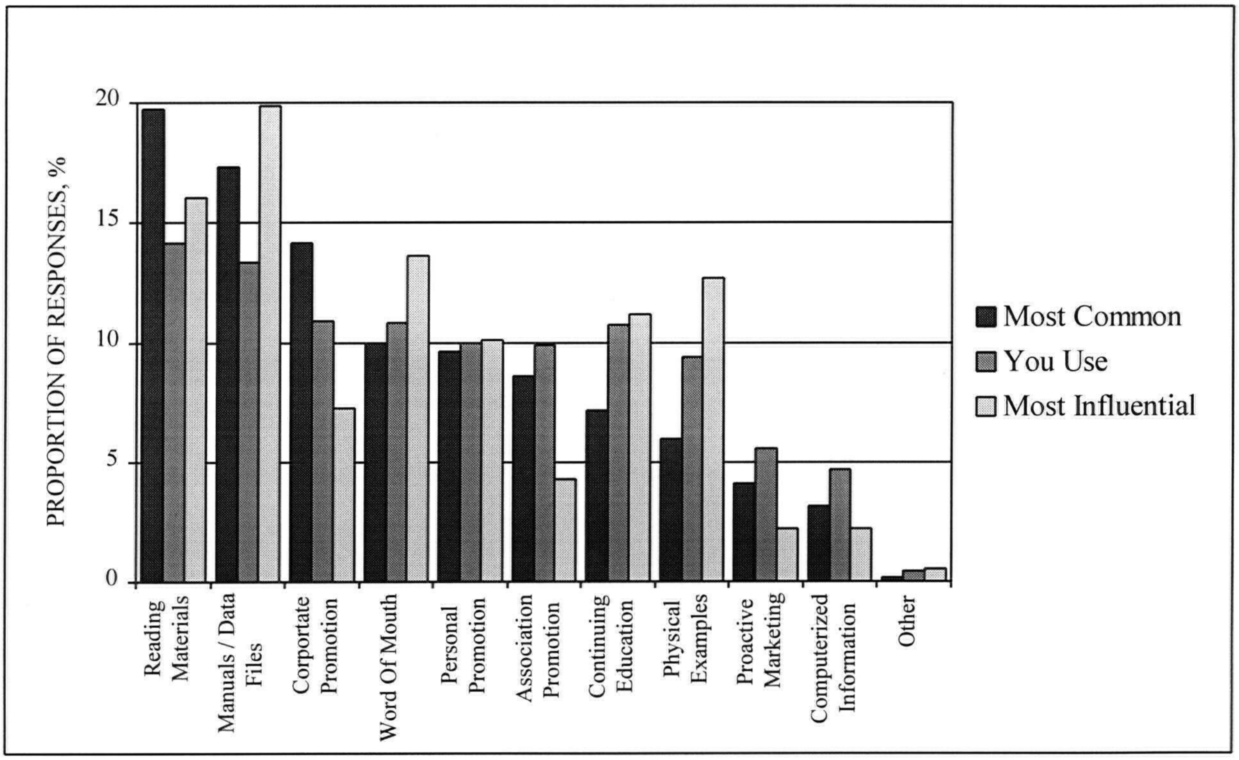

Figure 4.30: Methods of Obtaining Product Information on the Job.

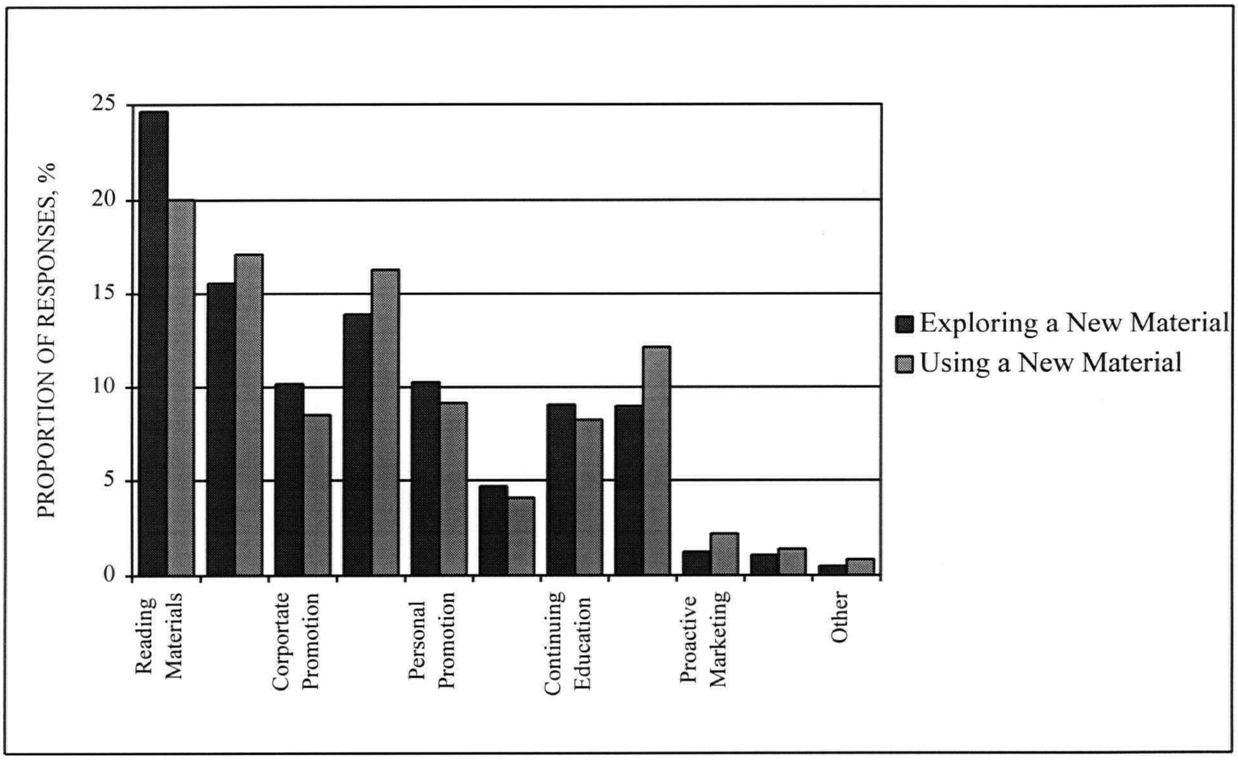

Figure 4.31: Methods of Obtaining Product Information on the Job which Resulted in Exploring/Using a New Material.

These results were again verified by asking designers which methods of obtaining product information resulted in them exploring the use of another material and actually using another material (Figure 4.31). As above, reading materials, followed by manuals / data files, and word of mouth, are the methods most commonly used in exploring and using new structural materials. Physical examples, corporate / personal promotion, and continuing education are seen as being relatively successful in terms of serving as a catalyst to the exploration and use of new materials. Finally, association promotion, proactive marketing, computerized information, and other methods are seen as being relatively unsuccessful in encouraging specifiers to explore and/or use a new structural material. It should be noted that, while most methods of obtaining product information result in more exploration than use, the inverse is true for manuals / data files, word of mouth, and physical examples (implying perhaps that these latter methods are more influential).

Next, respondents were asked whether or not they had designed a building four storeys or less using wood as the major structural component in 1993. The majority, 61.91%, said that they had and were subsequently asked to state which of the items listed in Table 4.13 would have encouraged them to change their minds and use another structural material. Conversely, the remaining 38.09% were asked to state which of the items listed would have encouraged them to change their mind and use wood. The majority of the respondents stated that they would not have used another structural material. It is interesting to note that 37.93% of the respondents would not have used wood, while, somewhat fewer, at 24.03%, said they would not have used another structural material. In other words, while wood users are somewhat amenable to the use of alternative structural materials, non-wood users feel more strongly about not using wood.

For both groups (wood and non-wood users), the remainder of the responses are apportioned approximately equally (between 0% and 8% of the responses), with no items clearly offering the greatest inducement to change. However, several interesting trends did emerge; some of which verify the results seen above. For example, physical examples, like case studies and example / demonstration buildings, scored highly (more than 10% of the responses) in both groups. Other items that scored reasonably highly include simpler codes, more technical research (especially with other materials), product seminars, lectures, and peers. Furthermore, a relatively large portion of the non-wood users state that better design tools, like manuals and software, might have encouraged them to use wood (this was true of wood users, as well, though not to the same extent). Association newsletters and advertisements, on the other hand, score very poorly (below 2% of the responses) in both groups. Trade shows, textbooks, and magazine articles (in the case of wood users) do not seem to fare well either. Apart from the other category (which included cost considerations, lack of opportunities, and specification by other parties), the remainder of the responses is fairly evenly split at between 3% and 5%.

Table 4.13: Methods of Obtaining Product Information that Encourage Designers to Use Another Material

In 1993, did you design a building 4 storeys or less that used wood as the major structural component	**Yes**	**No**
	61.91% ⇩	38.09% ⇩
If Yes (No), which of the following would have encouraged you to change your mind and use another structural material (wood)?	**Another Material (% of above)**	**Wood (% of above)**
would not have used another structural material	24.03%	37.93%
a magazine / journal article	4.16%	2.13%
simpler codes	5.39%	4.96%
better text books	2.47%	2.48%
more technical research	5.86%	3.90%
a product seminar	5.08%	4.61%
a product mailout / brochure	3.39%	3.55%
an advertisement	1.54%	0.00%
better design tools (manuals, software, etc.)	4.93%	6.74%
an association newsletter	0.92%	0.35%
a submitted design / drawing	4.01%	2.84%
a personal sales call / visit	3.85%	3.90%
a lecture / seminar	5.55%	3.55%
a peer / co-worker	5.24%	4.26%
an example / demonstration building	7.55%	6.03%
a trade show / exhibit	3.08%	1.77%
a case study	6.63%	6.74%
other	6.32%	4.26%

Learning More About Wood (Question 9):

Finally, the last part of *Section IV* asked respondents whether or not they would want to learn more about using wood in buildings four storeys or less. The majority of respondents, 66.86%, stated that they would, while 33.14% said that they would not. Respondents who said they did not want to learn more about wood use in buildings four storeys or less were asked why. These reasons are seen in Table 4.14. Almost 50% of the respondents claimed that they already use wood. Over 15% stated that wood is not used in their area. An equal split totaling slightly less than 20% said that wood is not used in their firm, wood design is not part of their job, and that they are too busy. Less than 5% simply stated that they are not interested. Finally, a variety of other reasons were also stated, including environmental impact, wood not being suitable / adequate for the buildings that they design, and a general dislike of wood.

Table 4.14: Reasons for Not Wanting to Learn More about Wood Use in Buildings 4 Storeys or Less.

already know how to use wood	49.13%
wood not used in this area	15.20%
other	11.70%
wood not used in this firm	6.43%
not part of my job	6.43%
too busy	6.43%
not interested	4.68%

Design Process and Philosophy (Section V):

Section V of the survey asked respondents about the design process and philosophy in buildings four storeys or less. Specifically, they were questioned on how the specification of structural materials is apportioned, the types of design and construction methods that they typically use, and the relative importance of a number of design considerations.

The Specification of Structural Materials (Questions 1 & 2):

The first question asked designers to state who the main specifier of structural materials in buildings four storeys or less is. The breakdown is seen in Figure 4.32. By far, most respondents (55.47%) thought that architects are the main specifiers of structural materials, followed by structural engineers (33.75%)[7]. Only a small portion of the respondents (5.04%) stated that owners / developers are the main specifiers, while clients, building contractors and other specifiers (cost consultants / estimators) together account for less than 6% of the responses.

[7] At first glance, this may not seem surprising given the 2:1 ratio of architects to structural engineers in the sample. However, the reader may be surprised to learn that 27.47% of the architects stated that structural engineers were the main specifiers of structural materials, while 32.21% of the structural engineers stated that architects were the main specifiers.

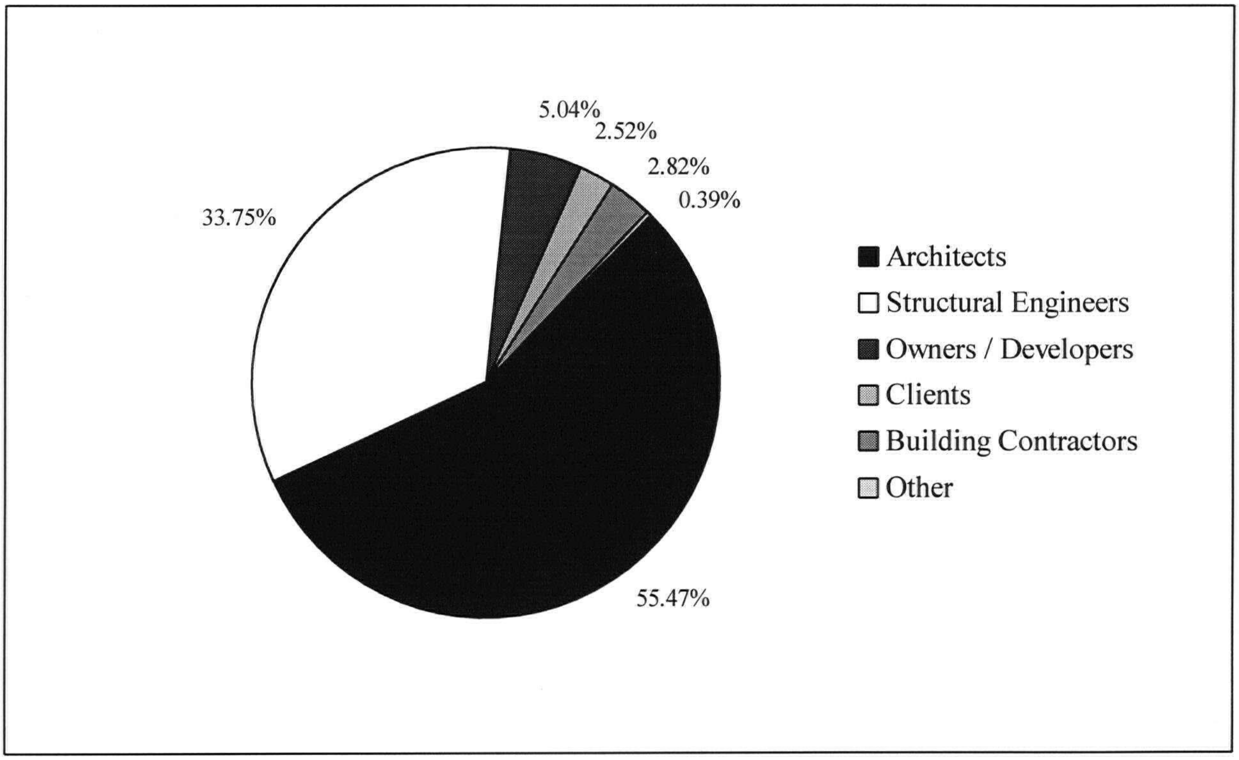

Figure 4.32: The Main Specifiers of Structural Materials (Buildings 4 Storeys or Less).

Designers were than asked if the specification of structural materials is done independently by the party that they selected. Only 21.30% said yes, while 78.70% said no. Respondents who stated that specification of structural materials is not done independently were asked to elaborate by estimating how the material selection process is apportioned (out of a score of 100). Means were computed and can be seen in Table 4.15. As well, a one-way analysis of variance was run which showed there to be significant differences between the means. Bonferroni's test revealed significant differences between the architects' and the structural engineers' apportionments. Furthermore, there were significant differences between these two groups and each of the remaining parties (excluding the other parties category, which was significantly less than the rest, the only significant difference in apportionment levels for this latter grouping occurred between owners / developers and building contractors). Thus, it can be said that, on average, 44.04% of the responsibility in specifying structural materials is the architects', while 34.44% is the structural engineers'. The roles of the remaining parties are still somewhat diminished, although, relative to the results seen in the first question, their participation in this group dynamic is seen to be more prominent. Owners /

developers, clients, and building contractors share 8.85%, 6.72%, and 5.24% of the responsibilities, respectively. Cost consultants / estimators account for the remaining 0.71%.

Thus, it can be seen that, based on these results, the main specifier of structural materials seems to be the architect, followed by the structural engineer. However, specification is, for the most part, not done independently. A more likely paradigm has the architect working with the structural engineer who acts as the primary consultant. Owners / developers, clients, and building contractors do have some input into the material selection process. However, their roles are seen as being more peripheral in nature.

Table 4.15: Apportionment of Structural Material Specification (Buildings 4 Storeys or Less).

Architects	44.04%
Structural Engineers	34.44%
Owners / Developers	8.85%
Clients	6.72%
Building Contractors	5.24%
Other	0.71%

Given this hypothesis, designers were asked to state the proportion of buildings that they have worked on in the past that have had their structural components independently specified by them. The breakdown of results can be seen in the first column of Table 4.16. The distribution of buildings individually specified by designers is multimodal. While 14.08% of the respondents never independently specify building materials for a project, 15.71% do this exclusively. Approximately half of the respondents independently specify 50% or fewer of the buildings that they have worked on in the past (with higher frequencies at 0%, between 1% and 10%, and between 41% and 50% of the buildings). The other half independently specify 50% or more of the buildings they have worked on in the past (with higher frequencies at 100% and between 71% and 90% of the buildings). The mean proportion of buildings specified independently by designers is 51.19%. Here again it can be seen that, while some buildings are independently specified, most are not. In fact, in some cases, designers never work alone in the material selection process.

Table 4.16 also includes a question on design from the *Personal Information* section. Here respondents were asked to state the proportion of their design workload that was devoted to buildings four storeys or less. Results of those respondents who completed the survey in full are seen in the second column. Most respondents (37.81%) said that all of their design workload is devoted to buildings four storeys or less. Almost 70% of the respondents said that at least 70% of their time is spent on these types of structures. Less than 25% of the respondents claimed to devote any less than 50% of their time to buildings four storeys or less. The mean proportion of a designer's workload apportioned to buildings four storeys or less is 76.11%. These results seem to indicate that this type of design is very prevalent indeed. The *Personal Information* section also collected information on whether or not respondents had been sued during the course of their professional design careers. Only 8.21% claimed that they had been.

Table 4.16: Breakdown of Respondents by Various Design Profiles.

Percentage: (Frequency Classes)	**Percentage of Buildings Specified Independently by Respondents** (Proportion of Respondents)	**Percentage of Respondents' Design Workload Devoted to Buildings 4 Storeys or Less** (Proportion of Respondents)
0%	14.08%	1.73%
1% - 10%	10.61%	7.10%
11% - 20%	7.14%	4.03%
21% - 30%	6.53%	4.03%
31% - 40%	3.47%	1.73%
41% - 50%	11.43%	5.76%
51% - 60%	3.27%	4.22%
61% - 70%	3.88%	3.07%
71% - 80%	13.88%	9.79%
81% - 90%	8.98%	13.24%
91% - 99%	1.22%	7.49%
100%	15.71%	37.81%

Design and Construction Methods (Questions 3 - 5):

Next, respondents were asked some basic questions on the design / construction process. First, they were asked whether their design philosophies were conducive to the use of wood as a structural material in buildings four storeys or less. The majority of designers, 76.33%, stated that their philosophies are conducive to wood use, with the remaining 23.67% saying no. They were also queried on the types of construction that they were most familiar with. Only 8.24% of the respondents cited post and beam construction as the method they are most familiar with, while 34.51% are more acquainted with light frame construction. The majority of respondents (57.25%), however, said that they are equally well-versed in both types of construction methods. Lastly, specifiers were asked about the design methods that they generally use for each of the structural materials (Table 4.17). Those that did not work with a specific material were asked to leave that material blank and are noted in the N/A column. For the remaining respondents, the working stress method is seen as the most common form of design for wood, steel, and masonry (ranging between 50% and 60% of the responses). Limit states design is prevalent only for concrete (at over 40% of the responses). Wood, steel, and masonry account for between 24% and 28% of the responses here. Some designers are equally familiar with both types of design, while even more are acquainted with alternative methods, such as ultimate strength, span tables, and consultation.

Table 4.17: Breakdown of Design Methods Used by Structural Material.

Structural Material:	Working Stress	Limit States	Both	Other	N/A
Wood	60.60%	24.58%	2.15%	5.49%	7.16%
Steel	57.38%	27.62%	2.62%	6.43%	5.95%
Concrete	37.62%	40.24%	1.19%	7.38%	13.57%
Masonry	50.48%	25.24%	0.95%	6.90%	16.43%

Importance of Various Considerations in Selecting Structural Materials (Question 6):

The last part of *Section V* asked respondents to rate the importance of a wide variety of considerations affecting the selection of structural materials in buildings four storeys or less. Designers were given a number of factors to rate in the following fashion: *1, not at all important; 2, somewhat important; 3, important; 4, very important; and 5, extremely important.* For each consideration, a mean was computed to obtain an importance weighting. Considerations, and their respective response breakdowns, were then listed in Figure 4.33 in order of importance. It can be seen that, in terms of importance, there is very little differentiation between factors affecting the selection of structural materials in buildings four storeys or less. In most cases, approximately 90% of the respondents stated that the factor in question was, in the least, important.

Designers considered the following factors (in order of importance weighting) to be the *most important* in terms of the material specification process (with approximately 90% of the respondents stating that the considerations are, at least, important, and over 60% of the respondents stating that they are very or extremely important):

- architectural considerations (light, space, sound, function, etc.);

- the cost of installing the material;
- whether or not the product has a proven record;
- material strength;
- material longevity;
- the fire performance of the material;
- preference of the architect; and
- preference of the structural engineer;

Designers considered the following factors (in order of importance weighting) to be of lesser importance than above, although still *very important* in terms of the material specification process (with approximately 90% of the respondents stating that the considerations are, at least, important, and between 40% and 60% of the respondents stating that they are very or extremely important):

- material costs;
- material consistency / quality;
- design considerations (simplicity of design, understandability of codes, amount of time required, etc.);
- the building occupancy;
- the ease of installing the material;
- the appearance of the material;
- preference of the owner / developer;
- material value;
- the consistency of material supply; and
- material adaptability;

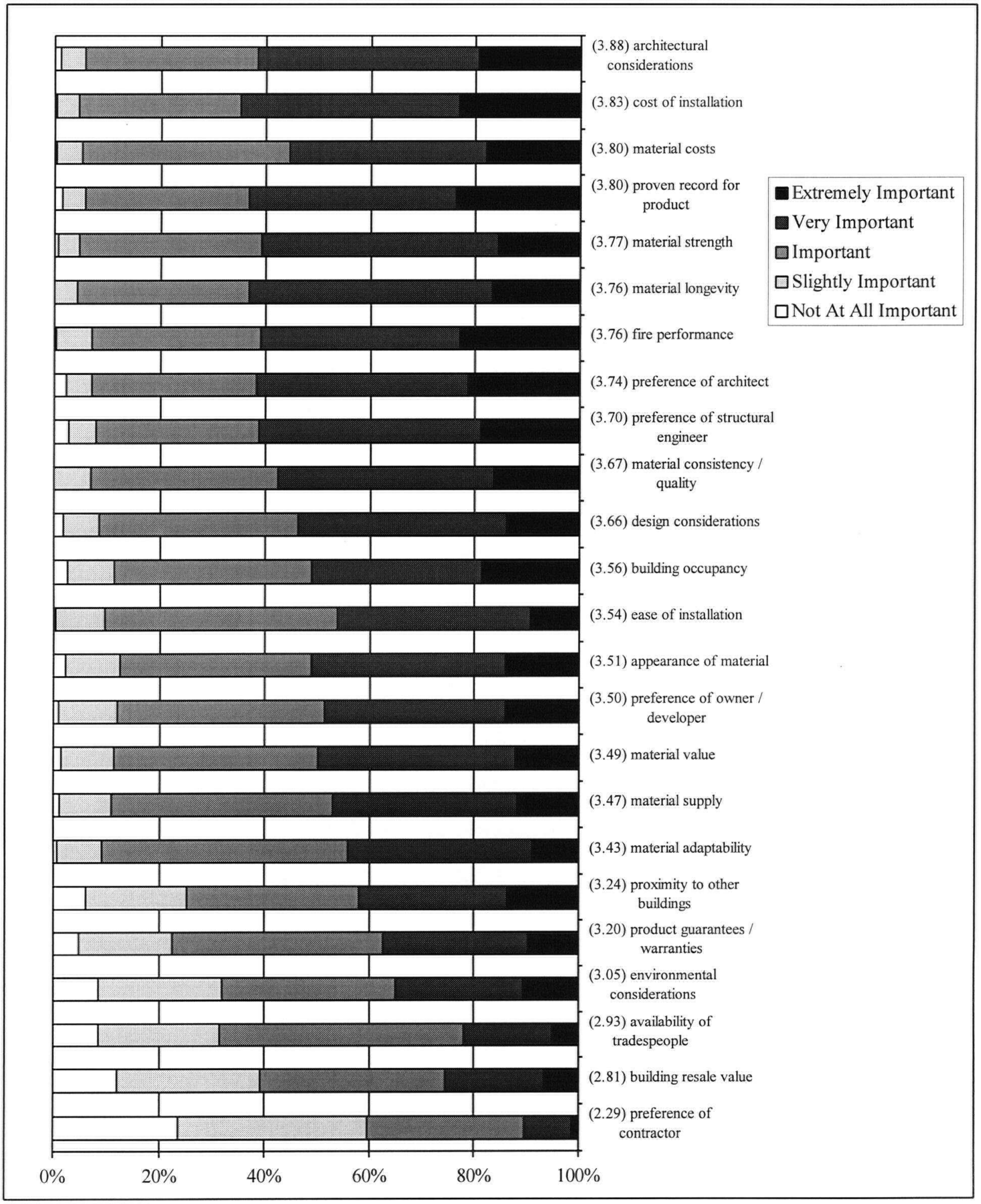

Figure 4.33: Importance of Design Considerations when Specifying Structural Materials (4 Storeys or Less).

In terms of material selection, proximity to other buildings and product guarantees / warranties are seen as being *moderately important*, with close to 80% of the respondents stating that these considerations are, in the least, important, and approximately 40% stating that they are either very or extremely important. Applying the same logic, it can be seen that environmental considerations, availability of tradespeople, and, to a lesser degree, building resale value, are even more inconsequential, although still *somewhat important*. Finally, preference of the contractor is seen by the majority of respondents as being relatively *unimportant* to the material specification process.

Environmental Issues (Section VI):

From the previous section, it can be seen that environmental considerations are considered somewhat important to the specification of structural materials in buildings four storeys or less. In fact, almost 70% of the respondents said that environmental issues are important (with approximately 35% saying that they were either very or extremely important, and less than 10% saying that they were unimportant). That said, *Section VI* of the survey dealt with issues of the environment. Specifically, questions common to a *Life Cycle Analysis* approach, whereby the environmental impact of each phase in a building's life is examined and quantified separately, were asked. For each structural material, questions pertaining to resource extraction, manufacturing, building installation, recylcability, energy efficiency, and active building service life, were asked in an attempt to better understand how environmental impact affects the material selection process.

Environmental Harm Ratings of Structural Materials (Question 1):

The first part of *Section VI* asked designers to rate wood, steel, concrete, and masonry on a number of environmental dimensions according to how harmful they felt the materials were to the environment. Restated, they were asked how they thought the various structural materials impacted on the global environment in terms of extracting and refining the raw resource, the manufacturing process, transporting the structural material, installing the building, and energy emissions from the building. A four point underlying metric scale was used to measure perceived harm to the environment for every structural material as follows: *1, completely harmless; 2, harmless; 3, harmful;* and *4, very harmful*. Respondents also had the determinant choice of stating that they had *never thought about the issue*.

Those that had never thought about the issues were tallied and their answers were excluded so as not to skew the averages. Means for the remaining answers were then computed for each structural material. A one-way analysis of variance ($\alpha = 0.05$) between structural materials was performed for each environmental dimension to see if there were any significant differences in means. When there were, Bonferroni's multiple comparison method was employed to determine which of the structural materials differed from one another. The results can be seen in Figure 4.34. Environmental dimensions are listed in order of perceived harm to the environment (from most harmful to least harmful). In other words, aggregate averages (ignoring structural materials) decrease as one moves down the plot. The same is true for the structural materials within each of the environmental dimensions. The materials that are perceived to be the most harmful are listed above all others. Shading has been used to indicate significant differences between structural materials. Like shaded materials occurring together (either black or white) mean that there were no significant differences between those materials on the environmental dimension in question. When shading differs between two consecutively listed materials (black versus white), there were significant differences noted (e.g., in *extracting the raw resource*, steel and wood are not significantly different, but wood and concrete are; in *refining the raw resource*, each material is significantly different, while in *transporting the building material*, no significant differences were observed). The moderate gray shading represents an overlap between materials. In other words, these structural materials were not statistically different from both the black and white shaded materials above and below (which were still significantly different), but rather fell somewhere in between (e.g., in *installing the building*, steel is not significantly different from either concrete or masonry, yet concrete and masonry are significantly different from each other). Each of the environmental dimensions are discussed in turn in order of perceived environmental harm.

- *Extracting the Raw Resource:* There appears to be no significant difference between steel and wood. Specifiers perceive their impact on the environment to be equally harmful. Concrete and masonry are thought of in more neutral terms (neither harmful or harmless, on average).

- *Refining the Raw Resource:* There are significant differences between each of the building materials. Steel is, by far, considered the most harmful, while concrete, masonry, and wood are each considered less and less harmful. On average, concrete is thought of as being somewhat harmful while masonry is more neutral. Wood, being somewhat harmless, was the least harmful structural material.

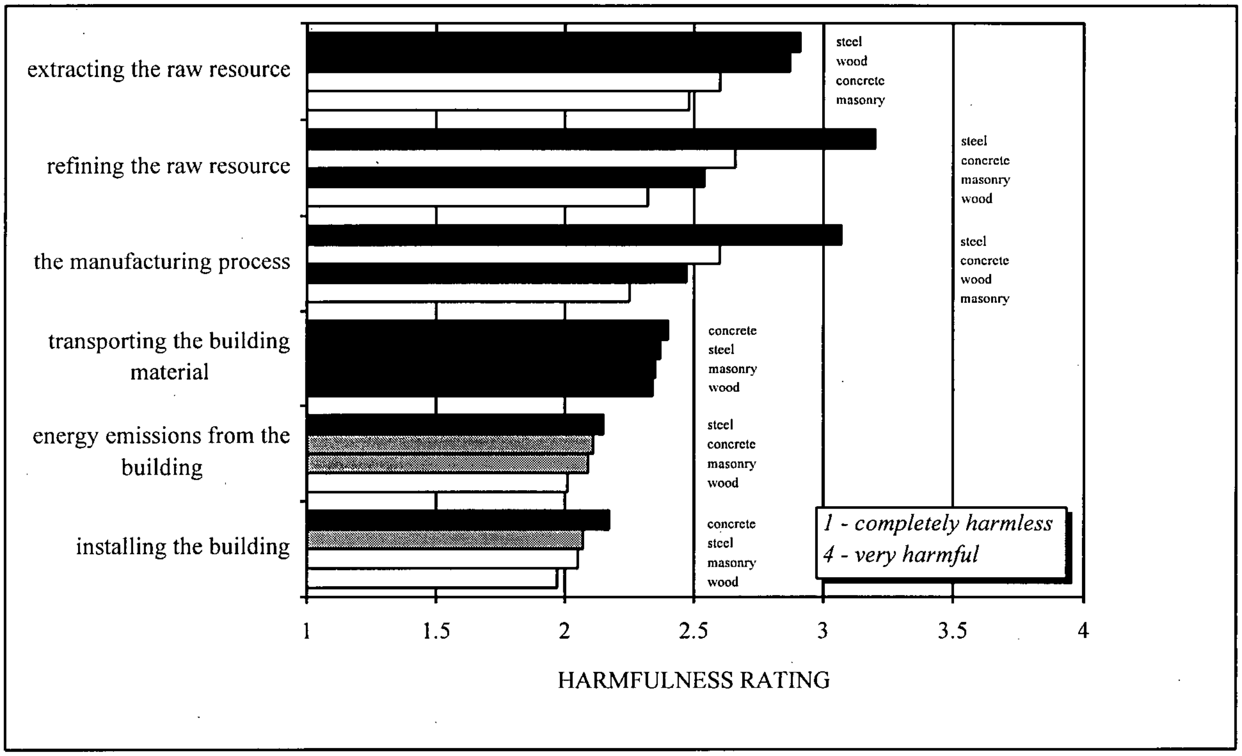

Figure 4.34: Perceived Impact of Structural Material Use on the Environment.

- *The Manufacturing Process:* Results obtained here are nearly identical to those obtained from *Refining the Raw Resource*, although manufacturing was considered slightly less harmful than refining in each case. Again, wood is thought of as being relatively environmentally benign while steel is perceived to be the most unfriendly material.

- *Transporting the Building Material:* There were no significant differences between the building materials. Specifiers perceive the impact of each material as being the same (somewhat harmless, on average).

- *Energy Emissions from the Building:* Although there were significant differences between materials (steel, concrete, and masonry in one grouping and concrete, masonry, and wood in the other, slightly less harmful grouping), each of the materials is viewed as harmless, on average. Despite the overlap in structural materials, it can be seen that steel is perceived to be more harmful than wood.

- *Installing the Building:* There were no significant difference between concrete and steel in one grouping, and between steel, masonry, and wood in another, slightly less harmful, grouping. Again, each of the materials is thought of as harmless, although concrete is considered more harmful than wood.

A substantial number of designers had never thought about these issues. These proportions can be seen in Table 4.18 for each building material on every environmental dimension. It is interesting to note that the proportion of specifiers who had never thought about these environmental issues is relatively constant, varying between 6% and 11% in most cases. The exception to this is in the *Energy Emissions from the Building* category. Here, a much larger proportion, 27% to 28% of all designers, had never thought about this issue and how it may vary according to which structural material is used. Equally interesting is the fact that, with one minor exception, wood has the smallest proportion of specifiers who had never thought about these issues. That is, wood and its relation to the environment is thought about more often than any of the other materials (especially masonry).

Table 4.18: Proportion of Designers that Have Never Thought of Structural Materials Impacting the Environment.

	Wood	Steel	Concrete	Masonry
Extracting the Raw Resource:	6.50%	9.00%	9.96%	10.43%
Refining the Raw Resource:	7.72%	7.93%	8.96%	10.22%
The Manufacturing Process:	7.99%	7.35%	8.87%	10.08%
Transporting the Building Material:	9.80%	10.00%	10.18%	10.00%
Energy Emissions from the Building:	27.70%	28.08%	27.71%	27.21%
Installing the Building:	10.22%	10.41%	10.22%	10.45%

Environmental Efficiency of Structural Materials (Question 2):

Next, respondents were asked to rank the efficiency of steel, concrete, wood, and masonry on two environmental dimensions: recycling of the material and energy use of buildings made from the material. A score of *4* was given to the *most efficient material*, while a score of *1* was given to the *least efficient material*. For each dimension, means were computed to obtain average rankings for each material and plotted in Figure 4.35. A one-way analysis of variance ($\alpha = 0.05$) and Bonferroni's test were again applied to see which, if any, of the materials differed. In each case, all of the structural materials differed.

In terms of recycling the material, steel is, by far, the most efficient material. This is followed by wood, masonry, and, lastly, concrete. The average rankings show that steel it is generally thought of as efficient when it comes to recycling, while masonry and concrete are not. Wood falls somewhere in between this continuum.

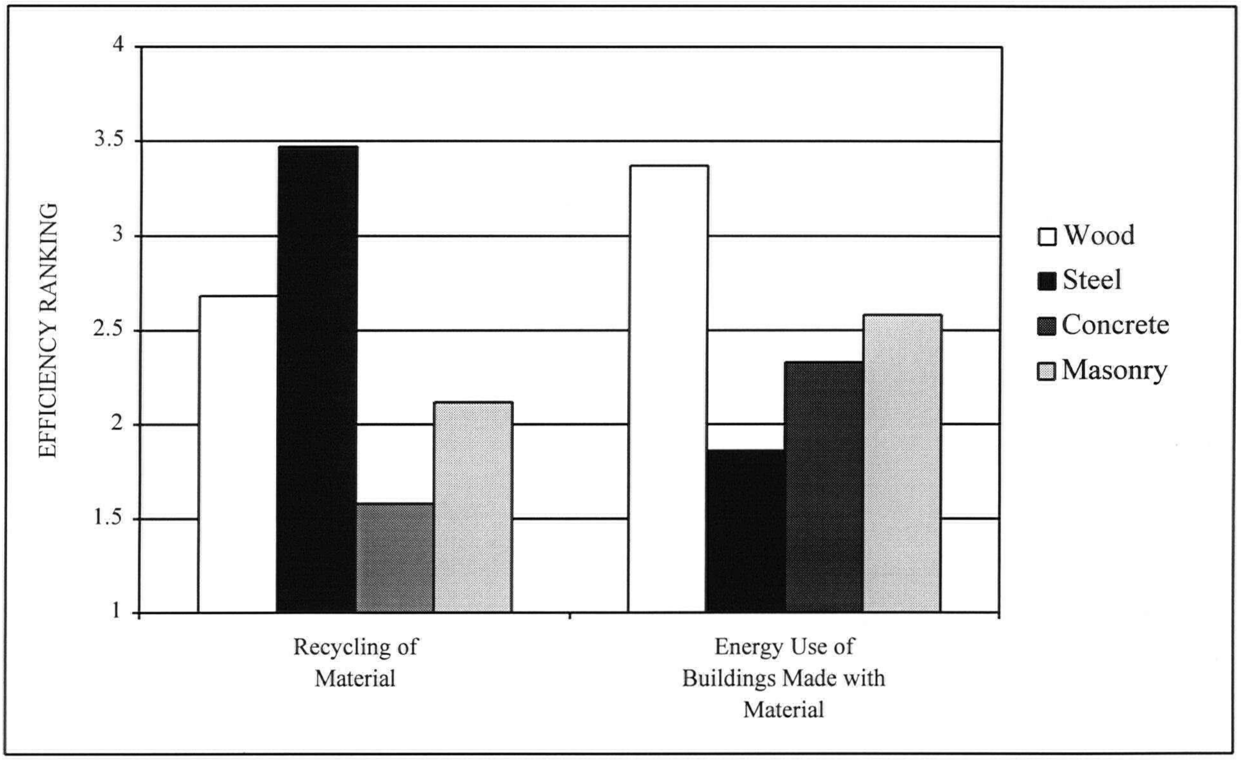

Figure 4.35: Perceived Environmental Efficiency of Structural Materials.

In terms of energy use of buildings made from each of the materials, specifiers felt that wood is, by far, the most efficient material. This is followed by masonry, concrete, and, lastly, steel. Buildings made of wood are generally thought of as energy-efficient, while steel buildings are not. Masonry and concrete buildings lie somewhere in between.

Active Service Lives of Structural Materials (Question 4):

Designers were also asked what they believe the active service lives of buildings four storeys or less to be when made of concrete, masonry, steel, and wood. Means were computed and plotted in Figure 4.36, while differences in means were tested with a one-way analysis of variance ($\alpha = 0.05$) and Bonferroni's test.

No significant differences were found in buildings made of steel, masonry, and concrete. All were expected to be in service for 80 to 90 years, on average. Wood, on the other hand, scored substantially lower at approximately 52 years and was the only material to significantly differ from the others.

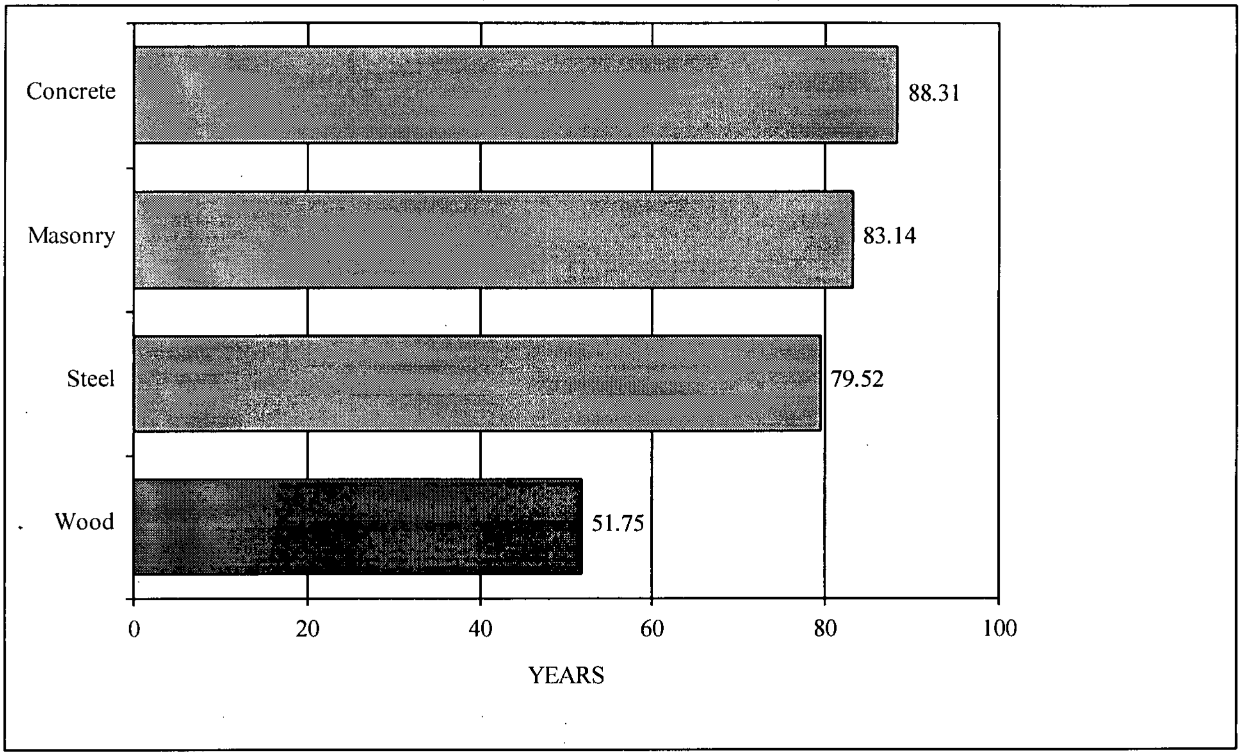

Figure 4.36: Expected Active Service Life of Buildings 4 Storeys or Less (by Structural Material).

Perceived Environmental Friendliness of Structural Materials (Questions 3 & 5):

Next, respondents were asked to rank steel, concrete, wood, and masonry according to how "green" or "environmentally friendly" they felt each was. A score of *4* was given to the material which ranked the highest, while those that ranked the lowest were given a score of *1*. As well, two of the earlier questions (on environmental impact and environmental efficiency) were aggregated to form an overall measure of environmental friendliness using the same scale. Means for each material were computed for both the ranking and the overall measure and are plotted in Figure 4.37. A one-way analysis of variance ($\alpha = 0.05$) and Bonferroni's test were again conducted to determine whether or not the means significantly differed.

The ranking shows wood and masonry to be the most environmentally friendly materials (there is no significant difference between the two). Concrete is less environmentally friendly, while steel is considered the most environmentally unfriendly material (the latter two materials were significantly different from all others). All four of the structural materials are significantly different using the overall measure of greenness. Wood is the most environmentally friendly material, followed by masonry, steel, and, lastly, concrete. It should also be noted that these findings are in complete agreement with the environmental ratings seen in Table 4.9 (this, coupled with the

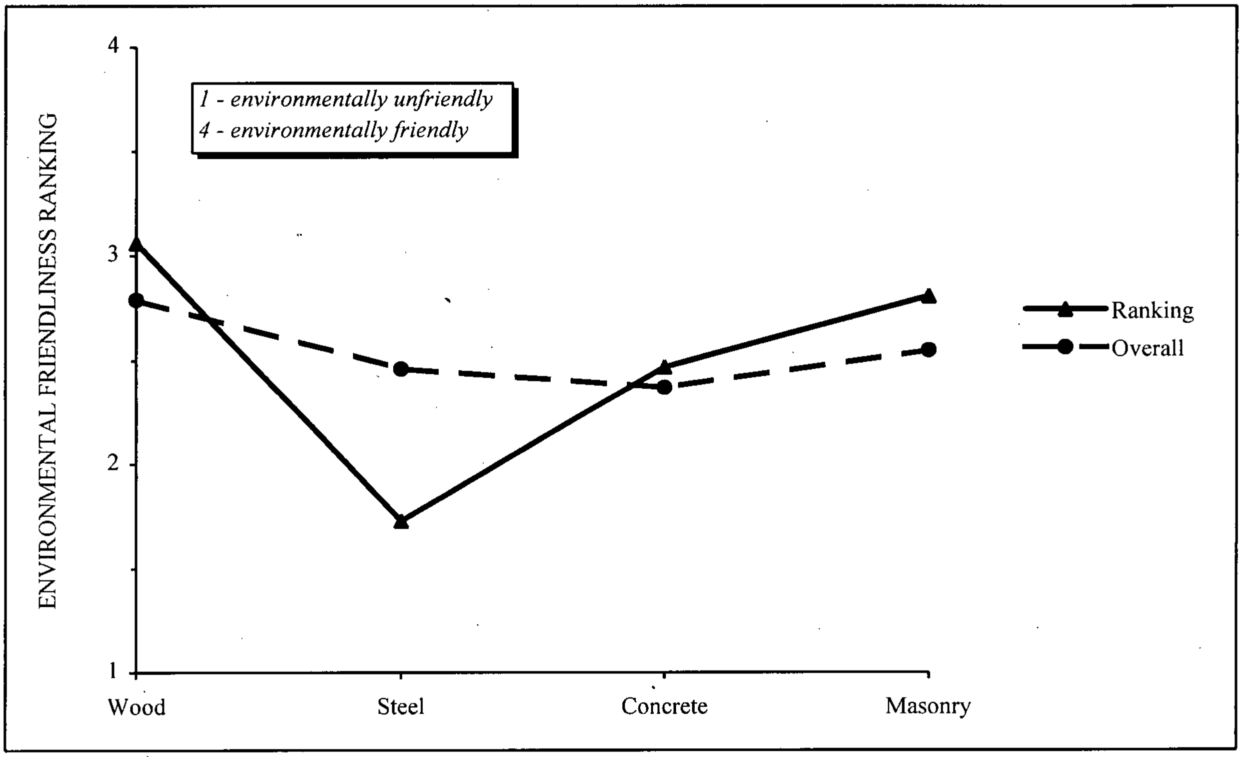

Figure 4.37: Perceived Environmental Friendliness of Structural Materials.

relative agreement seen in Figure 4.37, is again indicative of the reliability and validity of the survey instrument). Here, most materials rate reasonably well, with the exception of steel which is on the environmentally unfriendly side of the spectrum.

In each case, wood scores, or was in the group that scores, highest on the environmental friendliness scale. This is despite low scores for *service life* and *extracting the raw resource*. However, on every other dimension, wood performs moderately to very well. Masonry also scores highly, though it does not fare as well as wood. It performs moderately to very well on every dimension, except *recycling*. Depending on the test, concrete either places as the first or second most unfriendly material. Its scores are moderate on every environmental dimension except *recycling*, where it performs extremely poorly and *service life*, where its scores are very high. Steel is seen as the most environmentally unfriendly material based on its comparatively low ranking average and close second in the overall category. Although it scores well on *recycling*, this is far outweighed by its extremely poor performances on *extracting the raw resource*, *refining the raw resource*, *the manufacturing process*, and *energy use of buildings*. On all other dimensions, it scores moderately.

Finally, *Section VI* ended by giving architects and structural engineers the opportunity to voice their opinions on the environment in an open-ended question. While no analysis of these comments was undertaken, one very clear trend emerged: those specifiers who think of wood as an environmentally harmful alternative are also the most vociferous and outspoken in their views. This suggests that the most vocal are often misrepresented as the majority.

CHAPTER 5

RESULTS II - SEGMENTATION MODELS

In a data set this large and varied, it is often advantageous to divide the observations into logical groupings or segments. Information presented in this manner can be used to facilitate the development and implementation of marketing plans aimed specifically at those groups that are accessible and utilitarian. To this end, various segmentation models have been attempted. The first two models segmented the population on two of the more apparent dimensions: geography (place of residence) and professional orientation (architects vs. structural engineers). Here, univariate statistics were extensively utilized to ascertain what, if any, differences existed between groups. In the third model, both the population and miscellaneous variables were segmented by means of three multivariate statistical techniques: factor analysis (using principal components), cluster analysis (K-means), and multiple discriminant analysis. In each case, vast amounts of data were reduced and/or classified in an attempt to uncover underlying trends that could emerge as accessible segments. Information obtained by each of these segmentation models may be incorporated into various marketing strategies designed to increase the appropriate use of wood in the nonresidential sector.

Geographical Segmentation:

In most surveys, the logical first step in dividing a population into groups that are utilitarian and accessible is with a geographical segmentation model. Given that a stratified sampling scheme was used to collect information from respondents in this study, this is precisely the direction that was taken. However, due to the massive amounts of information obtained in the survey, the geographical segmentation was performed on a few key variables only. For the most part, this meant limiting the analysis to the use of wood products in each region. However, wherever pertinent, the use of other structural materials was also included.

That said, the distribution of sample units by geographical stratum (in this case, census region) can be seen in Table 5.1. Unfortunately, some of the strata were poorly represented, especially in Canada where sampling was not as concentrated as it was in the United States. Here, per stratum sample sizes were too small to estimate strata parameters with acceptable levels of precision. As a result, the twenty-one census regions were collapsed to form seven, broader geographical regions (as seen in Table 5.1). It should be noted that every attempt was made to collapse these regions into logical groupings; each with a sufficient sample size to ensure acceptable precision levels. In the United States, this meant simply incorporating the four geographical regions prescribed by the *Bureau of Census*: West, Midwest, South, and Northeast. In Canada, no such customary geographical delineations exist. Rather, census regions were collapsed, subject to the above stated objectives, as follows: West / North, Central, and East / Maritimes. Geographical segmentation models for a few key variables are discussed in turn for each of these collapsed regions.

Table 5.1: Distribution of Sample Units by Geographical Stratum and Collapsed Region.

Geographical Stratum:	Sample Size	Collapsed Geographical Region:	Collapsed Sample Size
United States:	**396**		
Pacific Mountain	86 25	West United States	111
West North Central East North Central	29 69	Midwest United States	98
West South Central East South Central South Atlantic	28 19 56	South United States	103
New England Middle Atlantic	30 54	Northeast United States	84
Canada:	**150**		
British Columbia Alberta Yukon Northwest Territories	24 27 1 4	West / North Canada	56
Saskatchewan Manitoba Ontario	6 4 50	Central Canada	60
Quebec Newfoundland Nova Scotia Prince Edward Island New Brunswick	26 2 5 0 1	Eastern / Maritimes Canada	34
Total	**546**		

Structural Material Use:

Question 4 in *Section I* of the survey asked respondents to state the proportion of buildings (four storeys or less) that they have designed in the past and that have used wood, steel, concrete, masonry, another material, or a combination as the main structural components. The average number of buildings that they designed in 1993 using these materials was also obtained. Regional means were computed and the breakdown is seen in Table 5.2 with (past) proportions seen first and actual quantities (1993) seen in parentheses. Based on past use levels, a visual representation of the market shares for each structural material across North America is seen in Figure 5.1. It should be noted that, in both cases, the other category was excluded because values obtained here were negligible.

For the most part, the market share for wood products appears to be substantive, never falling below 20%. The lowest shares for wood use occur in the Midwestern and Southern regions of the United States. Steel use is high in both of these regions, doubling masonry use, which is highest in the Midwest. The shares for concrete are more modest in these regions, while the use of materials in combination is popular in the Southern region (note that steel and masonry are used in combination most frequently, followed by wood and concrete).

At approximately half of the share, wood use is seen to be extremely high in both Western United States and Western / Northern Canada. This comes primarily at the expense of steel, which drops to its lowest level in both cases. Furthermore, the use of concrete and masonry is very low in these regions, while material combinations fare only somewhat better.

Although the use of wood products is reasonably high in Northeastern United States and Eastern / Maritimes Canada, steel captures approximately equivalent shares of the market here. In both regions, materials used in combination account for modest proportions of the share. In Northeastern United States, concrete use is extremely low, while masonry use is moderate. The opposite is true in Eastern / Maritimes Canada where concrete use is highest and masonry use is extremely low. A similar market situation is seen in Central Canada, although some differences do exist. For instance, although wood products use is not low, it is certainly more modest. Here, the use of steel is only slightly higher than that of wood, with the remainder of the share being fairly evenly split between masonry, concrete, and material combinations.

For the most part, the numbers of buildings designed per specifier in 1993 (seen in parentheses) seem to be consistent with the proportion of buildings designed in the past and the various trends seen above. It is interesting

Table 5.2: Proportion of Structural Material Use in the Past by Region (Buildings 4 Storeys or Less).

Region:	Wood	Steel	Concrete	Masonry	Combination
West United States	46.76% (9.66)	19.49% (3.63)	10.10% (1.69)	11.68% (3.20)	11.41% (0.82)
Midwest United States	22.39% (8.96)	35.32% (4.08)	12.68% (2.00)	16.68% (2.11)	12.93% (1.17)
South United States	22.18% (3.40)	33.05% (2.79)	14.80% (1.34)	12.76% (1.83)	17.16% (1.18)
Northeast United States	34.54% (9.51)	35.25% (3.00)	7.31% (0.37)	13.38% (1.28)	8.25% (1.28)
West / North Canada	51.98% (17.90)	18.15% (4.28)	11.19% (1.48)	6.36% (1.45)	12.32% (1.35)
Central Canada	26.54% (15.47)	27.78% (4.24)	15.22% (2.33)	13.08% (1.69)	17.37% (1.80)
Eastern / Maritimes Canada	35.88% (10.52)	35.36% (5.56)	16.61% (2.11)	3.67% (0.52)	8.33% (4.22)

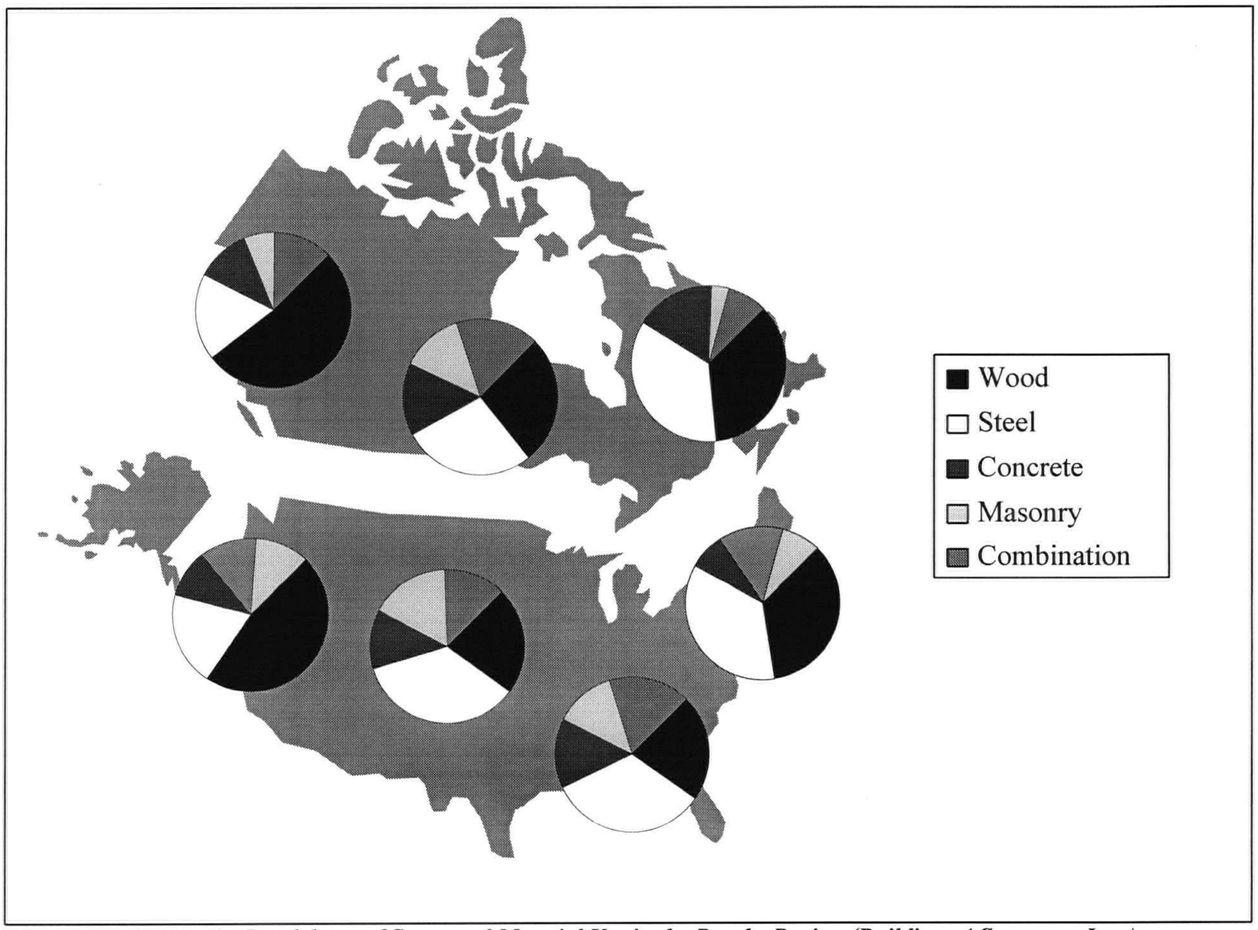

Figure 5.1: Breakdown of Structural Material Use in the Past by Region (Buildings 4 Storeys or Less).

to note that the number of buildings designed with wood is substantially higher than for any other material. Steel buildings are the second most popular structures across all regions, though design activity here is substantially less than with wood. These are followed by buildings designed with concrete, masonry, and material combinations, where few discernible differences in use levels are seen. Also interesting is the fact that the number of wood and steel buildings per designer seems to be higher in Canada than in the United States. These results seem to indicate that many, smaller structures are being built out of wood while fewer, larger structures are being built out of alternate materials. Furthermore, smaller-scale structures are more common in Canada than in the United States. Finally, it should be noted that these quantities are likely more accurate than the proportions seen above due to the fact that they represent more recent estimates of material use. This tendency to less accurately assess past levels of design activity may account for some of the inconsistencies seen in the data.

Structural Material Knowledge / Experience:

Question 3 in *Section II* of the survey asked respondents to state how knowledgeable and experienced they were with building materials / systems, including wood, steel, concrete, and masonry. A four-point underlying metric scale was used to measure familiarity levels on a per product basis, as follows: *1, not at all knowledgeable / experienced; 2, not very knowledgeable / experienced; 3, somewhat knowledgeable / experienced;* and *4, very knowledgeable / experienced.* In an attempt to reduce the number of variables in this analysis, individual product groups were not considered here. Rather, this information was aggregated and grand averages of knowledge / experience were computed for each respondent on two dimensions: wood products and other products / systems. Regional means were then obtained and are seen plotted in Figure 5.1.

The first notable trend is that knowledge and experience levels are closely correlated for both product groups. With the exception of other products in East / Maritimes Canada, experience levels are invariably (although only slightly) lower than knowledge levels, which is to be expected. Furthermore, in the case of wood products, the gap between knowledge and experience seems to widen in regions where familiarity is lowest. Also of note is the fact that, in every region, familiarity levels for wood products are lower than those of alternate materials. Scores for wood products consistently fall at or below the level of *somewhat knowledgeable / experienced*, while scores for other products consistently fall at or above this same rating.

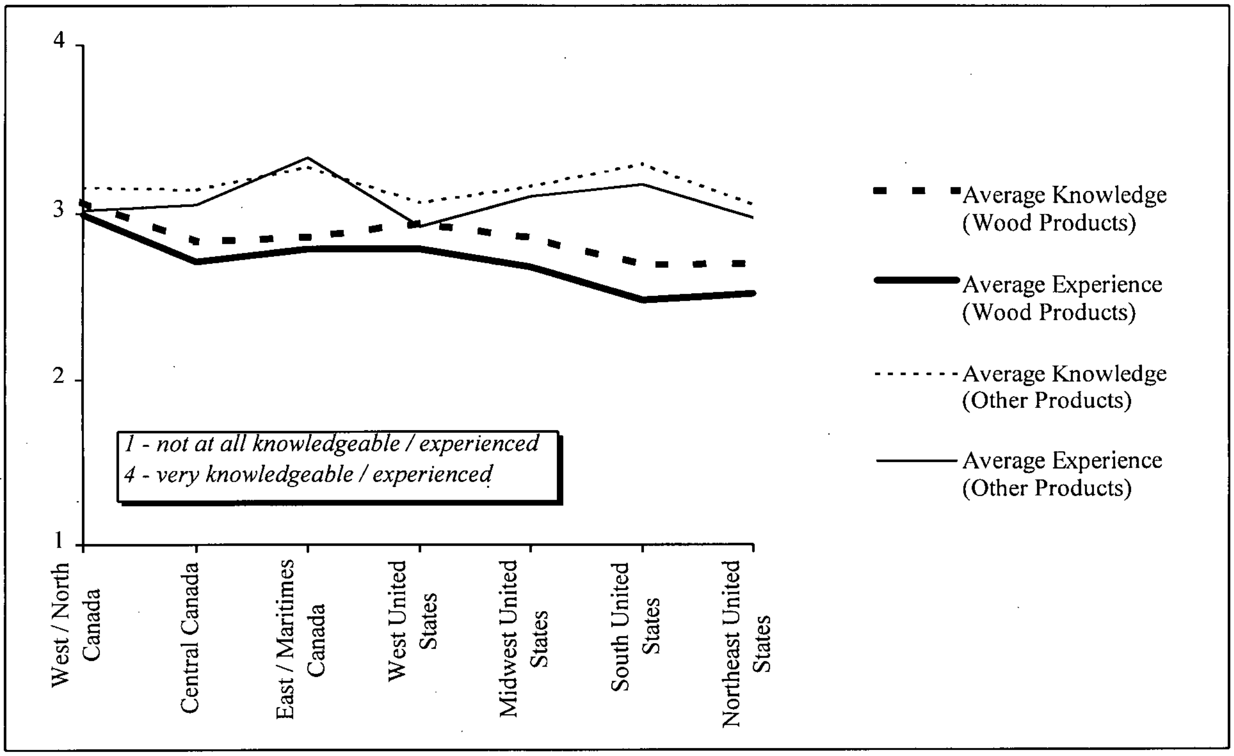

Figure 5.2: Average Knowledge/Experience of Wood and Other Products by Region.

Knowledge / experience levels for wood products are highest in Western / Northern Canada. In fact, they are comparable to, although slightly less than, the ratings for other products. Relatively high scores for wood products are also seen in Western United States and Eastern / Maritimes Canada. However, one major difference exists between these two regions. Where familiarity levels for other products are lowest in Western United States, they are decidedly high in Eastern / Maritimes Canada. Conversely, familiarity scores in Central Canada and Midwestern United States are very similar for both product groups. In each case, scores are seen to be intermediate (moderately low for wood products and moderately high for other products). Knowledge / experience levels for wood products are lowest in the Southern and Northeastern United States regions. Here, familiarity of other products is relatively high, especially in the South, where scores are second only to Eastern / Maritimes Canada.

Wood Use:

In *Section III* of the survey, *Question 5* asked respondents to state how favourable they were to the use of wood products in various applications (by end use, building height, and building area). Here, a five-point underlying metric scale was used to measure favourability to wood use for each specific application, as follows: *1, not at all favourable; 2, not favourable; 3, neutral; 4, favourable;* and *5, very favourable.* In the same section, *Question 9* asked respondents how likely they were to use wood products in the various components of buildings four storeys or less (roof, floor, and wall systems, interior partitions, exterior cladding, and interior trim / detail). Here, a four-point underlying metric scale was used to measure likelihood of wood use for each specific building component, as follows: *1, not at all likely; 2, not very likely; 3, likely;* and *4, very likely.* To reduce the number of variables in this analysis, grand averages of favourability to, and likelihood of, wood use were computed for every respondent. Regional means were then calculated in each case and can be seen plotted in Figure 5.2. Because of the use of two unlike scales, values cannot be directly compared (i.e., favourability being higher than likelihood). However, several interesting trends can still be noted.

In most cases, the two measurement criteria seem to be closely correlated. The exception is in Central Canada (and, to a lesser degree, Eastern / Maritimes Canada), where favourability to wood use is high, but likelihood of wood use is low. However, in every other region, likelihood and favourability ratings seem to follow one another closely.

Favourability ratings exist at a level slightly above the *neutral (3)* point in all regions. They are somewhat higher in Canada than they are in the United States. In Canada, favourability to wood use is highest in the anomalous Central

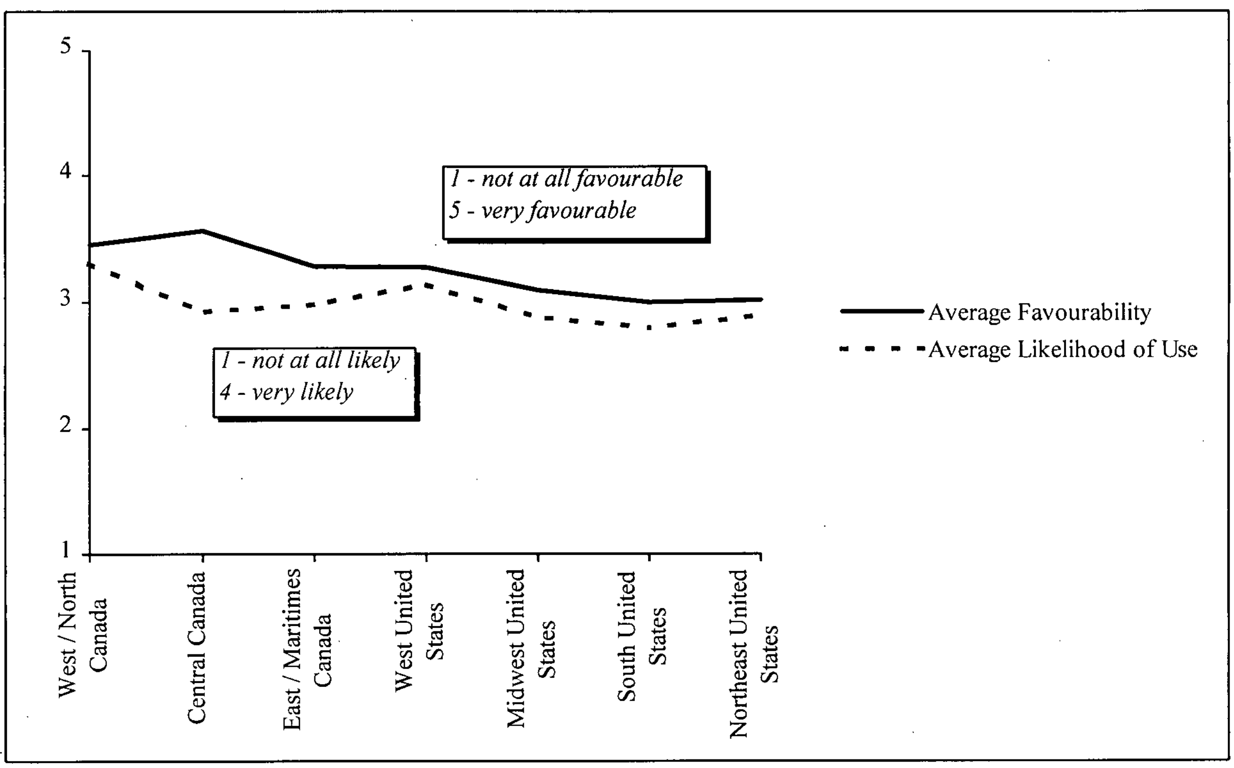

Figure 5.3: Average Favourability to/Likelihood of Wood Use by Region.

region, followed by the Western / Northern region and, lastly, the Eastern / Maritimes region. In the United States, favourability is highest in the West (although no greater than Eastern / Maritimes Canada). Slight decreases are seen as one moves eastward towards the Midwest and, lastly, to the Northeastern and Southern regions (which are approximately equal).

Likelihood ratings exist at a level slightly above or below the *likely (3)* category. Wood is most likely to be used in Western / Northern Canada and Western United States. Likelihood of use drops as one moves eastward across the continent to the Canadian Eastern / Maritimes region and the American Midwestern and Northeastern regions. Wood is least likely to be used in Central Canada and the Southern United States. That said, it should be noted that, apart from the West, per region likelihood ratings hardly deviate at all from one another (at a level slightly below *likely(3)*).

Product Attributes of Wood:

Question 1 in *Section II* of the survey asked respondents to rate wood, steel, concrete, and masonry on a number of qualitative dimensions. Several positive statements were made and respondents were asked to state which of the materials best and least fulfilled the quality described. Materials which *best fulfilled the quality described* where given a score of *1*, while those which *least fulfilled the quality described* where given a score of *-1*. The remaining materials were considered neutral and were given a score of *0*. Regional means for wood were computed and can be seen in Table 5.3. This table is closely based on the material attributes summary seen in Table 4.9. In both cases, qualitative statements are ordered such that, as one moves down the list, there is, on average, less and less agreement in the case of wood products. This has resulted in a continuum being devised, whereby positive numbers represent agreement and negative numbers (in parentheses) represent disagreement. Moreover, as means approach the two polar extremes (*1, -1*), the level of agreement / disagreement increases in magnitude. In effect, a regional attributes grid has been set up for wood products. Not only are perceived strengths and weaknesses of wood seen on a regional basis, but the extent to which these present potential problems and/or solutions is also determined.

Many conclusions can be drawn from a data set this large. The number of regional and qualitative comparisons is virtually endless[8]. As such, only the highlights are presented here. For instance, there is a substantial amount of

[8] Readers interested in devising and implementing marketing strategies for specific regions should use this data to perform more detailed inter-regional analyses.

Table 5.3: Wood's Fulfillment of Quality Described by Region (Regional Attributes Grid).

	West U.S.	Midwest U.S.	South U.S.	Northeast U.S.	West / North Canada	Central Canada	East / Maritimes Canada
material is warm and inviting	.94	.91	.92	.94	.98	1.00	1.00
material is simple to install	.81	.85	.80	.72	.84	.70	.77
material is attractive in appearance	.75	.67	.81	.77	.76	.86	.90
material is inexpensive to install	.83	.72	.76	.75	.74	.75	.74
tradespeople are readily available	.80	.64	.58	.72	.91	.65	.71
building costs are low	.61	.54	.54	.65	.81	.65	.77
material is adaptable	.66	.59	.53	.59	.63	.57	.74
material is simple to design with	.66	.64	.58	.60	.66	.49	.55
material is easy to obtain	.53	.61	.53	.67	.60	.49	.70
material is readily available	.55	.55	.42	.64	.57	.55	.68
material is inexpensive	.50	.45	.47	.45	.53	.47	.53
material has good value for the money	.46	.35	.31	.37	.60	.42	.71
material is competitively priced	.43	.20	.30	.45	.55	.36	.50
building codes are easy to understand	.53	.29	.15	.19	.42	.28	.10
material is environmentally friendly	(.07)	.24	.28	.29	.51	.63	.50
material is safe	.19	.01	.19	.12	.27	.18	.22
fire codes are easy to understand	.09	0.00	(.02)	.01	0.00	.06	.04
supply of material is consistent	(.07)	(.07)	(.08)	.09	.11	.21	.17
material is strong	(.11)	(.27)	(.03)	(.04)	.18	.02	.37
material is easy to maintain	(.42)	(.33)	(.42)	(.19)	(.29)	(.06)	.17
material is durable	(.48)	(.44)	(.39)	(.23)	(.04)	(.16)	.03
material is uniform	(.51)	(.28)	(.40)	(.33)	(.09)	(.14)	(.18)
material is long-lasting	(.52)	(.36)	(.45)	(.36)	(.13)	(.05)	.04
material is priced consistently	(.49)	(.50)	(.27)	(.30)	(.39)	0.00	(.10)
material is of consistent quality	(.44)	(.30)	(.41)	(.46)	(.33)	(.12)	(.20)
material is fire resistant	(.64)	(.64)	(.59)	(.69)	(.57)	(.61)	(.45)
material is non-combustible	(.79)	(.69)	(.75)	(.76)	(.59)	(.71)	(.74)

agreement pertaining to wood products between regions on several qualitative dimensions. On the positive side, wood fulfills many of the qualities described, regardless of location. These include the following, in order of magnitude:

- it is warm and inviting;
- it is simple to install;
- it is attractive in appearance;
- it is inexpensive to install;
- tradespeople are readily available;
- building costs are low;
- it is adaptable;
- it is simple to design with; and
- it is easy to obtain and readily available.

Wood also fulfills the following qualities to a lesser extent:

- it is inexpensive;
- it has good value for the money; and
- it is competitively priced.

On the negative side, there is universal agreement that wood does not fulfill some of the qualities described. These include the following, in order of magnitude:

- it is combustible;
- it is not fire resistant; and, to a lesser degree
- it is not of consistent quality.

Several regional differences were also noted, including the following:

- Canadian designers perceived wood to be a somewhat strong material, while American designers perceive it to be slightly weak.
- Both countries believe that wood is not durable, uniform or long-lasting. However, these perceptions are much more pronounced in the United States.
- With the exception of the American Midwest, wood is thought of as being a fairly safe material.
- Wood is thought of as a high maintenance material in the United States. In Canada, this is true to a lesser extent in every case but one. In Eastern / Maritimes Canada, wood is thought of as somewhat low maintenance. Also, in general, wood is considered harder to maintain the further west one goes.
- Wood prices are seen as inconsistent in all regions, especially in the West and more so in the United States.
- Wood supply is perceived as being marginally consistent in Canada, and marginally inconsistent in the United States.
- Wood is thought of as an environmentally friendly alternative in all regions but the American West. Canadians perceive wood to be more environmentally friendly than Americans.
- Building codes for wood are generally fairly simple to understand, getting easier the further west one goes. Fire codes, for the most part, are thought of as neither easy nor difficult to understand. However, they do seem to become slightly more understandable in Western United States, Central Canada, and Eastern / Maritimes Canada.

Finally, it should be noted that similar regional analyses were performed on steel, concrete, and masonry. Although the results are not shown here, they are, like wood products, fairly consistent with those seen in Table 4.9. That said, some interesting regional trends should be noted. For instance, masonry is viewed more favourably in the United States than in Canada for the most part. Furthermore, it is viewed more favourably in the Eastern regions of each nation. Conversely, concrete is viewed more favourably in Canada than in the United States. However, it is viewed consistently within each country. Lastly, no obvious trends emerged for steel. It is viewed fairly consistently across North America.

Drawbacks to Wood Use:

The last geographical segmentation model incorporated data from *Question 10* in *Section III* of the survey which asked respondents to choose, from a list, the three greatest drawbacks to wood use in buildings four storeys or less. A regional breakdown showing the proportion of responses is seen in Table 5.4. The fact that wood *burns* is the most commonly cited drawback in most regions. This problem is most pronounced in the Midwestern, Southern, and Northeastern regions of the United States, as well as the Western / Northern region of Canada. The fact that wood *deteriorates / rots* is of major concern to respondents in the Southern portion of the United States. It is of lesser importance to the remaining American respondents, although still a commonly stated problem. In Canada, there appears to be some concern for this problem, especially in the Western / Northern region, though it is certainly not as conspicuous as in the United States. The fact that wood is a *variable / inconsistent material* concerns respondents from Western United States. In the remaining regions, concern is fairly evenly distributed at a moderately widespread level. Another not uncommonly cited drawback to wood use is the fact that it is *not durable*. Here, the problem seems to be most prevalent in the West, decreasing slightly as one moves eastward. Conversely, the fact that wood is *not strong* is generally not seen as a problem in the West, although it is more frequently cited in the Eastern regions. The fact that wood is *costly* is not seen as a major drawback in most regions. It is, however, more frequently cited in Central Canada. *Other problems* (e.g., span and code limitations, deflection, and maintenance concerns) are also not seen as major drawbacks to wood use in most regions. Here, concern is

Table 5.4: Regional Breakdown (Proportion of Responses) of Drawbacks to Wood Use (Buildings 4 Storeys or Less).

	West U.S.	Midwest U.S.	South U.S.	Northeast U.S.	West / North Canada	Central Canada	East / Maritimes Canada
it burns	22.89%	27.99%	28.67%	26.48%	27.74%	24.39%	21.11%
it deteriorates / rots	21.13%	25.00%	31.12%	21.46%	18.98%	10.98%	8.89%
it is variable / inconsistent	19.01%	11.57%	9.44%	13.24%	10.22%	14.63%	11.11%
it shrinks and swells	13.03%	9.33%	6.29%	10.50%	18.25%	15.24%	21.11%
it is not durable	10.21%	8.40%	7.69%	6.85%	10.95%	9.76%	8.89%
it is not strong	4.23%	6.53%	6.64%	8.22%	5.11%	10.37%	10.00%
it is costly	5.99%	4.85%	3.15%	5.02%	0.73%	7.93%	5.56%
other	3.17%	5.04%	4.90%	5.48%	5.84%	4.27%	7.78%
it is difficult to design with	0.35%	1.31%	2.10%	2.74%	2.19%	2.44%	5.56%

highest in Eastern / Maritimes Canada. Finally, the least frequently mentioned shortcoming is the fact that wood is *difficult to design with.* With the exception of Eastern / Maritimes Canada, concern levels are negligible.

Professional Segmentation:

The next segmentation model that was attempted was by professional group. In this survey, two very distinct professions, each with varying sets of attitudes, perceptions, and beliefs, are represented: structural engineers (numbering 161) and architects (numbering 392). As such, separate analyses should be performed on each group, especially with regards to design, education, and their workplace environments. An approach of this nature serves to facilitate the creation and implementation of marketing plans aimed specifically at each design segment.

Workplace Environment:

Sections V and *VII* of the survey asked several questions pertaining to designers' workplace environments. The means of these characteristics are summarized in Table 5.4 according to professional group. To see if there were any significant differences between professional groups, various two-tailed significance tests ($\alpha = 0.05$) were performed on each of the numerical and proportional means.

Table 5.4: Comparison of Some Workplace Characteristics by Professional Group (Averages).

Average...	**Structural Engineers**	**Architects**
number of years practicing:	19.71	18.29
number of years at present place of work:	11.43	11.18
number of full-time architects at present place of work:	4.92	13.88
number of full-time structural engineers at present place of work:	28.85	3.36
number of employees at present place of work:	382.72	190.05
number of designers at place of work that design buildings 4 storeys or less: *	7.00	11.90
number of designers at place of work that design buildings 4 storeys or less using wood:	2.72	3.98
number of designers at place of work that specialize in wood buildings 4 storeys or less:	1.51	1.47
proportion that are self-employed	35.67%	42.55%
proportion that have been sued in their professional careers:	5.88%	9.19%
proportion of design workload devoted to buildings 4 storeys or less: *	60.86%	82.49%
proportion of buildings that have had structural components independently specified:	47.76%	52.60%
proportion whose design philosophy is conducive to the use of wood:	69.39%	79.17%

* = significant differences observed.

Differences between numerical averages were tested using a two-tailed t-test ($\alpha = 0.05$). Given the visible variation seen in Table 5.4, significant differences were expected for most groups. However, only one category, *number of designers at place of work that design buildings four storeys or less*, showed a significant difference (denoted with an asterisk). Upon closer examination, it was discovered that variances between groups were clearly not homogenous. Furthermore, the distributions were, for the most part, non-normal. In an attempt to account for these influences, the analysis was re-run using a two-tailed t-test ($\alpha = 0.05$) assuming unequal variances, with and without logarithmic transformations (to normalize the data). Unfortunately, the results were the same. As a result, very little, statistically speaking, can be concluded with respect to differences between architects and structural engineers on these variables. That said, the workplace environments of structural engineers do appear to be somewhat larger than those of architects. However, architects have more people on staff that design buildings four storeys or less (11.90 versus 7.00 employees). In both groups, fewer employees are able to design wood buildings four storeys or less. Even less employees specialize in these types of structures. Finally, there seems to be an equivalent amount of movement from one job to another. For both professional groups, the average number of years at their present place of work is less than the number of years that they have been practicing.

Differences between mean proportions were tested using a two-tailed z-test ($\alpha = 0.05$). The comparison between architects and structural engineers revealed no significant differences in every category except one (denoted with an asterisk). A significantly higher proportion of the architects' design workload (82.49%) is devoted to buildings four storeys or less, while structural engineers spend less time (60.86%) on these types of structures. For both groups, design philosophies are generally conducive to the use of wood in this type of application and lawsuits are infrequent. Finally, approximately half of the respondents in each group have independently specified building materials themselves.

The Specification of Structural Materials:

Question 1 in *Section V* of the survey asked respondents to comment on the parties involved in the specification of structural materials in buildings four storeys or less. Results are summarized in Table 5.5 by professional group. First, structural engineers and architects were asked to identify the main specifiers of structural materials in buildings four storeys or less. Two very distinct paradigms emerged from this analysis. As expected, the majority of respondents in each group feel that they are the principal specifiers. In the case of structural engineers, 48.99%

Table 5.5: The Main Specifiers of Structural Materials / Apportionment of Material Specification by Professional Group.

	Main Specifiers		Apportionment of Specification	
	Structural Engineers	Architects	Structural Engineers	Architects
Architects	32.21%	65.38%	31.98%	48.74%
Structural Engineers	48.99%	27.47%	39.47%	32.45%
Owners / Developers	8.72%	3.57%	12.41%	7.44%
Clients	6.71%	0.82%	8.10%	6.17%
Building Contractors	3.36%	2.20%	6.55%	4.71%
Other	0.00%	0.55%	1.49%	0.49%

agree that they are the main specifiers. In this scenario, architects account for only 32.21% of the responses. Even more peripheral are the roles of owners / developers and clients, who are thought of as main specifiers 8.72% and 6.71% of the time, respectively. The contribution of building contractors and other parties in the specification process is seen as negligible. Conversely, in the case of architects, fully 65.38% agree that they are the main specifiers of structural materials. Here, structural engineers account for only 27.47% of the responses, while the roles of the remaining parties are seen as inconsequential for the most part.

This said, respondents were asked to state whether or not the main specifier that they identified acts independently in the selection process. In both groups, there is notable agreement, with 78.08% of structural engineers and 78.89% of architects stating that specification is not done individually. These respondents were than asked to estimate how the selection of structural materials is apportioned between the various parties involved. The results, seen in Table 5.5, are more evenly distributed than above. In this paradigm of working co-operatively, structural engineers said that 39.47% of the responsibility for specifying materials is theirs', while architects account for 31.98%. Owners / developers are somewhat influential at 12.41% of the apportionment, while clients and building contractors account for 8.10% and 6.55%, respectively. Although still comparatively unimportant, the role of other parties, like cost consultants and material suppliers, is more pronounced here. Architects, in a slightly less democratic fashion, stated that 48.74% of the responsibility for specifying materials is theirs', while structural engineers account for 31.98%. Ignoring other parties, whose contribution is again negligible, the remaining 18.32% is fairly evenly distributed between owners / developers (7.44%), clients (6.17%), and building contractors (4.71%). As above, it is difficult to draw any conclusions pertaining to the specification of structural materials in buildings four storeys or less. However, it is clear that both structural engineers and architects play very important roles in the material selection process.

Design and Construction Methods:

In *Section V* of the survey, respondents were asked to comment on the design and construction methods that they typically use. *Question 3* dealt with issues of design. For each structural material, respondents were asked to state which design method they generally utilize: working stress design or the more recently developed limit states design. Results, seen in Table 5.6 for each structural material, reveal some very interesting differences between professional groups. Compared to other materials, structural engineers are much more familiar with limit states methods in steel and, especially, concrete design. Architects, on the other hand, seem less reliant on working stress methods for masonry design. In the case of wood products design, there is little difference between the two professional groups. Here, working stress design is used far more frequently than limit states design by both architects and structural engineers. It should be noted that a small percentage of respondents use each of the methods (less than 2% of the architects and less than 4% of the structural engineers). As well, some respondents use another design method altogether. Between 8% and 10% of the architects typically use engineering consultants to assist them in their designs, while less than 3% of the structural engineers incorporate ultimate strength methods, span tables, and plastics analysis. Finally, this question was not applicable to many of the architects (between 18% and 20% in the cases of masonry and concrete, and between 5% and 9% in the cases of wood and steel). Inapplicability was lower for structural engineers (although between 11% and 14% claimed that they were unable to answer the question as it pertained to wood and masonry).

Table 5.6: Breakdown of Design Methods by Structural Material and Professional Group.

	Structural Engineers		Architects	
Structural Material:	**Working Stress**	**Limit States**	**Working Stress**	**Limit States**
Wood	59.86%	25.17%	61.03%	24.26%
Steel	47.97%	46.62%	62.50%	17.28%
Concrete	22.30%	72.30%	45.96%	22.79%
Masonry	66.62%	16.22%	41.91%	30.15%

Question 4 of the same section asked respondents about the construction method that they were most familiar with: post and beam or light frame construction. Fully, 71.23% of the structural engineers stated that they are equally familiar with both, while only 51.52% of the architects answered likewise. Of the remaining structural engineers, 12.33% said that they are more familiar with post and beam construction, while 16.14% claimed to be more familiar with light frame methods. In the case of architects, only 6.61% are more familiar with post and beam construction, while the remaining 41.87% are more familiar with light frame methods.

The results of this analysis seem to indicate that, generally speaking, structural engineers are more well-rounded in their knowledge of construction methods than architects. Furthermore, they seem better acquainted with newer design techniques. These conclusions are not surprising, given that a knowledge of design and construction processes is an integral part of any structural engineer's job. What is surprising is the fact that their experience with limit states design, as it pertains to wood, is almost as low as it is for architects. In other words, structural engineers do not seem to be evolving as quickly for wood products as they are for steel and concrete, in terms of design methods.

Educational / Promotional Issues:

In an attempt to contextualize the above findings, *Questions 1,5*, and *6* of *Section IV*, which dealt with issues of learning, were also segmented by profession. *Question 6* asked respondents to rate three methods of acquiring knowledge (education, on the job training, and work experience) as they pertain to steel, concrete, wood, and masonry. In each case, a four-point underlying metric scale was used to rate knowledge as follows: *1, no knowledge of material gained; 2, little knowledge of material gained; 3, some knowledge of material gained;* and *4, much knowledge of material gained.* Means were computed for each professional group and are seen plotted in Figure 5.3 (structural engineers) and Figure 5.4 (architects).

From Figure 5.3, it can be seen that structural engineers primarily learn about steel and concrete throughout the entire span of their design careers. At school, the average scores for steel and concrete lie between *some* and *much knowledge gained.* Conversely, wood's average score lies between *little* and *some knowledge gained,* while masonry's score falls slightly below *little knowledge gained.* Scores for steel and concrete decrease slightly with on the job training, but come back up to the same level with work experience. In the case of masonry and wood, scores

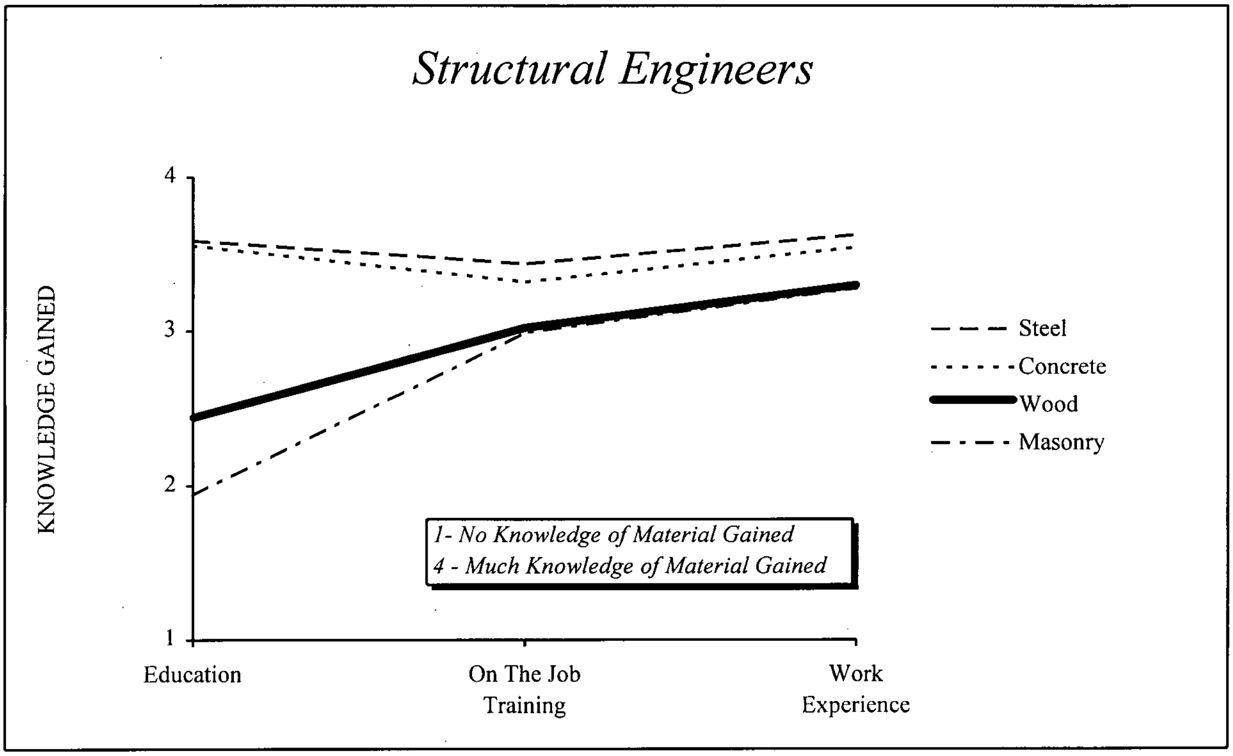

Figure 5.4: Effectiveness of Various Methods in Acquiring Knowledge about Structural Materials (Structural Engineers).

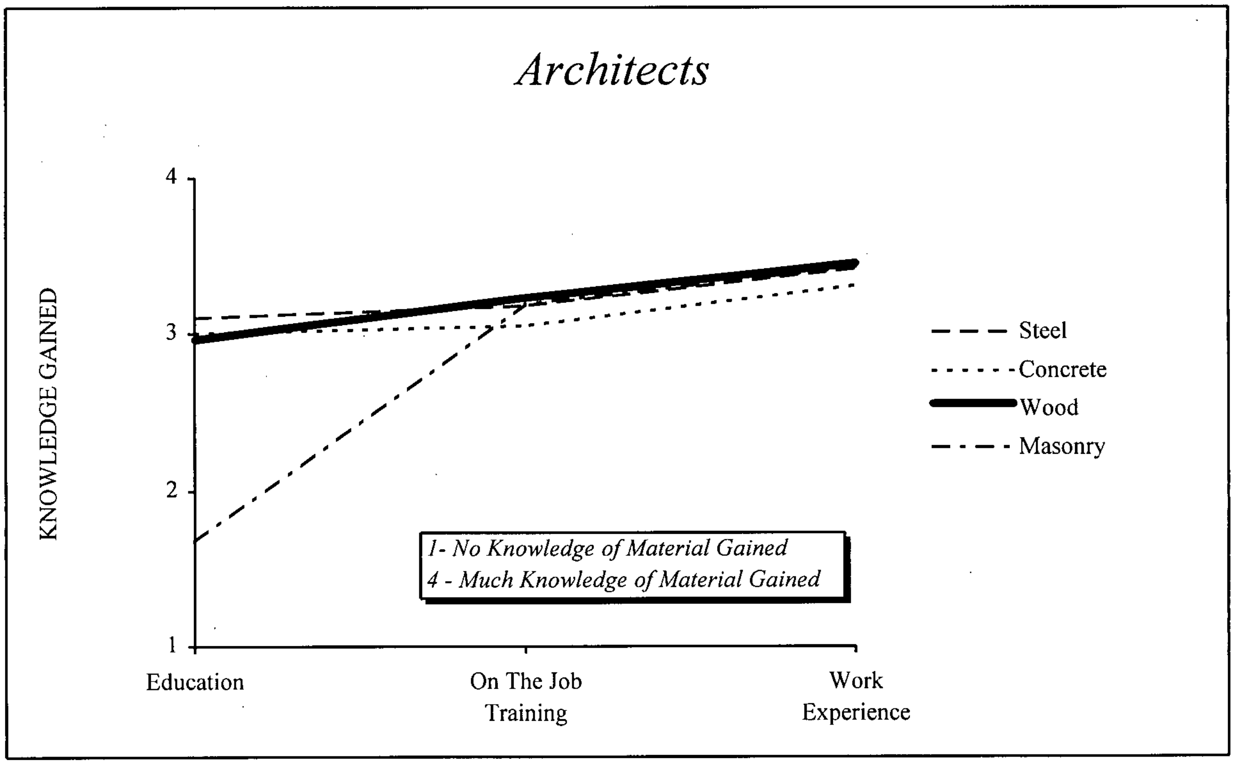

Figure 5.5: Effectiveness of Various Methods in Acquiring Knowledge about Structural Materials (Architects).

simultaneously increase to *some knowledge of material gained* with on the job training, increasing to a slightly higher level with work experience (although still somewhat lower than steel and concrete).

Figure 5.4 shows an entirely different picture for architects. Wood, steel, and concrete all receive similar ratings in each category. At school, *some knowledge* of each material is gained, on average (although steel's scores are slightly higher). Only masonry does poorly with scores somewhat below *little knowledge of material gained.* However, masonry soon catches up to the rest of the materials with on the job training. Here, each of the materials have scores at or above *some knowledge of material gained,* each increasing even further with work experience (only concrete is somewhat lower).

The major difference between structural engineers and architects is that knowledge levels for steel and concrete are consistently very much higher in the engineering group. Conversely, levels for wood are somewhat higher for architects, while masonry levels remain approximately the same in both groups. For architects, knowledge of materials converges at work, while there is a distinct gap between steel / concrete and wood / masonry for structural engineers. Finally, architectural training at school puts far less emphasis on masonry, while engineers receive less formal training in both masonry and wood design.

These latter results are reflected in *Question 5* of the same section, which asked respondents to estimate the proportion of time spent at school that was devoted to the structural materials at hand. For structural engineers, 40.15% and 39.30% of the time at school was spent on steel and concrete, respectively. Only 13.63% of the curriculum was devoted to wood, while 6.33% was devoted to masonry. Time spent on the various structural materials was more evenly distributed for architects. Steel, concrete, and wood accounted for 29.73%, 25.78%, and 26.18% of the design curriculum, respectively. Masonry was taught 16.29% of the time, while other materials (plastics, aluminum, composites, and tensiles) made up the remaining 2.01%.

Question 2 of the same section, which asked respondents about design education orientations, was also segmented by profession. The majority of structural engineers, 60.93%, claimed that the orientation of their schooling was technical. Practical and scientific orientations were cited 19.87% and 17.88% of the time, respectively, while a business orientation was cited only 1.32% of the time and an artistic orientation was not mentioned at all. Conversely, architects cited artistic and practical orientations each 34.52% of the time and technical orientations 26.30% of the time. Scientific and business orientations accounted for the remaining 2.74% and 1.92%, respectively. Thus, it can be said that structural engineers think of education as technical, for the most part. Conversely, architectural schooling is thought of in more artistic and practical terms.

Finally, *Question 7* in *Section IV* of the survey queried respondents on the process of learning about new products / systems specifically on the job. Specifically, they were asked to list the methods of learning that they typically use, as well as the ones that are most common and most influential. The results, seen in Table 5.7, were again segmented in an attempt to determine how to most efficiently promote wood products to each of the professional groups. The methods of learning are ordered from most to least common (according to all respondents).

On the whole, structural engineers and architects appear to be similar with respect to their methods of learning about new products / systems on the job. However, a few notable differences can be observed. For instance, the most popular methods of learning for architects are by reading materials, followed by manuals / data files. Each of these methods are approximately equally influential. For structural engineers, the inverse seems to be true. Manuals / data files are a little more common and far more influential than reading materials. Personal promotion seems to be somewhat more common and influential among architects, while the same is true for continuing education among structural engineers. Word of mouth is approximately equally common in both groups, although much more important to architects. Computerized information, although relatively uncommon, seems to be more widely accepted in the engineering profession. Conversely, architects cite physical examples as being a more common, and

Table 5.7: Methods of Obtaining Product Information on the Job by Professional Group.

	Structural Engineers			Architects		
	Most Common	You Use	Most Influential	Most Common	You Use	Most Influential
Reading Materials	18.66%	13.83%	15.25%	20.12%	14.29%	16.33%
Manuals / Data Files	20.57%	13.36%	26.44%	16.17%	13.37%	17.53%
Corporate Promotion	13.64%	11.11%	6.78%	14.36%	10.83%	7.44%
Word of Mouth	10.77%	10.40%	10.17%	9.72%	11.02%	14.89%
Personal Promotion	7.89%	9.57%	7.80%	10.23%	10.15%	10.92%
Association Promotion	8.85%	11.47%	5.08%	8.51%	9.27%	3.96%
Continuing Education	8.61%	11.11%	13.90%	6.62%	10.59%	10.20%
Physical Examples	4.78%	6.97%	8.14%	6.36%	10.39%	14.29%
Proactive Marketing	2.87%	6.38%	2.03%	4.56%	5.27%	2.28%
Computerized Information	3.35%	5.67%	4.41%	3.10%	4.24%	1.44%
Other	0.00%	0.12%	0.00%	0.26%	0.59%	0.72%

much more influential, approach to learning about new products / systems. Proactive marketing is comparatively uncommon in both groups, although more so for structural engineers. Both professions find corporate promotion to be relatively common, although unimportant. The same is true for association promotion, which is even less common and influential.

This analysis shows that the implementation of marketing plans aimed at designers should take their respective professions into account. That said, structural engineers and architects are very similar in their assessments of the most influential methods of learning on the job. Reading materials and manuals / data files are, by far, the most effective means of educating specifiers about new products / systems. Structural engineers, in particular, seem to place a great deal of value on manuals / data files. As such, marketing programs aimed at increasing product usage among structural engineers and architects must include some form of reading material, manual, or data file. Marketing strategies geared towards structural engineers specifically should also incorporate some type of continuing education program, coupled with physical examples. Likewise, the use of physical examples, in conjunction with personal promotion and continuing education, would likely be extremely beneficial to marketers attempting to increase product awareness among architects. For both professional groups, word of mouth is also an influential means of learning about new products / systems. However, it is very difficult to use this as a means of educating specifiers. Nonetheless, the fact that both design professions place a high value on word of mouth increases the likelihood of success for new, well-regarded products and systems.

Segmentation by Data Reduction and Classification:

In the cases of geographical and professional groupings, approaches to segmentation models are obvious. However, in a survey of this magnitude, accessible segments and/or data trends may not be immediately apparent amidst the vast array of variables that exist. Recently developed multivariate statistical techniques have been effectively used in marketing research to uncover these types of underlying patterns. Here, three methods have been successfully employed to segment both data and observations. *Factor analysis*, although not a segmentation procedure per se, is a data reduction technique used to summarize large quantities of data into smaller, meaningful dimensions. *Cluster analysis* and *multiple discriminant analysis* are classification techniques used to segment large groups of observations (in this case respondents) based on similarities between them. Each method, and their respective analyses, will be described in turn[9].

Factor Analyses:

Factor analysis is a multivariate data reduction technique used to summarize and reduce data. It attempts to analyze interrelationships between large sets of variables and, in so doing, uncover common and latent underlying dimensions or factors which can explain them in terms of variation. In other words, large sets of data are reduced into smaller sets of (hopefully) meaningful factors; each factor consisting of several variables with some common underlying dimension that account for and explain variation in the sample. In each factor, some of the variables load higher than others, which is to say that some variables are more highly correlated to the factor than others. It is the highly loading variables which should be used to determine the latent meaning of each factor. It should also be noted that, by rotating these factor loadings in *n* dimensional space, factors are extracted in order of variation explained. That is, each successive factor accounts for less and less variance in the data (i.e., the variance structures of each variable within a factor become more dissimilar). As a result, the highest degree of communality is seen in the factors extracted first. In this study, three factor analyses were performed on importance ratings, product attributes, and buildings designed in an attempt to reduce data and uncover any underlying communalities between variables (and ultimately, respondents). Each one is discussed in turn, with rotated factor loadings for each analysis seen in Appendix F.

Factor Analysis #1 - Importance Ratings by Professional Group:

Question 6 in *Section V* of the survey asked respondents to state the importance of various considerations when selecting structural materials for use in buildings four storeys or less. A five-point scale was used to measure importance on a number of qualitative dimensions, as follows: *1, not at all important; 2, slightly important; 3, important; 4, very important;* and *5, extremely important.* Results were professionally segmented and broken down by response (for analysis in the previous section) as they were in Figure 4.33. Unfortunately, like the findings seen in Figure 4.33, there was little difference both between considerations and professional groups. That is, specifiers

[9] Although not explicitly referenced, the following literature has been helpful in understanding and explaining these complicated techniques:

- Dillon, W.R. and M. Goldstein, 1984. *Multivariate Analysis: Methods and Applications*. John Wiley & Sons, N.Y.
- Hair, J.F., R.E. Anderson and R.L. Tatham, 1987. *Multivariate Data Analysis*. Macmillan Publishing Co., N.Y.
- Johnson, R.A. and D.W. Wichern, 1992. *Applied Multivariate Statistical Analysis*. Prentice Hall, N.J.
- Norusis, M.J., 1993. *SPSS for Windows User's Guide, Release 6.0*. SPSS, Inc., Il.

tend to place a great deal of importance on each of the considerations in question, for the most part. In an attempt to obtain more meaningful results in this analysis, the professional breakdown approach was abandoned for the multivariate technique of factor analysis.

Separate factor analyses were performed for structural engineers and architects on the importance ratings seen in *Section V*. Here, the method of principal components, which considers all types of variance at once (common, specific, and error), was employed in conjunction with an orthogonal VARIMAX rotation (generally recommended) to obtain the factor solutions. Scree tail tests of eigenvalues indicated that a five factor solution would suffice in each case (57.8% and 50.0% of the total variation is explained for structural engineers and architects, respectively). The results of the factor analyses can be seen in Table 5.8 for both professional groups, while the rotated factor loadings are displayed in Appendix F. Note that factors are, in fact, extracted in order of the amount of variation that they each explain. That is, the variance structures of the importance ratings among respondents are most similar in the first factors extracted. That is not to say that these factors are considered more important than the others. Rather, they possess the highest degree of communality.

The first factor extracted for structural engineers can be thought of as *engineering considerations*. These include issues of material strength, longevity, consistency, quality, and adaptability. To a lesser extent, ease and cost of installation, as well as the preference of structural engineers, are also considered here. The second factor extracted can be thought of as *product attributes* and includes variable such as guarantees, warranties, and environmental use implications. The fire performance of the material and proven product records are also included. *Economic considerations*, like material costs, value, and supply, as well as availability of tradespeople, is the third factor to be extracted. The fourth factor can be thought of as *building concerns*, including occupancy, proximity to other

Table 5.8: Factor Analysis on Importance of Various Considerations when Selecting Structural Materials (by Profession).

Factor	Structural Engineers		Architects	
	Underlying Communality:	**Cumulative Variance Explained**	**Underlying Communality:**	**Cumulative Variance Explained**
1	Engineering Considerations	28.5%	Building / Economic Considerations	23.5%
2	Product Attributes	37.6%	Engineering Considerations	32.0%
3	Economic Considerations	45.2%	Installation Concerns	38.7%
4	Building Considerations	51.9%	Architectural Considerations	44.7%
5	Other Party's Concerns	57.8%	Specifiers' Preferences	50.0%

structures, and, to a lesser degree, owner / developer preference. Finally, the fifth factor can be thought of as *other party's concerns*, such as the preference of architects and contractors.

A very different scenario emerges in the case of architects. The first factor to be extracted can be thought of as *economic / building considerations*. These include material value, supply, and costs, product guarantees / warranties, proven product records, and building resale values (on the economic side), as well as proximity to other buildings and occupancy (on the building side). The second factor can be thought of as *engineering considerations* like material longevity, consistency, and quality and, to a lesser extent, material adaptability and strength. *Installation concerns*, like preference of contractors, availability of tradespeople, and cost / ease of installation is the third factor to be extracted. The fourth factor can be thought of as *architectural considerations*, including material appearance, environmental impact, simplicity of design, and issues of light, space, sound, and function. Finally, the fifth factor, *specifiers' preferences*, refer to the preference of architects, structural engineers, and owners / developers.

As mentioned previously, the factors extracted first are not necessarily the most important in terms of criteria for selecting structural materials in buildings four storeys or less[10]. Rather, they are the most similar in their variance structures. Even though each of the individual variable's importance ratings may differ in absolute terms within the first factors extracted, these variables are most alike in relative terms. Restated, for each respondent, increases (decreases) in one variable coincide with increases (decreases) in the others contained within that factor. That said, the order in which factors were extracted does have very fundamental implications in the development of marketing programs aimed specifically at the two professional groups. Because an argument can be made that each of the considerations are considered, at least, somewhat important, the first factors can be thought of as the most efficient means of selling a product's attributes to prospective buyers. In other words, due to the fact that respondents rated the importance of several variables in the same relative manner, the first factors effectively convey a great amount of information to a large and relatively homogenous audience (with minimum effort). The logical corollary to this argument is that, the later a factor is extracted, the less focus and appeal it has as a marketing tool. As such,

[10] In fact, an analysis of means, by profession, for each factor's variables (not included here) reveals the following. For structural engineers, the most important considerations in selecting structural materials are related to engineering. These are followed by economic considerations, product attributes, building considerations, and other party's concerns. For architects, the most important considerations are architectural. These are followed by specifiers' preferences, engineering considerations, building / economic considerations, and installation concerns.

marketing strategies aimed at structural engineers should include information that addresses engineering concerns (like material strength, longevity, consistency, and quality) and, to a lesser extent, economic concerns (like material costs, value, and supply). Conversely, marketing efforts directed at architects should address building / economic concerns (like material supply, costs, guarantees / warranties, proven product records, occupancy, and resale value) and, to a lesser degree, the engineering considerations seen above.

Factor Analysis #2 - Product Attributes by Structural Material:

Question 1 in *Section II* of the survey, which collected product attributes data, has been summarized in Table 4.9 for each structural material and Table 5.3 for wood products in every region. To reiterate, this question asked respondents to rate wood, steel, concrete, and masonry on a number of qualitative dimensions. Several positive statements were made and respondents were asked to state which of the materials best and least fulfilled the quality described. Materials which *best fulfilled the quality described* where given a score of *1*, while those which *least fulfilled the quality described* where given a score of *-1*. The remaining materials were considered neutral and were given a score of *0*. Here, four separate factor analyses were performed on wood, steel, concrete, and masonry in hopes that the underlying dimensions that were extracted would reveal communalities between benefits sought and/or potential shortcomings for each structural material.

Again, the method of principal components was employed in conjunction with an orthogonal VARIMAX rotation. However, scree tail tests were not used to obtain the factor solutions in this case. Rather, more meaningful results emerged when all factors with eigenvalues values exceeding one (explaining more variation than variables considered on their own) were extracted. In the case of wood, a seven factor solution accounting for 59.7% of the variation was obtained. Eight factors were obtained for steel explaining 62.8% of the variation. For concrete and masonry, six factor solutions emerged accounting for 56.8% and 61.3% of the variation, respectively. The results of the four factor analyses can be seen in Table 5.9 for each structural material, while the rotated factor loadings are displayed in Appendix F.

In each case, the *material properties* factor is extracted early in the analyses, which is to say that it accounts for a large proportion of the variation. In the cases of wood and masonry, it explains the most variation, while in the cases of steel and concrete, it is extracted second. This factor refers to material durability, strength, maintainability,

Table 5.9: Factor Analysis on Fulfillment of Quality Described (by Structural Material).

Factor	Wood		Steel	
	Underlying Communality:	**Cumulative Variance Explained**	**Underlying Communality:**	**Cumulative Variance Explained**
1	Material Properties	22.5%	Material Supply	25.3%
2	Economic Considerations	33.2%	Material Properties	34.7%
3	Material / Price Consistency	40.0%	Material / Building Costs	40.4%
4	Material Adaptability / Simplicity	45.7%	Installation Concerns	45.6%
5	Building Costs	50.8%	Understandability of Codes	50.5%
6	Understandability of Codes	55.4%	Material Consistency	55.1%
7	Design / Aesthetic Concerns	59.7%	Design / Aesthetic Concerns	59.1%
8	N/A		Fire Concerns	62.8%
Factor	**Concrete**		**Masonry**	
	Underlying Communality:	**Cumulative Variance Explained**	**Underlying Communality:**	**Cumulative Variance Explained**
1	Economic Considerations	25.1%	Material Properties	33.6%
2	Material Properties	35.7%	Economic Considerations	42.9%
3	Installation Concerns	41.9%	Installation Concerns	48.2%
4	Design / Aesthetic Concerns	47.7%	Design / Aesthetic Concerns	53.2%
5	Understandability of Codes	52.7%	Understandability of Codes	57.4%
6	Material Consistency	56.8%	Material Consistency	61.3%

and permanence. In the cases of wood, concrete, and masonry, it also refers to fire resistance and combustibility. For each material (especially wood and masonry), specifiers are very alike in their relative perceptions of these product attributes. Referring to Table 4.9, it can be seen that these attributes are generally viewed very favourably in the cases of steel, concrete, and to a lesser extent, masonry. Unfortunately, wood products are generally not viewed favourably on this dimension. In other words, the highest degree of variable communality among specifiers here is based on a negative perception towards wood; there is a mutual feeling that wood products are of inferior quality.

The *economic considerations* factor is also extracted early for each structural material. It accounts for the most variation in concrete and the second most in wood and masonry. In the case of steel, this factor was collapsed into two: *material supply* (extracted first) and *material / building costs* (extracted third). These factors refer to issues of material costs, supply, and value and, in the case of steel, building costs. Referring to Table 4.9, it can be seen that these economic attributes are perceived positively by specifiers as they pertain to wood products. In fact, in most cases, wood scores somewhat higher than the other structural materials (especially on the dimension of cost). That said, the other three structural materials also seem to do well on this economic factor. This is especially prevalent in the case of supply consistency, where the scores for wood are comparatively low. Thus, it can be stated that there is a high degree of relative agreement among specifiers with respect to economic concerns (both in terms of variance structures and between materials). Each of the structural materials is viewed positively for the most part. In the case of wood, there is a clear perceived price advantage. However, at the same time, supply is thought of as inconsistent.

The third factor extracted for wood products can be thought of as *material / price consistency*. Specifiers believe, in a relatively similar manner, that wood is inconsistently priced and lacking in uniformity / quality (as seen in Table 4.9). While no such factor exists for the remaining materials, *material consistency* on its own was extracted sixth in each case. On average, specifiers believe that steel is an extremely high quality, consistent material, followed by masonry, which is thought of in more moderate terms. Conversely, concrete is not seen in this light at all, although its scores are not as low as wood's. That said, little variation is explained by this factor for steel, masonry, and concrete. A much higher degree of communality exists in the case of wood products lacking consistency, both in quality and price.

While *installation concerns* (simplicity and cost of installing buildings, material adaptability) are extracted relatively early for steel (fourth), concrete (third), and masonry (third), no such grouping for wood emerged. Rather, these attributes are seen in two factors: *material adaptability / simplicity* (extracted fourth) and *building costs* (extracted fifth). Interestingly, Table 4.9 shows that for steel, masonry, and concrete, these attributes are not viewed very positively. In the case of wood, the opposite is true. Here, buildings made of wood are seen as inexpensive and simple to install, while wood as a material is thought of as adaptable. The degree of communality for each material is approximately equal.

The two factors which explain the least amount of variation for each structural material, but still account for some underlying communalities between specifiers, are *understandability of codes* (fire and building codes) and *design / aesthetic concerns* (design simplicity and attractiveness). In the case of wood, fire codes are seen as being more difficult to understand, on average (refer to Table 4.9). Conversely, building codes are easily understood for all materials. By far, wood is thought of as the most attractive material, followed distantly by masonry. Steel and concrete are not perceived as being attractive at all. Wood is also thought of as the easiest material to design with, followed by steel, masonry, and, lastly, concrete. Finally, one anomalous factor, *fire concerns*, emerged for steel. For every other material, fire resistance and combustibility emerged in the *material properties* factor. However, here it did not for some reason. Although its scores are not as low as wood's, steel is not thought of as particularly fire resistant or noncombustible relative to concrete and masonry.

In terms of promotional / research activities for wood products, the results of this analysis are far reaching. In the case of wood products, specifiers are most similar in their relative perceptions of *material properties*, *economic considerations*, and *material / price consistency*. In other words, for each of these factors, increases in one variable coincide with increases in the others contained within that factor. Furthermore, most of the variables that make up each factor are simultaneously rated either positively or negatively (this is not necessarily a truism in every factor analysis, although it did occur here). As such, promotional campaigns which concentrate on these three areas would likely be the most efficient use of available resources, in terms of appealing to a wide, homogenous, and interested audience. Perceptions of wood's physical qualities (durability, strength, fire resistance, maintainability, permanence, consistency, and uniformity) are, for the most part, negative. Based on how highly rated these attributes are for other structural materials, these are benefits that are clearly sought, but not obtained, in the case of wood. Promotional activities should centre around dispelling the conceptions that are untrue and communicating the results of research efforts that focus on improving these attributes (especially in the area of fire safety). Conversely, with the exception of supply and price consistency, wood is seen as being advantageous with respect to economic concerns (material / building costs and value). Promotional efforts should reinforce these strengths, and market wood products as being the material of choice in terms of cost savings. On the research side, the issue of improving supply channels, as well as pricing, should also be thoroughly examined and communicated. That said, other factors extracted in this analysis should not be ignored. For instance, a more obvious attribute, like wood's aesthetic qualities, could easily be at the forefront of any marketing program. The simplicity of design and adaptability associated with wood products might also be considered.

Factor Analysis # 3 - Building Types by Structural Material:

Part of *Question 7* in *Section I* of the survey asked about the frequency with which respondents incorporate wood, steel, concrete, and masonry into the various types of buildings that they design (by end use). A five-point underlying metric scale measured frequency of material use for each building type, as follows: *1, always use this material; 2, very often use this material; 3, sometimes use this material; 4, rarely use this material;* and *5, never use this material.* Means were computed for each building type and are seen plotted in Figure 4.13. Four separate factor analyses were performed on this data for each structural material to see if any underlying communalities could be uncovered with respect to the types of buildings specifiers design.

Again, the method of principal components was employed in conjunction with an orthogonal VARIMAX rotation to obtain the factor solutions. Scree tail tests of eigenvalues indicated that a three factor solution would suffice in each case (the rotated factor loadings can be seen in Appendix F). For wood, the three factors extracted accounted for 74.5% of the variation (49.9%, 15.1%, and 9.1%, respectively). For steel, 65.5% of the variation was explained (42.9%, 13.4%, and 9.2% for each factor, respectively). In the case of concrete, the three factors accounted for 77.7% of the variation (58.5%, 12.5%, and 6.8%, respectively). Finally, the most successful factor analysis, on masonry, explained 86.3% of the variation in the data (74.7%, 6.5%, and 5.1%, respectively).

Unfortunately, for every structural material, the post-hoc analyses of underlying communalities failed to yield any meaningful factors among building types. That is not to say that the results are inconsequential (the first factors still explain a significant proportion of the variation in the data). Rather, data must be presented in a different fashion; one in which the concept of common dimensionality is ignored. This is what has been done in Table 5.10. Here, for each structural material, the factor in which every building type belongs is listed (the numbers in parentheses refer to buildings which did not load as highly as others in that factor). Alongside the factor classifications are the frequency rankings obtained from Figure 4.13. A ranking of *1* means that the material in question is used most frequently in that application, while a ranking of *4* means that it is the least used material. Building types are listed in order of wood use, with buildings in which wood is most frequently used appearing first.

The presentation of data in this manner has effectively set up a grid which shows, not only the average frequency of structural material use for each building type, but also the relative consistency or stability of material use. Structural materials that rank highly for the various building types obviously have a good share of the market for that

Table 5.10: Factors Obtained for Building Types and their Respective Rankings of Structural Material Use.

Building Type (End Use):	Wood		Steel		Concrete		Masonry	
	Factor	Rank	Factor	Rank	Factor	Rank	Factor	Rank
Low-rise Multifamily Residences	1	1	2	4	(1)	3	1	2
Farm Structures	3	1	3	2	1	4	3	3
Religious Buildings	1	1	(1)	3	1	4	1	2
Seniors' Residences	1	1	2	3	(3)	3	1	2
Restaurants	1	1	(2)	1	1	3	1	2
Commercial / Residential Combinations	1	2	2	1	(3)	2	1	3
Offices	(3)	3	1	1	3	2	(1)	2
Hotels / Motels	1	4	3	2	(1)	1	(1)	3
Recreational Buildings	(2)	4	(2)	1	1	3	1	2
Commercial Buildings	(3)	4	(1)	1	3	3	(2)	2
Entertainment Facilities	(2)	4	1	1	1	2	1	3
Schools	2	4	2	1	(2)	3	1	2
Public Buildings	2	4	3	1	2	2	1	3
Industrial Buildings	2	4	(1)	1	(3)	2	2	3
Hospitals	2	4	(3)	1	2	2	(2)	3

application. When coupled with factor classifications, an indication of market volatility is also obtained due to the fact that the first factors to be extracted are the most alike in their variance structures. Although absolute use levels may vary between building types contained within the first factor, there is little variation in relative terms. Restated simply, for each respondent, as the use of a structural material increases for one building type, so too do its use levels increase for all of the buildings contained within that factor. As such, the markets for structural materials are most stable in buildings which are extracted early in the respective analyses. Conversely, markets for structural materials are more volatile in buildings extracted later in the analyses. Therefore, for each material, the likelihood of having market share eroded away by alternative materials (for the building type in question) increases with each successive factor that is extracted.

With rankings of *1* and extractions on the first factor, wood use in low-rise multifamily residences, religious buildings, seniors' residences, and restaurants is high and extremely stable. Market erosion by other structural materials is least likely in these applications. The same can be said about steel in offices, entertainment facilities and, to a lesser extent, commercial and industrial buildings. Concrete has a high share and a relatively high degree of stability in the hotels / motels sector, while masonry does not rank highly at all. In each of these applications, wood use is lowest. The logical corollary to this argument is that, for offices, entertainment facilities, commercial and industrial buildings, and hotels / motels, the likelihood of market penetration by wood products is lowest. This is not to say that wood use in these applications is not feasible. Rather, strong and concerted marketing campaigns must be implemented in these areas to erode the shares of steel and concrete.

The results also show that several, more attainable, opportunities exist for wood use. Steel also has the highest market shares for recreational buildings, schools, public buildings, and hospitals, while wood has the lowest, in each case. In these sectors, factors for steel were extracted second or third, which is to say that steel use, on the whole, is more volatile. Codes permitting, this presents a tremendous opportunity for wood products to capture a higher share of the market at the expense of steel, as well as concrete and masonry (which also have higher shares than wood, although their markets are more stable in many cases).

Commercial / residential combinations also present a different opportunity for wood products. Here, wood use is second only to steel, which means that many examples of this type of application are already in existence. Taking advantage of the lack of stability that exists for steel in this sector, promotional campaigns, which make use of "demonstration buildings", could be used effectively to penetrate this market. Farm structures present another interesting problem. Here, the share for wood products is high, but extremely unstable. Proactive marketing efforts, which stress the disadvantages of using other structural materials for this application, could be used to protect wood's share.

Thus, the key to success for wood products to successfully penetrate the nonresidential sector lies in subtle variations in marketing strategies. On one hand, concentrated promotional efforts must address the fact that wood *can* be viably used as a structural alternative in certain applications (offices, entertainment facilities, commercial and industrial buildings, and hotels / motels). On the other, marketing programs must be used to show that wood *should* be used in different contexts (recreational buildings, schools, public buildings, hospitals, and commercial / residential combinations). That said, the forest products industry should not ignore high wood use buildings (low-rise multifamily residences, religious buildings, seniors' residences, restaurants, and farm structures). Rather, a preventative marketing approach to protect and/or increase the share of wood products in these applications should be taken.

Cluster Analyses:

Cluster analysis is a multivariate statistical technique used to classify variables or observations into logical segments or "clusters". Like factor analysis, this technique utilizes a similarities approach in the interpretation and classification of data. However, where factor analysis attempts to uncover underlying communalities in the data, the objective of cluster analysis is to obtain a solution which maximizes variation between groupings and minimizes variation within groupings. Ideally, each (usually predetermined) cluster should be distinct and homogenous. The resulting groupings should be logical, accessible, and conducive to profiling. Finally, there should be little or no loss of information in the cluster solution.

Several clustering techniques exist, each with slight variations in how similarity measures are managed and cluster solutions obtained. In this analysis, a so-called "nonhierarchical procedure", the K-means clustering technique, was employed. Designed for large data sets, this method uses a divisive sequential threshold procedure to place each observation into the preselected cluster whose mean value or "seed" is most similar. The mean value for each cluster, initially guessed at, is recomputed in a reiterative fashion each time an observation is placed in a cluster. When all observations have been successfully classified, the cluster analysis is complete. Had a smaller data set been selected for the analysis (a small group of variables and not a large set of observations, for example), a "hierarchical" procedure could have been employed, whereby clusters are agglomerated or built up one variable at a time. However, the objective of this analysis was to logically segment observations (respondents) into meaningful groups. Unfortunately, due to the magnitude of observations in this study, clustering was limited to the use of a computationally less complex nonhierarchical technique.

Upon completion of a cluster analysis, cluster averages are used to interpret the meaning of each segment. Typically, each cluster is then profiled on various demographic and/or related variables in an attempt to explain how each of the segments differ. This is precisely what was done in this analysis. Observations were clustered on two dimensions: favourability to wood use and familiarity with wood products. In each case, three clusters emerged representing low, moderate, and high levels for both dimensions. Respondents, in each cluster, were profiled according to various design and demographic characteristics in order to ascertain how segments with low levels of favourability / familiarity differed from segments with higher levels. Both cluster analyses are discussed in turn.

Cluster Analysis #1 - Segmentation of Respondents by Favourability to Wood Use:

The first cluster analysis performed was on the favourability to wood use data obtained from *Question 5* in *Section III* of the survey. By way of a reminder, this question asked respondents to state how favourable they were to the use of wood in various building applications four storeys or less. Several K-means cluster analyses were performed on the respondents using this data as input. A three cluster solution emerged as the best, both in terms of latent cluster meaning (determined by observing the final cluster means) and cluster membership. *Cluster 1*, somewhat under-represented at only 56 respondents, refers to specifiers with a low favourability to wood use. *Cluster 2*, at 214 respondents, refers to specifiers with moderate favourability ratings. Finally, *Cluster 3*, at 146 respondents, refers to specifiers who are highly favourable towards the use of wood products in buildings four storeys or less. Already, these results seem to indicate that the market position for wood, in terms of favourability to use, is good. While 35.10% of the respondents are highly favourable to wood use, only 13.46% are not. The remaining 51.44% of the respondents fall into the moderately favourable category.

That said, full respondent profiles were performed on each of the clusters. Means for each segment were computed and are seen in two tables. Table 5.11 shows the cluster means of various design characteristics, while Table 5.12 is a breakdown of demographic information. Statistical tests were performed on each of the variables, excluding billings per year, in an attempt to determine how the three clusters contrast with one another (that is, on which variables are significant differences observed). Unfortunately, due to the varying nature of the data, three separate types of statistical tests had to be incorporated to obtain this information. A series three two-tailed z-tests (α = 0.05), comparing two groups at a time (*Cluster 1* vs. *Cluster 2*, *Cluster 2* vs. *Cluster 3*, and *Cluster 1* vs. *Cluster 3*), was performed on every variable containing proportional data (e.g., proportion qualified to design wood buildings, proportion presently designing wood buildings, etc.). A simple one-way analysis of variance (α = 0.05) was used to determine whether the means of the non-proportional variables (e.g., age, number of employees, etc.) significantly differed. When differences were observed, Bonferroni's multiple comparison method was employed to determine the cluster(s) in which the differences were occurring. Finally, a one-way analysis of variance (α = 0.05), coupled with Bonferroni's method, was again used on the average proportions data (e.g., average proportion of time devoted to buildings four storeys or less, [average] proportions of past material use, [average] proportions of buildings

Table 5.11: Breakdown of Design Characteristics on Favourability to Wood Use Clusters.

Cluster: **(Favourability to Wood Use Level)** **(Cluster Membership)**	**Cluster 1 (Low) (13.46%)**	**Cluster 2 (Moderate) (51.44%)**	**Cluster 3 (High) (35.10%)**
average proportion of time devoted to buildings 4 storeys or less:	73.69%	75.57%	77.19%
proportion qualified to design wood buildings 4 storeys or less:	75.00% *a*	83.18% *ab*	88.36% *b*
proportion presently designing wood buildings 4 storeys or less:	42.86% *a*	58.41% *b*	71.53% *c*
proportion whose design philosophy is conducive to wood use:	50.91% *a*	72.73% *b*	87.41% *c*
in buildings 4 storeys or less, proportion that...			
like seeing wood used as a structural material:	14.29% *a*	35.07% *b*	77.40% *c*
do not like seeing wood used as a structural material:	39.29% *c*	14.69% *b*	2.74% *a*
sometimes like seeing wood used as a structural material:	46.43% *b*	50.24% *b*	19.86% *a*
in buildings 4 storeys or less, proportion that...			
intend on using *more* wood:	0.00% *a*	6.19% *a*	17.48% *b*
intend on using *less* wood:	42.86% *c*	19.52% *b*	6.99% *a*
intend on using *the same amount of* wood:	57.14% *a*	74.29% *b*	75.52% *b*
proportion who want to learn more about wood:	46.30% *a*	62.00% *b*	63.57% *b*
proportion that have been sued in their professional careers:	5.45%	6.22%	8.45%
breakdown of past material use in buildings 4 storeys or less:			
steel	34.39% *b*	33.87% *b*	23.38% *a*
concrete	11.59%	13.96%	10.13%
wood	25.63% *a*	26.85% *a*	43.70% *b*
masonry	17.37%	11.20%	10.40%
other	0.00%	0.03%	0.03%
combination	9.17%	14.09%	12.35%
breakdown of buildings designed in the past by end use:			
offices	13.42%	12.71%	12.48%
commercial buildings	8.38%	7.30%	5.99%
industrial buildings	12.06%	16.14%	15.34%
hospitals	6.57%	8.04%	4.92%
schools	13.26%	12.43%	10.92%
hotels / motels	1.47%	2.34%	2.47%
restaurants	1.91%	2.66%	2.14%
public buildings	12.36% *c*	9.70% *b*	7.73% *a*
recreational buildings	1.43%	1.87%	2.79%
entertainment facilities	1.32%	1.43%	1.35%
religious buildings	3.96%	3.79%	4.11%
farm structures	0.13% *a*	0.30% *ab*	0.91% *b*
multifamily dwelling units	3.58% *a*	5.86% *a*	10.44% *b*
seniors' residences	2.09%	2.37%	2.26%
detached homes / duplexes	10.83% *a*	10.43% *a*	12.28% *b*
commercial / residential combinations	3.26%	1.70%	1.71%
other	3.96%	0.93%	2.15%
breakdown of buildings designed in the past by building height:			
1 storey	41.21%	43.58%	43.27%
2 storeys	24.56%	28.07%	30.24%
3 storeys	11.52%	11.85%	14.18%
4 storeys	9.73%	6.15%	5.32%
5 storeys or more	12.98%	10.35%	6.99%
breakdown of buildings designed in the past by building area:			
less than 10,000 square metres	72.88%	71.80%	70.93%
10,000 to 50,000 square metres	17.33%	18.86%	15.96%
over 50,000 square metres	9.79%	8.83%	13.11%

Table 5.12: Demographic Breakdown on Favourability to Wood Use Clusters.

Cluster: (Favourability to Wood Use Level) (Cluster Membership)		Cluster 1 (Low) (13.46%)	Cluster 2 (Moderate) (51.44%)	Cluster 3 (High) (35.10%)
professional group:	structural engineers	30.36% *ab*	21.50% *a*	35.62% *b*
	architects	69.94% *ab*	78.50% *b*	64.38% *a*
gender breakdown:	male	92.59%	95.26%	91.03%
	female	7.41%	4.74%	8.97%
geographical breakdown:				
Canada		**16.07%**	**20.86%**	**42.07%**
	West / North Canada	5.36% *a*	8.06% *a*	14.48% *b*
	Central Canada	3.57% *a*	7.11% *a*	20.00% *b*
	Eastern / Maritimes Canada	7.14%	5.69%	7.59%
United States		**83.93%**	**79.14%**	**57.93%**
	West United States	14.29%	17.06%	19.31%
	Midwest United States	16.07% *ab*	23.22% *b*	8.97% *a*
	South United States	33.93% *b*	20.85% *a*	14.48% *a*
	Northeast United States	19.64%	18.01%	15.17%
average age (years):		43.93	44.45	44.73
average years practicing:		18.96	17.44	17.40
average years employed at present place of work:		11.33	10.59	10.39
proportion that are self-employed:		36.36% *ab*	32.86% *a*	47.59% *b*
average number of full-time primary designers:		13.85	13.52	22.81
average number of full-time secondary designers:		1.51	4.37	3.18
average number of designers at place of work...				
	that design buildings 4 storeys or less:	11.86	9.29	10.24
	design buildings 4 storeys or less using wood:	1.91	3.01	3.55
	specialize in designing wood buildings 4 storeys or less:	2.41	0.87	1.98
breakdown of total billings per year:				
	under $100,000	13.95%	12.28%	22.76%
	$100,000 to $500,000	25.58%	22.22%	30.08%
	$500,001 to $1,000,000	4.65%	11.70%	12.20%
	$1,000,001 to $2,000,000	13.95%	14.04%	8.13%
	$2,000,001 to $5,000,000	11.63%	14.04%	8.13%
	$5,000,001 to $10,000,000	11.63%	12.87%	6.50%
	over $10,000,000	18.60%	12.87%	12.20%
breakdown of billings per year (buildings 4 storeys or less):				
	under $100,000	15.79%	15.43%	28.18%
	$100,000 to $500,000	26.32%	30.25%	30.00%
	$500,001 to $1,000,000	7.89%	11.11%	13.64%
	$1,000,001 to $2,000,000	21.05%	13.58%	7.27%
	$2,000,001 to $5,000,000	18.42%	14.20%	7.27%
	$5,000,001 to $10,000,000	5.26%	8.64%	8.18%
	over $10,000,000	5.26%	6.79%	5.45%
breakdown of billings per year (wood buildings 4 storeys or less):				
	under $100,000	82.14%	57.89%	54.74%
	$100,000 to $500,000	3.57%	29.32%	27.37%
	$500,001 to $1,000,000	10.71%	6.77%	8.42%
	$1,000,001 to $2,000,000	3.57%	4.51%	3.16%
	$2,000,001 to $5,000,000	0.00%	0.00%	2.11%
	$5,000,001 to $10,000,000	0.00%	1.50%	4.21%
	over $10,000,000	0.00%	0.00%	0.00%

designed in the past). However, the proportions here had to be modified by means of an arcsin transformation. The rationale behind this approach is that average proportions analyzed on their own have to be considered binomial in nature (i.e., there are only two choices). That is, when comparing a specific average proportion in a data set across three clusters, the remaining variables in that data set should be taken as one. In the case of a comparison between past wood use levels, data is assumed to be binomial because either specifiers use wood or they do not. The use of any one of the alternative materials is assumed to mean, for the sake of this test, that wood is not being used. An arcsin transformation serves to normalize this type of binomial data, thus allowing the assumptions of normality for an analysis of variance to be met.

In Tables 5.11 and 5.12 (as well as Tables 5.13 and 5.14 in the subsequent cluster analysis), significant differences between cluster averages are denoted by means of an alphabetic system, which allows for a ready comparison simply by observing the tables. When letters are displayed alongside the mean values (*a*, *b*, or *c*), at least one significant difference is observed between cluster means on that variable. For these variables, means with the same letter associated with them are not significantly different, while means with different letters are (e.g., *a* versus *b*). Furthermore, each successive letter represents a cluster with a significantly higher average value; the *a* cluster mean is significantly lower than the *b* cluster mean which is, in turn, significantly lower than the *c* cluster mean. Letters occurring together (e.g., *ab*) refer to the fact that these means are not significantly different from the means above and below them. However, significant differences are observed between the high (*b*) and low (*a*) averages in these cases. Finally, some variables have no letters associated with them. Here, no significant differences are observed at all.

Looking first at the summary of design characteristics seen in Table 5.11, several interesting comparisons between clusters emerge. In terms of designing buildings four storeys or less, no differences were observed between clusters. However, a significantly greater proportion of specifiers in the high favourability group are more qualified and experienced in designing these structures out of wood. This makes sense, given that 87.41% of these respondents say that their design philosophies are conducive to the use of wood. Significantly fewer respondents, 72.73% and 50.91%, for the moderate and low favourability groups, respectively, concur with this sentiment.

The vast majority of specifiers in the high favourability group like seeing wood used as a structural material in buildings four storeys or less, with less than 20% only liking it sometimes and a negligible proportion not liking it at all. In the significantly different moderate grouping, just over half of the respondents sometimes like seeing wood used structurally. Over 35% of the respondents like seeing wood used in this way while the remaining minority does not. In the low favourability cluster, again approximately half of the respondents like to see wood used structurally. However, almost 40% do not like to see wood used in this way, while only 14.29% do. Interestingly, the majority of respondents in each cluster intend on using the same amount of wood in future designs (especially in the moderate and high groupings). Only 17.48% of the high favourability grouping intend on using more wood, while 6.19% of the moderate grouping, and none of the low favourability grouping, state likewise. The results are reversed when asked about using less wood in the future, with 42.86%, 19.52%, and 6.99% of the respondents agreeing in the low, moderate, and high clusters, respectively. Finally, many respondents expressed a desire to learn more about wood products, especially in the moderate and high favourability groupings.

Clusters were also profiled on material use and past buildings designed. Most structural materials, with the exception of wood and steel, do not significantly differ between clusters. However wood use is significantly higher in the high favourability group, while steel use is significantly higher in low and moderate favourability groups. In each case, there seems to be a very clear trade off between steel and wood. In terms of past buildings designed, very few significant differences are again noted. In fact, no differences exist between clusters in terms of building height and area. However, some significant differences in end use are seen. A higher proportion of specifiers in the low favourability group design public buildings, followed by specifiers in the moderate cluster and, lastly, the high cluster. The proportion of farm structures designed in the high favourability group is significantly higher than in the low favourability group, but not the moderate grouping (that said, the proportion of farm structures designed is fairly minimal across all clusters). In the case of dwelling units, either multifamily or detached, the proportion designed by the high favourability group is significantly higher than in either of the remaining two clusters.

Looking at the breakdown of demographic characteristics in Table 5.12, very few significant differences between clusters emerge. The high favourability cluster consists of significantly more structural engineers (and less architects) than the moderate grouping. Furthermore, a significantly higher proportion of designers are self-employed in the high grouping compared to the moderate grouping. There also seems to be some interesting geographical effects between clusters. For instance, in the West / North and Central Canadian regions, the proportion of designers that are highly favourable to wood use is significantly higher than in either of the other two clusters. The proportion of respondents from the American Midwest region is higher in the moderate cluster than in the low cluster. Finally, in the American South, a significantly higher proportion of designers fall in the low favourability category compared to the other two. That said, no other significant demographic differences between clusters were observed, either in age, years at work, or number of employees.

While no statistical tests were performed on the billings per year data (due to its complicated nature), some interesting trends were noted. Looking at total billings per year, the high favourability cluster consists of a greater amount of smaller firms. In fact over, 65% of the firms sampled in this cluster bill $1,000,000 or less per year, compared to approximately 45% in both of the other groupings. At between 25% and 28% of the responses, low and moderate clusters have a greater proportion of medium-sized firms ($1,000,000 to $5,000,000) than the high favourability cluster, at approximately 16%. Finally, the low favourability grouping is more highly represented by large firms (over $5,000,000 per year) at over 30% of the mentions, with proportions for moderate and high groupings at approximately 25% and 17%, respectively. The above results are confirmed by the billings per year for buildings four storeys or less data. In the high cluster, over 70% of the respondents claim that these billings account for less than $1,000,000 of revenue per year. The comparable figures for the moderate and low groups are approximately 40% and 57%, respectively. In other words, buildings four storeys or less account for more revenue in the low and moderate favourability groups than in the high favourability group. Lastly, looking at the breakdown of billings per year for wood buildings four storeys or less, it can be seen that these types of structures account for less than $1,000,000 in revenues the majority of the time (over 90% of the respondents in each case). The major difference between clusters can be seen in the $2,000,000 to $10,000,000 range. Here, billings account for over 6% of the responses in the high favourability cluster, 1.5% of the responses in the moderate favourability grouping, and nothing in the low favourability segment.

To summarize, the most qualified and experienced designers of wood buildings four storeys or less show up in the high favourability cluster. As expected, their opinion of wood is comparatively high, as is their use. The high favourability group utilize wood much more often than either of the other two groups at the expense of steel. Logically, the low and moderate clusters use steel much more than wood with the same trade off effect. Unfortunately, the proportion of designers who intend on using more wood in future designs, although highest in the high favourability cluster, is relatively low for each grouping (never exceeding 18% of the responses). The majority of designers intend on using the same amount of wood in their designs, which, in the case of the low and moderate clusters, is comparatively modest. In terms of buildings designed, the high favourability cluster tends to concentrate more on residential structures (both multifamily and detached), while the low favourability cluster (and the moderate group, to a lesser extent) designs a greater number of public buildings.

In terms of demographics, a large proportion of designers from the West / North and Central regions of Canada are highly favourable to wood used in buildings four storeys or less, while a large proportion of designers in the Southern United States are highly unfavourable to this type of use. Somewhat inconclusive is the fact that the high favourability cluster contains significantly higher proportions of structural engineers and self-employed designers than the moderate favourability cluster (but not the low favourability group). While further analyses in these areas should be undertaken, it is clear (by inferring from these results) that these two segments account for a greater proportion of high wood users. Finally, respondents from larger firms, generally speaking, seem to be less favourable to wood use in buildings four storeys or less than those who work in smaller firms.

Cluster Analysis #2 - Segmentation of Respondents by Familiarity with Wood Products:

The second cluster analysis performed was on the familiarity to wood products data obtained from *Question 3* in *Section II* of the survey. This question asked respondents to state how knowledgeable / experienced they were with a vast array of structural and non-structural wood products. Several K-means cluster analyses were performed on the respondents using this data as input. A three cluster solution emerged as the most optimal one, both in terms of latent cluster meaning (determined by observing the final cluster means) and cluster membership. *Cluster 1*, which contained 140 respondents, refers to specifiers whose experience / knowledge of wood products is low. *Cluster 2*, at 154 respondents, refers to specifiers with moderate familiarity ratings. Finally, *Cluster 3*, at 160 respondents, refers to specifiers who consider themselves knowledgeable and experienced with the many wood products in existence. Unlike the cluster analysis above, cluster membership here is equally distributed. That is, while 33.92% of the respondents have high degrees of knowledge and experience with regards to wood products, 30.84% do not. The remaining 35.24% of the respondents fall into the moderately familiar category.

Full respondent profiles using various statistical tests were performed on each of the clusters in exactly the same manner as the previous cluster analysis. The means for each segment are seen in Tables 5.13 (design characteristics) and 5.14 (demographic information). It should be noted that a third cluster analysis, on experience /

Table 5.13: Breakdown of Design Characteristics on Familiarity with Wood Products Clusters.

Cluster: (Familiarity with Wood Products Level) (Cluster Membership)	Cluster 1 (Low) (30.84%)	Cluster 2 (Moderate) (35.24%)	Cluster 3 (High) (33.92%)
average proportion of time devoted to buildings 4 storeys or less:	68.69% *a*	78.34% *b*	82.58% *b*
proportion qualified to design wood buildings 4 storeys or less:	66.19% *a*	90.00% *b*	96.10% *b*
proportion presently designing wood buildings 4 storeys or less:	40.58% *a*	69.38% *b*	77.78% *b*
proportion whose design philosophy is conducive to wood use:	65.44% *a*	76.92% *b*	87.58% *c*
in buildings 4 storeys or less, proportion that...			
like seeing wood used as a structural material:	38.52% *a*	55.00% *b*	53.25% *b*
do not like seeing wood used as a structural material:	19.26% *b*	9.38% *a*	9.74% *a*
sometimes like seeing wood used as a structural material:	42.22%	35.63%	37.01%
in buildings 4 storeys or less, proportion that...			
intend on using *more* wood:	12.69% *b*	6.88% *a*	9.21% *ab*
intend on using *less* wood:	14.93%	16.25%	23.03%
intend on using *the same amount of* wood:	72.39% *ab*	76.88% *b*	67.76% *a*
proportion who want to learn more about wood:	62.96%	62.84%	59.57%
proportion that have been sued in their professional careers:	4.32%	10.32%	7.95%
breakdown of past material use in buildings 4 storeys or less:			
steel	39.60% *b*	25.65% *a*	24.62% *a*
concrete	17.15% *b*	10.61% *a*	9.20% *a*
wood	19.31% *a*	39.71% *b*	40.01% *b*
masonry	9.87%	11.81%	13.46%
other	0.04%	0.01%	0.00%
combination	13.30%	12.20%	12.71%
breakdown of buildings designed in the past by end use:			
offices	12.79%	12.92%	14.32%
commercial buildings	6.50%	6.51%	6.60%
industrial buildings	21.89% *b*	15.91% *ab*	10.64% *a*
hospitals	10.14% *b*	4.98% *a*	5.11% *a*
schools	13.48%	10.87%	10.41%
hotels / motels	1.63%	2.26%	2.12%
restaurants	1.99%	2.59%	2.65%
public buildings	11.35%	7.88%	8.45%
recreational buildings	1.71%	1.95%	2.28%
entertainment facilities	0.98% *a*	1.05% *a*	1.87% *b*
religious buildings	1.82% *a*	4.36% *b*	5.40% *b*
farm structures	0.14% *a*	0.52% *b*	0.87% *b*
multifamily dwelling units	3.05% *a*	6.89% *b*	8.58% *b*
seniors' residences	1.55%	2.13%	3.03%
detached homes / duplexes	6.75% *a*	14.44% *b*	14.99% *b*
commercial / residential combinations	0.96% *a*	1.10% *ab*	2.38% *b*
other	3.27% *b*	1.88% *ab*	0.30% *a*
breakdown of buildings designed in the past by building height:			
1 storey	43.42%	44.05%	44.93%
2 storeys	24.74% *a*	31.04% *b*	31.35% *b*
3 storeys	12.73%	11.58%	13.19%
4 storeys	8.17%	5.27%	4.72%
5 storeys or more	10.95% *b*	8.07% *ab*	5.81% *a*
breakdown of buildings designed in the past by building area:			
less than 10,000 square metres	67.82%	74.88%	75.73%
10,000 to 50,000 square metres	20.29%	16.49%	15.72%
over 50,000 square metres	11.12%	8.63%	8.55%

Table 5.14: Demographic Breakdown on Familiarity with Wood Products Clusters.

Cluster: **(Familiarity with Wood Products Level)** **(Cluster Membership)**		**Cluster 1** **(low)** **(30.84%)**	**Cluster 2** **(moderate)** **(35.24%)**	**Cluster 3** **(high)** **(33.92%)**
professional group:	structural engineers	34.29%	25.63%	25.32%
	architects	65.71%	74.38%	74.68%
gender breakdown:	male	92.65%	93.67%	94.81%
	female	7.35%	6.33%	5.19%
geographical breakdown:				
Canada		**19.71%**	**22.16%**	**33.77%**
	West / North Canada	4.38% *a*	5.70% *a*	14.29% *b*
	Central Canada	10.95%	12.03%	11.69%
	Eastern / Maritimes Canada	4.38%	4.43%	7.79%
United States		**80.29%**	**77.84%**	**66.23%**
	West United States	15.33% *a*	27.21% *b*	17.53% *a*
	Midwest United States	18.25%	15.82%	20.13%
	South United States	25.54%	16.46%	16.23%
	Northeast United States	21.17%	18.35%	12.34%
average age (years):		43.20 *a*	47.06 *b*	45.14 *ab*
average years practicing:		16.45	19.22	18.37
average years employed at present place of work:		9.62	11.69	11.62
proportion that are self-employed:		23.02% *a*	46.45% *b*	46.71% *b*
average number of full-time primary designers:		34.67	10.05	11.15
average number of full-time secondary designers:		8.84	2.75	1.80
average number of designers at place of work...				
that design buildings 4 storeys or less:		17.67 *b*	6.65 *a*	9.39 *a*
design buildings 4 storeys or less using wood:		2.42 *a*	3.21 *ab*	5.68 *b*
specialize in designing wood buildings 4 storeys or less:		0.72	1.41	2.47
breakdown of total billings per year:				
	under $100,000	11.01%	17.42%	18.32%
	$100,000 to $500,000	20.18%	33.33%	27.48%
	$500,001 to $1,000,000	7.34%	9.09%	14.50%
	$1,000,001 to $2,000,000	8.26%	13.64%	11.45%
	$2,000,001 to $5,000,000	15.60%	9.09%	7.63%
	$5,000,001 to $10,000,000	14.68%	6.82%	7.63%
	over $10,000,000	22.94%	10.61%	12.98%
breakdown of billings per year (buildings 4 storeys or less):				
	under $100,000	16.19%	21.37%	20.34%
	$100,000 to $500,000	22.86%	37.61%	31.36%
	$500,001 to $1,000,000	5.71%	10.26%	13.56%
	$1,000,001 to $2,000,000	14.29%	9.40%	12.71%
	$2,000,001 to $5,000,000	17.14%	8.55%	9.32%
	$5,000,001 to $10,000,000	10.48%	7.69%	7.63%
	over $10,000,000	13.33%	5.13%	5.08%
breakdown of billings per year (wood buildings 4 storeys or less):				
	under $100,000	17.42%	61.62%	21.37%
	$100,000 to $500,000	33.33%	24.24%	37.61%
	$500,001 to $1,000,000	9.09%	6.06%	10.26%
	$1,000,001 to $2,000,000	13.64%	4.04%	9.40%
	$2,000,001 to $5,000,000	9.09%	1.01%	8.55%
	$5,000,001 to $10,000,000	6.82%	2.02%	7.69%
	over $10,000,000	10.61%	1.01%	5.13%

knowledge ratings of other products (steel, concrete, and masonry) was also performed. However, the cluster profiles obtained in this analysis were, not surprisingly, very similar to those seen for wood products, albeit in reverse. That is, the low familiarity clusters for other materials were almost identical to the high familiarity clusters for wood products, and vice verse. In all likelihood, the composition of respondents in these clusters is the same, for the most part. For this reason, the cluster analysis on familiarity with other products was excluded.

As expected, the wood products familiarity profiles observed here are similar, in many instances, to the favourability profiles seen above. However, in this analysis far more statistical differences are observed, probably due, in part, to the cluster memberships being more evenly distributed here. Looking first at the summary of design characteristics in Table 5.13, it can be seen that the low familiarity cluster differs on several variables pertaining to buildings four storeys or less. This segment spends significantly less time designing these types of structures than either the moderate or high familiarity clusters (where no significant differences were observed). Furthermore, fewer respondents in this group are qualified and experienced in the design of wood buildings four storeys or less. These results are confirmed by the fact that only 65.44% of the respondents in the low familiarity cluster feel that their design philosophies are conducive to the use of wood. The proportion of designers that concur is significantly higher in both the moderate and high groupings (each also significantly different at 76.92% and 87.58%, respectively).

Over half of the respondents in the moderate and high familiarity groupings like to see wood used as a structural material in buildings four storeys or less, while significantly fewer respondents (less than 40%) in the low cluster agree. In fact, approximately 20% of the respondents in the low cluster do not like seeing wood used in this way, while, in the statistically similar moderate and high clusters, proportions did not exceed 10%. No differences are observed between clusters of individuals who sometimes like seeing wood used in buildings four storeys or less, with proportions ranging between 35% and 43%. Asked about future intentions, a significantly higher proportion of respondents in the low cluster (12.69%) state that they would use more wood than in the moderate cluster (6.88%), while the high cluster was statistically similar to both groups (falling somewhere in between at 9.21% of the responses). That said, no differences were observed between clusters when specifiers were asked whether they would use less wood in the future. Finally, the majority of respondents in each cluster intend on using the same amount of wood in the future, with the moderate grouping being significantly higher than the high grouping, and the low grouping falling somewhere in between the two.

In terms of past material use, steel and concrete have significantly higher shares in the low familiarity cluster than in either of the other two (with the share of steel being higher in each case). Conversely, wood use in the moderate and high groupings is significantly higher than in the low cluster. With regards to buildings, the respondents in the low familiarity cluster design a significantly higher proportion of industrial buildings compared to those in the high familiarity group (but not the moderate group). This same trend is seen in the other buildings category (which refers to nonbuilding structures mostly), although to a much lesser degree. As well, the proportion of hospitals designed is higher in the low cluster than either of the other two. In many of the buildings, the past design proportions are statistically similar in the moderate and high familiarity clusters, but significantly higher than the low familiarity group. These include religious buildings, farm structures, multifamily dwelling units, and detached homes / duplexes. In one case, entertainment facilities, the proportion designed in the high familiarity segment is significantly higher (albeit small) than either of the other two groupings. In the case of commercial / residential buildings, the proportion designed in the high familiarity grouping is significantly higher than in the low familiarity grouping, but not the moderate cluster. In terms of height, significant differences are seen in two storey buildings and buildings five storeys or more. Respondents in the moderate and high familiarity clusters design significantly more two storey buildings than in the low cluster. Conversely, respondents in the low cluster design a significantly greater proportion of buildings five storeys or more compared to the low cluster (but not the moderate one). Finally, it should be stated that no cluster differences are observed in the analysis of building area.

Looking at the breakdown of demographic information seen in Table 5.14, very few distinctions between clusters again emerge. That said, there does appear to be an age effect. Designers in the moderate cluster are significantly older than those in the low familiarity group, but not the high familiarity group. As well, higher proportions of designers in the moderate and high groups (between 46% and 47%) are self-employed compared to the low grouping (at just over 23%). The average number of employees that design buildings four storeys or less at the respondents' places of work is significantly higher in the low familiarity group than in either of the other two. However, the average number of employees that design wood buildings four storeys or less in this cluster is significantly less than in the high familiarity category, but not the moderate one. No differences are observed in the number of employees that specialize in these types of wood structures; the numbers are all equivalently small. Finally, with the exception of the Western regions, no geographical cluster differences are observed. However, the proportion of designers in the high familiarity cluster is significantly greater in West / North Canada. In the West United States, the same trend is observed for the moderate segment.

Again, while no statistical tests were performed on the billings per year data, some notable trends emerged. Looking at total billings per year, it can be seen that approximately 60% of the sampled firms represented in the moderate and high clusters are small (less than $1,000,000 per year in billings), compared to just over 38% in the low cluster. Medium sized firms (between $1,000,000 and $5,000,000 per year in billings) are more evenly distributed throughout the clusters accounting for approximately 24%, 22%, and 19% of the responses in the low, moderate, and high familiarity groupings, respectively. Finally, at over 37% of the responses, the low familiarity cluster seems to be comprised of a higher proportion of large firms (over $5,000,000 in billings per year) compared to the moderate and high clusters, at approximately 17% and 20%. These results are reflected in the billings per year for buildings four storeys or less data. Here, these types of structures account for less than $1,000,000 in revenues in 65% to 69% of the firms in the moderate and high familiarity segments. The comparable figures for the low cluster is slightly below 45%, which is to say that buildings four storeys or less account for more revenue than firms in the moderate and high clusters. Lastly, looking at the billings per year for wood buildings four storeys or less, it can be seen that over 90% of the respondents in the moderate grouping claim that these structures account for less than $1,000,000 in revenues. The comparable figures for the low and high clusters are approximately 60% and 70%, respectively. In other words, in the two extreme familiarity groupings, wood structures account for a larger proportion of revenues. This is expected in the high familiarity cluster, where over 30% of the billings per year for wood buildings four storeys or less exceed $1,000,000. More surprising is the fact that these types of structures account for more than $1,000,000 in revenues over 40% of the time in the low familiarity cluster.

To summarize, the most qualified and experienced designers of wood buildings four storeys or less show up in the clusters that are moderately or highly familiar with wood products. As expected, their opinion of wood is comparatively high, as is their use. These two groups utilize wood much more often than the low familiarity cluster at the expense of steel and, to a lesser degree, concrete. In the low familiarity grouping, concrete use increases less than 10%, while increases in the use of steel are effectively double this amount. Unfortunately, the proportion of designers who intend on using more wood in future designs is relatively low for each grouping (never exceeding 13% of the responses). That said, the highest proportion of designers who would like to use more wood in the future occurs in the low familiarity cluster, which implies that this segment has a desire to learn more about wood products. The majority of designers, especially in the moderate grouping, intend on using the same amount of wood in their designs, while the remaining designers, between 14% and 23% in each case, intend on using less. This is especially relevant in the low familiarity cluster, where wood use is low but the desire to learn more about wood products is high. In terms of buildings designed, the low familiarity cluster tends to favour industrial buildings, hospitals, and, to a lesser degree, nonbuilding structures. The moderate and high familiarity clusters seem to concentrate more on buildings typically associated with wood use, like residential structures (both multifamily and detached), farm structures, and religious buildings. On its own, the high familiarity segment is seen to design a greater number of entertainment facilities and commercial / residential combinations (neither of which is particularly common). In terms of building size, the low familiarity cluster designs a greater proportion of larger buildings (in this case, five or more storeys), while the moderate and high familiarity clusters concentrate more on smaller scale (two storey) projects.

In terms of the demography of the clusters, a large proportion of designers from the Western regions of both Canada and the United States are either highly or moderately familiar with wood products. Apart from this observation, no other regional trends are observed. In terms of workplace environments, much greater proportions of designers in the moderate and high familiarity groupings are self-employed and, for the most part, older. The number of employees per firm that design buildings four storeys or less is higher in the low familiarity grouping than in either of the other two, although a greater proportion of employees design these types of structures with wood in the high familiarity cluster. Finally, respondents from larger, more diverse firms seem less familiar with wood products, comparatively speaking (although they often use wood in their designs). In general, two conclusions can be drawn from this analysis. The first is that familiarity for wood products increases the further west one goes. Second, an underlying tendency exists whereby familiarity with wood products increases as firm size decreases.

Multiple Discriminant Analyses:

Multiple discriminant analysis (M.D.A.) is a multivariate statistical technique that is analogous to multiple (linear) regression. Both methods make use of linear combinations of metric, independent variables to describe the behaviour of a dependent variable. However, where the dependent variable in multiple regression is metric, in multiple discriminant analysis, it is categorical. As such, the objective of multiple discriminant analysis is to obtain a linear solution of independent variables that will discriminate between two or more a priori defined groups and enable the user to predict which of the groups an observation will fall into (based on the set of independent variables). This is achieved by a process, like cluster analysis, which minimizes the within-group variance and maximizes the between-group variance, to obtain a linear discriminant function, as follows:

$$Z = W_1X_1 + W_2X_2 + \ldots + W_mX_m$$

where: Z = *the discriminant score;*

X = *the independent variables;*

m = *the number of independent variables;*

W = *the discriminant weights (coefficients).*

With this discriminant function, the linear combination of independent variables and discriminant weights is used to obtain each observation's discriminant score. The discriminant score is then compared to a "cutting score", which is based on the number of observations and the "centroid" or mean in each group. Observations whose discriminant scores fall below the cutting score are placed into one group, while observations whose scores exceed this criterion are placed into the other. In this way, easily obtained independent variables (from future data sets) can be used to predict into which of the a priori defined groups each observation would fall. It should be noted that two group solutions require only one discriminant function for predictive purposes, while three group solutions require two, and n groups require $n - 1$ solutions.

In this analysis, the objective was not to obtain discriminant functions for predictive reasons. Rather, it was to determine the extent to which each of the independent variables discriminated between distinct sets of groups. This can be achieved by observing the magnitude of each coefficient or discriminant weight. The larger the weighting, the more discriminating power it has in that function. Furthermore, the sign of the coefficient shows the direction in which each independent variable discriminates. Negative coefficients contribute in the direction of the group with the lower centroid value, while positive coefficients contribute in the direction of the group with the higher one. That said, the use of discriminant weights in this manner is problematic due to the fact that, like multiple regression, the coefficients are subject to multicollinearity and instability. For this reason, the comparable use of discriminant loadings, which measure the associations between each of the independent variables and the discriminant function, is more frequently recommended.

In total, six multiple discriminant analysis models were attempted in this study: three 2-group models and three 3-group models. The predefined groups (dependent variables) were based on answers obtained from six different questions in *Sections III* and *V* of the survey, each of which categorized respondents according to some facet of wood use. The questions, and their respective response breakdowns (dependent variable groupings), were as follows:

Section III / Question 1:

Do you presently design buildings four storeys or less using wood as the main structural component?

yes: 320 (62.02%) *no: 196 (37.98%)*

Section III / Question 2:

Do you intend on using more or less wood in future designs?

yes: 45 (8.86%) *no: 95 (18.70%)* *the same: 368 (72.44%)*

Section III / Question 3:

In general, do you like seeing wood used as a structural material in buildings four storeys or less?

yes: 251 (49.12%) *no: 70 (13.70%)* *sometimes: 190 (37.18%)*

Section III / Question 4:

Do you feel that you are qualified to design buildings four storeys or less in wood?

yes: 436 (84.33%) *no: 81 (15.67%)*

Section III / Question 10:

Would you want to learn how some of the aforementioned problems (drawbacks to wood) can be overcome?

yes: 291 (60.25%) *no: 40 (8.28%)* *already know how: 152 (31.47%)*

Section V / Question 5:

Would you say that your design philosophy was conducive to the use of wood as a structural material in buildings four storeys or less?

yes: 387 (76.33%) *no: 120 (23.67%)*

In an attempt to obtain linear functions which could discriminate between the above groupings, several demographic and design characteristics were incorporated into the models as independent variables. Unfortunately, due to the nature of the analysis, the independent variables were limited to measures that were metric (excluding categorical variables like gender, residence, billings per year, etc. from the study). Ultimately, six independent metric variables were utilized as follows: *(1) age of designer; (2) years as a practicing designer; (3) years at present place of work; (4) number of primary designers at present place of work; (5) proportion of buildings independently specified by designer (respondent);* and, *(6) proportion of workload devoted to designing buildings four storeys or less.* Thus, the objectives of these multiple discriminant analyses were two-fold. The first task was to ascertain whether or not these demographic / design characteristics could be used to differentiate between the wood use groups seen above. If indeed they could be, the second task was to determine the relative influence and direction of each of these variables in discriminating between the wood use groups.

To this end, the six multiple discriminant analyses were performed on the wood use data sets incorporating the various demographic / design characteristics. The Mahalanobis stepwise procedure, which enters (or does not enter) independent variables separately based on their discriminating power, was not considered here due to the fact the number of independent variables was not large and the objective was not to obtain an efficient, predictive model. Rather, the simultaneous (with prior probabilities) method, whereby independent variables are entered and considered concurrently, was used. This way, the resulting discriminant functions contained information pertaining to each of the independent variables, and not just the ones with the highest discriminating powers.

Various diagnostic and validation tests used in multiple discriminant analysis (some analogous to multiple regression) are seen for each of the six functions in Tables 5.15 (for the 2-group models) and 5.16 (for the 3-group models). The chi-square ratio refers to the significance of each model. Beneath the chi-square ratios are their respective probabilities. A probability level which falls below 0.05, in this case, means that the model is significant, while a probability level exceeding 0.05 means that the model is not well defined and should not be used to discriminate between groups. Squaring the canonical correlation gives the proportion of the variance in the dependent variable that is accounted for by the model (seen below it). The hit ratio refers to the proportion of respondents that are correctly grouped using the obtained discriminant function. For the discriminant function to be valid, the hit ratio should exceed the proportional chance criterion seen above it. This statistic refers to the

Table 5.15: Diagnostic / Validation Tests of 2-Group M.D.A. Models.

Section / Question:	III / 1	III / 4	V / 5
chi-square ratio	19.693	24.803	6.940
model significance	0.003	0.000	0.327
canonical correlation	0.213	0.238	0.128
% variance in the dependent variable accounted for by model	4.54%	5.65%	1.63%
proportional chance criterion	52.77%	73.16%	63.21%
hit ratio	65.50%	84.26%	57.56%
accept or reject model?	accept	accept	reject

Table 5.16: Diagnostic / Validation Tests of 3-Group M.D.A. Models.

Section / Question:	III / 2	III / 3	III / 10
chi-square ratio	1.989	1.516	1.701
model significance	0.851	0.911	0.889
canonical correlation	0.069	0.060	0.065
% variance in the dependent variable accounted for by model	0.47%	0.36%	0.42%
proportional chance criterion	57.56%	39.25%	48.14%
hit ratio	74.12%	50.12%	61.61%
accept or reject model?	reject	reject	reject

Table 5.17: Diagnostic / Validation Tests of Revised 3-Group M.D.A. Models.

Section / Question:	III / 2	III / 3	III / 10
chi-square ratio	8.806	1.669	8.127
model significance	0.185	0.948	0.229
canonical correlation	0.284	0.080	0.170
% variance in the dependent variable accounted for by model	8.04%	0.64%	2.89%
proportional chance criterion	55.36%	64.56%	85.53%
hit ratio	66.36%	76.98%	89.36%
accept or reject model?	reject	reject	reject

proportion of correct classifications that can be obtained without the aid of a discriminant function (i.e., by guessing).

The results in Tables 5.15 and 5.16 show that, in each case, the hit ratio exceeds the proportional chance criterion. However, the proportion of variance explained is low in the 2-group models (1.63% to 5.65%) and very low in the 3-group models (0.36% to 0.47%). As well, all of the 3-group models, and one of the 2-group models, are not significant. For these reasons, only *Questions 1* and *4* from *Section III* can be accepted for further analysis. Here, although the variance accounted for is low in each case, the models are highly significant. That is, the discriminant functions are well defined, albeit somewhat noisy. It should be noted that an attempt was made to re-run the 3-group models using only 2-groups in each case. In *Section III*, the *same, sometimes,* and *already know how* categories were excluded from *Questions 2, 3,* and *10*, respectively. The results, shown in Table 5.17, again indicated that these models are clearly not significant and should be rejected (although the hit ratios exceeds the proportional chance criteria in each case, and *Question 2* accounts for a comparatively high amount of variation).

The centroids (group means), cutting scores, discriminant weights (coefficients), and discriminant loadings for each of the two successful discriminant functions can be seen in Table 5.18. For *Question 1* in *Section III*, the centroid for the group that presently designs buildings four storeys or less using wood as the main structural component is -0.171, while the centroid for the group that presently does not design these structures is 0.277. For *Question 4* in *Section III*, the centroids for the two groups that are and are not qualified to design buildings four storeys or less in wood are 0.106 and -0.560, respectively. In each case, the discriminant weights can be used in conjunction with the independent variables to predict the group into which each observation would fall. For *Question 1*, respondents whose discriminant scores exceed the cutting score would be classified in the *no* group (presently not designing wood buildings four storeys or less), while, for *Question 4*, respondents scoring higher than the cutting score would be classified in the *yes* group (qualified to design wood buildings four storeys or less).

Although this predictive ability is of some interest, the objective of this analysis is to determine how each of the demographic / design variables contributes to the discriminating powers of the functions. In other words, this study is attempting to determine which, if any, of the demographic / design variables are conducive to the use of wood in applications four storeys or less. As previously stated, this is best achieved by observing the magnitude and sign (in relation to the centroids) of the discriminant loadings.

Table 5.18: Discriminant Functions of Successful 2-Group M.D.A. Models.

Section / Question:	III / 1		III / 4	
centroid 1 (yes)	-0.171		0.106	
centroid 2 (no)	0.277		-0.560	
cutting score	0.105		-0.453	
Discriminant Function Variables:	**Discriminant Weights**	**Discriminant Loadings**	**Discriminant Weights**	**Discriminant Loadings**
age of designer	-1.179	-0.102	-0.314	-0.079
years as a practicing designer	1.539	0.235	-0.317	-0.107
years at present place of work	-0.313	-0.131	0.627	0.266
# of primary designers at place of work	0.533	0.560	-0.565	-0.540
% of buildings independently specified by designer	-0.350	-0.380	0.485	0.531
% of workload devoted to buildings 4 storeys or less	-0.202	-0.228	0.461	0.459

Looking first at *Question 1*, several interesting conclusions can be drawn pertaining to whether or not respondents presently design wood buildings four storeys or less. The variable that loads highest in this function is the *number of primary designers at place of work.* This is the most important demographic characteristic in determining whether or not respondents presently design wood structures. The fact that it is positive and the *no* centroid is negative indicates that the larger the firm is, the less likely respondents are to design wood buildings four storeys or less. The second highest loading variable is the *proportion of buildings independently specified by designer*. This variable contributes negatively, which is to say that respondents who specify buildings on their own are more likely to use wood in buildings four storeys or less. Two independent variables, *years as a practicing designer* and the *proportion of workload devoted to buildings four storeys or less*, load moderately high. As a result, they do not contribute as much to the discriminating power of the function as the above variables. That said, in the former case, the longer respondents have been in practice, the less likely they are to design wood structures four storeys or less. In the latter case, respondents who devote much of their time to buildings four storeys or less are more likely to design these types of structures with wood. The two remaining variables, *age of designer* and *years at present place of work*, did not load highly at all. What contribution they do make is negative, which is to say that, as years increase in each case, the likelihood of wood use increases, as well.

As expected, the results obtained in *Question 4*, which classifies respondents according to whether or not they feel qualified to design wood buildings or not, are similar to those seen above. While the *number of primary designers* *at place of work* again loads highest, the *proportion of buildings independently specified by designers* loads very high, as well. The former variable contributes negatively, which in this case means that the more designers a firm employs, the less qualified respondents tend to be in designing wood buildings four storeys or less. The latter variable contributes positively, which means that respondents who independently specify buildings more often feel more qualified to design these types of structures. Also loading highly and positively is the *proportion of workload devoted to buildings four storeys or less* variable. Here, respondents who devote more time to buildings four storeys are more qualified to design these types of structures in wood. The *years at present place of work* variable loads moderately high and positively, as well. To some degree, the longer a respondent has been employed at their present place of work, the less likely it is that they feel qualified to design wood buildings four storeys or less. Finally, the two remaining variables, *age of designer* and *years as a practicing designer*, do not load highly at all. What contribution they do make is negative, which is to say that, as years increase in each case, the likelihood of respondents feeling qualified to design wood structures decreases.

To summarize, very few differences are observed between groups who presently do not design buildings and groups who do not feel qualified to do so. In each case, three factors are extremely influential in determining the extent to which they do not design these types of structures. First, firms which employ larger numbers of designers tend to specify wood less often in buildings four storeys or less. Second, designers who incorporate other parties into the material selection process tend to specify wood less often in these types of structures. Finally, to a lesser extent, the less time that designers devote to buildings four storeys or less, the less likely they are to use wood in these types of applications. It should be noted that these characteristics are, by no means, the only ones that can be utilized to discriminate between the users and non-users of wood products in buildings four storeys or less. Several variables, like gender, place of residence, and billings per year, had to be excluded due to the fact that they were not metric in nature.

CHAPTER 6

SUMMARY AND DISCUSSION

In this section, the major findings of the research are reiterated and inferred onto the population of designers as a whole. Recommendations for increasing the use of wood in the nonresidential sector are also offered, based on these results. Finally, potential topics for studies that incorporate additional analyses of this data are briefly touched upon. However, before any of these subjects can be discussed, the various forms of error that can enter into an analysis of respondents sampled with a mail survey must be explained and accounted for.

Notes on Error in Mail Surveys:

Ultimately, the goal of most mail surveys is to infer results obtained from a representative sample of respondents onto the entire population in question. This said, mail surveys are subject to two types of error, *random sampling error* and *systematic error* or *bias*, each of which makes the process of inference much more complicated than simply reporting the results of the questionnaire. In order to accurately convey information pertaining to populations as a whole, these two types of error must be accounted for and minimized. These errors, and their respective methods of redress, are each discussed in turn.

Random Sampling Error:

Random sampling error is defined as "the statistical fluctuation that occurs because of chance variation in the elements selected for a sample *(39)*." In other words, the results of any representative sample would likely differ from results obtained by a census (whereby every element in the population is surveyed). It is this fluctuation that is thought of as random sampling error. While it cannot be eliminated, random sampling error can be reduced by increasing sample size. Furthermore, this type of error can be estimated by means of confidence limits *(39)*. It should be noted that the size of the sample in this analysis is comparatively large and confidence limits are extensively used to report key findings in the upcoming discussion.

Systematic Error:

Systematic or *nonsampling error* is defined as "the error resulting from some imperfect aspect of the research design that causes respondent error or from a mistake in the execution of research *(39)*." Generally speaking, it manifests itself in form of results persistently deviating "in one direction from the true value of the population parameter *(39)*." This so-called "sample bias", though impossible to eliminate, can be minimized by careful and thoughtful attention to survey design and implementation.

The two major categories of systematic error are *administrative error* and *respondent error*. *Administrative error* is essentially a mistake or oversight "caused by the improper administration or execution of a research task *(39)*." In mail surveys, the two most commonly encountered forms of administrative error are *sample selection error*, caused by a poorly executed sampling procedure or an inadequate sampling design (and resulting in an unrepresentative sample), and *data processing error*, which occurs as a result of incorrect data coding, entry, editing, analyses, and/or tabulation *(39)*. In this study, administrative error was minimized by adhering both to a strict attention to every detail of the sampling procedure (see Chapter 3) and a rigid examination of each data processing phase.

Respondent error is defined as "the sample bias resulting from some respondent action or inaction *(39)*." Thus, as the definition implies, this error takes on two forms: *response bias* and *nonresponse error*. These two types of error are, perhaps, the most critical in terms of being able to infer results from a survey onto the population as a whole. Each is discussed in turn.

Response Bias:

Response bias is defined as "the bias that occurs when respondents tend to answer questions in a certain direction that consciously or unconsciously misrepresents the truth *(39)*." As the definition suggests, there are two ways in which an individual can distort information: *deliberate falsification* or *unconscious misrepresentation*. Occasionally, respondents deliberately falsify information to conceal personal information, appear intelligent or mediocre, avoid embarrassment, or purposefully skew results. Conversely, some respondents may attempt to be honest and truthful, but may unconsciously answer questions incorrectly, usually due to a case of misunderstanding questions, being given too little information to correctly answer questions, or being unable to adequately express their feelings *(39)*. Again, there is no way of avoiding this type of bias. However, it can be minimized in the design and implementation of questionnaires. In this study, procedural guidelines set forth by the *Total Design Method*

(10) were strictly followed. First developed in the 1970's, this method describes how each question should be designed and ordered, as well as how the mail-out should be executed (refer to Chapter 3). Rigid adherence to the procedures prescribed by the *Total Design Method* has been shown, not only to reduce response bias, but to maximize response rate *(10)*.

This brings into question the larger issues of *validity* and *reliability*, both of which are required to infer survey results onto a population. *Validity* refers to measurement error or "the ability of a scale to measure what it was intended to measure *(39)*". This is especially prevalent in the case of measuring attitudes, which are, at best, difficult to define and observe. That said, very little exists by way of testing the validity of mail questionnaires. For the most part, designers of surveys must rely on agreement among professionals that a scale is accurately measuring what it is intended to measure ("face validity"). Correlation of a measured variable with other similar variables ("criterion validity") and hypothetical theories ("construct validity") can also be used to show that a scale is valid *(39)*.

Reliability is "the degree to which measures are free from random error and therefore yield consistent results *(39)*." In other words, the measuring instrument should be reproducible both in terms of *repeatability* over time and *internal consistency* within the questionnaire. While no method, apart from re-administering the survey, exists to measure repeatability, internal consistency can be easily measured by including several similar questions in a survey and comparing the results. That said, the one known method of increasing the reliability of a survey instrument is to maximize response rates.

In this study, *face validity* was met by adhering to scales and question formats known to be valid measures of behaviour. Generally speaking, accepted underlying metric scales were extensively used to measure beliefs, attitudes, perceptions, and facts (see Chapter 3 for further details). Although too numerous to recount here, *construct validity* was met in several instances where the results obtained in this analysis were in complete agreement with the theories expounded by researchers, architects, and structural engineers in the preliminary studies of this report (Chapters 1, 2, 4, and 5). In terms of *reliability*, the response rate of 21.35% obtained in this study was well within the range for acceptable population inferences *(5, 20)*, while the issue of *repeatability*, although important, was not considered critical here because results were limited to a single point in time (that said, the upcoming section shows that there was some degree of temporal repeatability in the results). Finally, because several like questions were posed in the survey (see the Building Design, Building Material Use, Education / Promotion, and Environmental Issues sections in Chapter 4), both *reliability* and *validity* could easily be tested. In each case, there was remarkable agreement between the similar inquiries. That is, the questionnaire met both the conditions of *criterion validity* and *internal consistency.*

Nonresponse Error:

Perhaps the single most critical form of bias in mail surveys is *nonresponse error.* Generally speaking, this is the usually the limiting factor in not being able to infer results onto the entire population simply because it is the least controllable form of error. Unlike the above errors, attention to survey design and implementation does not necessarily ensure a successful reduction in nonresponse bias. That said, nonresponse error can be thought of as "the statistical differences between a survey that includes only those who responded and a perfect survey [or census] that would also include those who failed to respond *(39)*." In other words, it is the error caused by those people who refuse to cooperate in the survey or cannot, for some reason, be contacted. It is essential to ensure that those who did respond to the questionnaire are representative of those who did not (i.e., statistically similar). Otherwise, nonresponse error has occurred in the survey and true population parameters cannot be estimated without bias *(10)*. To avoid this, it is imperative that the nonresponse rate be minimized. Essentially, this is achieved by maximizing response rates and encouraging nonrespondents to reply.

Two methods, both of which examine possible biases in response patterns, are commonly recommended for detecting the presence of nonresponse error. Demographics of the sample can be compared to available demographic information for the population *(39)*. In this study, demographic information pertaining to the geographical breakdown of the population of designers is seen in Table 3.1. This table shows the distribution of respondents (by geographical stratum) that were asked to participate in the study. Since the participants in this study were selectively sampled (by address) from the entire population, the proportion of designers in each stratum is, by definition, representative of the population as whole. These proportions can then be compared to the actual geographical distribution of responses seen in Table 4.4 to test for nonresponse error. In fact, this is exactly what was done. A series of two-tailed z-tests ($\alpha = 0.05$) were used to compare the population proportions with the response proportions. In each case, no significant difference was observed. That is, no bias pattern in response was observed on this particular demographic characteristic. Although not entirely conclusive, it is indicative of the fact that there is little or no nonresponse error entering into the analysis.

The presence of nonresponse error can also be tested by making additional efforts "to obtain data from the underrepresented segments of the population *(39)*". Results of the survey are then compared to those obtained from the underrepresented groups in an attempt to detect patterns in nonresponse bias. An argument can be made that, by having two separate mailouts in this study, communication with "nonrespondents" has already been accomplished. In effect, those who answered the first questionnaire can be thought of as the respondents, while those who answered the second questionnaire can be thought of as the underrepresented segment who required more encouragement to fill out the questionnaire (although both groups were analyzed at once). That said, these two mailout groups can be compared to detect nonresponse. In fact, this is what was done. Due to the magnitude of information in the study, means of only six key variables (pertaining to building design under four storeys, wood use, and workplace characteristics) were tested in this manner. Depending on the nature of the variable, one of three different statistical tests (two-tailed z-tests, two-tailed t-tests, and two-tailed t-tests with arcsin transformations) were utilized to compare means of the two mailout groups. The means for both groups on each of the six variables are seen in Table 6.1. Each variable's respective statistical test, as well as the question in the survey from which the data was obtained, are also presented. Again, no significant differences were observed between the two mailout groups on any of the tested variables. That is, there does not seem to be any form of response bias in the data. This

Table 6.1: Comparison of Several Key Variables by Mailout.

Variable:	**Mailout 1 Mean**	**Mailout 2 Mean**
proportion of buildings that have had structural components independently specified: (2-tailed z-test on Question 2, Section V)	51.73%	50.18%
proportion presently designing buildings 4 storeys or less: (2-tailed z-test on Question 1, Section III)	64.99%	57.06%
proportion of design workload devoted to buildings 4 storeys or less: (2-tailed t-test with arcsin transformation on Question 12, Section VII)	75.72%	76.83%
proportion of design workload devoted to nonresidential structures: (2-tailed t-test with arcsin transformation on Question 3, Section I)	64.75%	68.71%
proportion of past wood use: (2-tailed t-test with arcsin transformation on Question 4, Section I)	34.59%	31.12%
number of years in practice: (2-tailed t-test on Question 5, Section VII)	18.77	18.47

information, coupled with the demographic analysis above, supports the claim that nonresponse error, if it indeed exists here, is not a concern in this analysis. It also shows that the survey instrument is *reliable* in terms of repeatability.

Inference onto the Population:

The facts here seem to indicate that results obtained in this analysis can, indeed, be inferred onto the entire population of architects and structural engineers in North America. Wherever possible, systematic error was minimized by a careful attention to survey design, mailout execution, and data processing. This served, not only to reduce response bias and administrative error, but to increase response rates, as well as the reliability and validity of the survey instrument. Nonresponse error, which is more difficult to control, does not seem to be an issue in this study. Finally, although random sampling error can never be eliminated, it is accounted for in the upcoming discussion of key findings by means of 95% confidence limits.

Key Findings:

The key findings of this research are discussed in three sections. The first section, *Structural Material Use*, deals with, not only the use of wood and other materials in buildings four storeys or less, but also the factors affecting structural material use. The second section, *Building Design*, is a discussion of the various types of structures that are designed and the building materials that are typically used in these applications. The third section, *Specifiers of Structural Materials*, profiles designers on a number of demographic and design-related characteristics. Wherever pertinent, the use of 95% confidence limits was incorporated into the analysis to facilitate inferences onto the entire population of North American specifiers. That is, the population mean occurs within a 95% interval constructed around (plus or minus) the sample mean. In cases like this, results should be extrapolated onto the population as a whole in the following manner: *in nineteen out of twenty samples (taken similarly), a confidence interval constructed in this way will contain the population mean.*

Structural Material Use:

Structural material use is discussed in two parts: the use of wood products and the use of other materials like steel, concrete, masonry, material combinations, and alternative materials. In each case, relative use is reported, along with a discussion of various product attributes and familiarity levels. However, the analysis of wood products use is much more in-depth.

The Use of Wood Products:

Wood Use Levels:

The past share for wood products use in buildings four storeys or less is 33.36% [± 4.01%]. This translates into a per respondent average of 9.78 [± 3.16] structures that were built in 1993, making wood North America's most widely used structural material in buildings four storeys or less. That said, several geographical trends are also noted. The market shares for wood use in the seven regions analyzed here are reported, in order of magnitude (the wider confidence intervals are a result of smaller per stratum sample sizes). The average number of wood buildings designed in 1993 per specifier appear parenthetically alongside the shares.

- West / North Canada: 51.98% [± 13.09%], (17.90 [± 9.60] buildings);
- West United States: 46.76% [± 9.28%], (9.66 [± 4.59] buildings);
- Eastern / Maritimes Canada: 35.88% [± 17.16%], (10.52 [± 7.81] buildings);
- Northeast United States: 34.54% [± 10.17%], (9.51 [± 2.10] buildings);
- Central Canada: 26.54% [± 11.17%], (15.47 [± 10.52] buildings);
- Midwest United States: 22.39% [± 8.25%], (8.96 [± 9.17] buildings);
- South United States: 22.18% [± 8.02%], (3.40 [± 8.05] buildings).

Wood use is highest in the western regions (West / North Canada and West United States). The second highest use areas occur in the eastern regions (Eastern / Maritimes Canada and Northeast United States). The remaining regions are seen to have comparatively low levels of wood use (Central Canada, Midwest United States, and South United States). It is interesting to note that, in Canada, the average number of wood structures designed in 1993 is higher than in the United States. In general, Canadian specifiers design more, likely smaller, wood structures than their American counterparts. However, the large amounts of variation seen in each region is indicative of the fact that, across North America, there are specifiers who design very many wood structures (possibly homes), while others design few, if any.

In terms of design preference, wood ranks second only to (and closely behind) steel. That said, 84.33% [± 3.13%] of specifiers feel qualified to design buildings four storeys or less using wood as the main structural component, while only 62.02% [± 4.22%] actually do so. Of more concern is the fact that only 8.86% [± 2.46%] of designers intend on using more wood in the future, while 18.70% [± 3.39%] intend on using less. The majority of designers, 72.44% [± 3.89%], have no intention of changing their usage levels one way or the other. By segmenting the population of designers into the users and non-users of wood (i.e., those that presently design and/or feel qualified to design buildings four storeys or less), three interesting trends are noted. First, firms that employ less designers tend to specify wood in buildings four storeys or less more often than larger firms. Second, designers who specify structural materials independent of other parties tend to use wood more often in these types of structures. Third, the more time that designers devote to buildings four storeys or less, the more likely they are to use wood in these types of applications.

In buildings four storeys or less, wood is most likely to be used in the nonstructural application of interior trim / detail. The likelihood of wood use in roof systems and interior partitions is seen as moderate. Finally, wood is least likely to be used in exterior wall systems, floor systems, and exterior cladding.

Product Attributes:

Wood products possess several qualities, both positive and negative, according to the specifiers of structural materials in buildings four storeys or less. It is interesting to note that these attributes are, for the most part, universal across all regions. Also notable is the fact that the ratings for wood are, comparatively speaking, either very high or very low. That is, specifiers seem to perceive the attributes of wood products very strongly, either in the positive or negative direction. In order of magnitude, the five most highly rated positive qualities for wood are as follows:

- it is warm and inviting;
- it is simple to install;
- it is attractive in appearance;
- it is inexpensive to install;
- tradespeople are readily available.

Conversely, the five most highly rated negative qualities for wood are as follows:

- it is combustible;
- it is not fire resistant;
- its quality is not consistent;
- it is not priced consistently;
- it is not long-lasting.

Thus, on the upside, wood is seen as an attractive material which is relatively simple and inexpensive to install. However, it is also thought of as a short-term material of low quality, lacking in price consistency and fire resistance. All of the above product attributes for wood can be summarized according to similarities between variance structures among respondents. In other words, for certain sets of common attributes, more variation is accounted for (specifiers are more alike with respect to their responses). For wood products, the three sets of attributes which explain the highest amount of variation among specifiers are material properties, economic considerations, and material / price consistency. The first and last sets of attributes are considered drawbacks to wood use, while the middle set is considered beneficial. Other sets of attributes, which account for less variation, include material adaptability / simplicity, building costs, understandability of codes, and design / aesthetic concerns. Each of these sets of attributes is considered advantageous to wood use.

Related to the above findings are the four most commonly cited drawbacks to wood use in buildings four storeys or less (i.e., each with more than 10% of the responses). They are, in order of response frequency:

- the fact that wood burns;
- the fact that wood deteriorates / rots;
- the fact that wood is variable / inconsistent;
- the fact that wood shrinks and swells.

With the exception of the American South, the single-most cited drawback to wood use in every region of North America is the fact that wood burns. In the Southern United States, the fact that wood deteriorates / rots is the most frequently mentioned problem. This problem is also very pronounced in every region but Central and Eastern / Maritimes Canada. Specifiers in the West United States region commonly mention the fact that the variable / inconsistent nature of wood is a serious detriment to use. This is also true, to a lesser extent, in Central Canada and the Northeast United States. In the remaining regions, the variability / inconsistency issue is not as frequently cited. Finally, Canadian designers consider the fact that wood shrinks and swells to be more problematic than American designers. It should also be noted that 60.12% [± 4.36%] of designers would like to learn more about how some of these drawbacks can be overcome, while the remaining designers either do not or already know how.

The majority of specifiers feel that buildings four storeys or less made primarily out of wood are easy to build, comfortable, attractive, and functional. To a lesser extent, these structures are also considered inexpensive to build, and well insulated. However, for the most part, they are not considered long-lasting or sound-proof. Designing with wood is largely thought of as simple and gratifying. However, many respondents also feel that it is time-consuming. Approximately half of the designers feel that, with wood, design calculations and connections are simple while building codes are understandable. However, the majority of designers feel that fire codes are not very understandable and that fire protection is difficult to build into wood structures. Finally, while slightly less than 20% of the designers feel that rot / pest damage is overwhelming with wood, only 40% do not.

For the most part, wood products are seen as being less costly than alternative structural materials in terms of material expenses, building installation, labour, and total building costs. However, no clear trends in cost savings are noted in the design and finishing phases of construction. Generally speaking, wood buildings require the same, or sometimes fewer, number of designers, specifiers, structural engineers, and contracting crews. The same can be said about construction workers / tradespeople, who seem to be more readily available in the case of wood construction.

The majority of designers also believe that wood withstands loads well (dead loads, seismic loads, wind loads, and especially live loads). It also fulfills the architectural requirements of buildings well in terms of space, function, light, and structure. Most designers state that design errors and omissions and building failures occur no more frequently with wood compared to other structural materials. That said, many designers state that building and liability insurance are difficult to obtain when wood is used structurally. Of more concern is the fact that the majority of designers state that these two types of policies (especially building insurance) are more expensive when wood is used.

In terms of environmental impact, wood is thought of as the most environmentally friendly material by designers. This is in spite of negative perceptions that specifiers have towards wood with regards to extracting the raw resource and active service lives of buildings (i.e., the harvesting of forests is seen as environmentally harmful, while wood buildings are not thought of as long-lasting). However, on every other environmental dimension, wood scores moderately to very well. Comparatively speaking, wood is seen as being the least environmentally harmful material in terms of refining the raw resource, the manufacturing process, transporting the building material, energy emissions from wood buildings, and building installation. Furthermore, buildings made of wood are thought of as the most energy-efficient, while wood itself is thought of as a material that is conducive to recycling (second only to steel). Finally, it is interesting to note that the specifiers who think of wood as an environmentally unfriendly alternative are also the most vociferous and outspoken in their views.

Familiarity with / Favourability to Wood Products:

With regards to structural wood products, designers seem to be most knowledgeable / experienced with lumber studs, dimension lumber, and, to a lesser extent, pitched roof trusses. They are, on average, somewhat familiar with floor trusses, timbers, glu-lam beams, and wood I-beams. Knowledge and experience ratings decrease even more with parallel chord trusses, laminated veneer lumber, and composite lumber. Finally, familiarity with parallel strand lumber and stressed skin panels is, for the most part, minimal. Likewise for non-structural wood products, plywood has high knowledge and experience ratings. Designers are also relatively well acquainted with siding / plank decking and particleboard. However, they do not, on average, seem to be very familiar with oriented strand board, medium density fibreboard, and waferboard.

Regionally speaking, familiarity levels of wood products are highest in West / North Canada. They are moderate in remaining Canadian regions, as well as the Western and Midwestern regions of the United States. Knowledge and experience levels for wood products are lowest in the Southern and Northeastern portions of the United States. Finally, with one exception, familiarity levels for wood products are consistently lower than those of other materials (steel, concrete, and masonry) across all regions. In the West / North Canadian region, experience levels for wood and other products are approximately equal.

Alternatively, the population of designers can also be segmented into groups with low, moderate, and high levels of familiarity with wood products. In general, higher familiarity levels for wood products are seen in designers who devote more time to buildings four storeys or less, feel qualified and/or presently design wood buildings four storeys or less, and incorporate wood use into their design philosophies. These designers also like seeing wood used as a structural material, although they do not, for the most part, intend on using more wood in the future. That said, the higher familiarity segments use much more wood compared to steel and concrete. Conversely, steel and concrete are used more often in the low familiarity group at the expense of wood. Designers with more experience and knowledge of wood products tend to design more residential buildings (detached homes / duplexes, multifamily dwelling units, commercial / residential combinations), as well as small nonresidential buildings (entertainment facilities, religious buildings, farm structures). Furthermore, a higher proportion of two storey buildings is seen in this group. Designers with less experience and knowledge of wood products tend to design a greater amount of larger nonresidential buildings (industrial buildings, hospitals) and structures that exceed five storeys in height. In terms of demographics, larger proportions of the high familiarity segments come from the Western regions. They also tend to be somewhat older and are, in many instances, self-employed. Those designers who are not self-employed, but are still highly familiar with wood products, tend to work in smaller firms (both in terms of billings per year and number of designers employed). That said, these firms paradoxically employ a greater number of specifiers capable of designing wood buildings four storeys or less.

With regards to buildings four storeys or less, 49.12% [± 4.33%] of designers like seeing wood used structurally, while 13.70 [± 2.98%] do not, and the remainder do only sometimes. Regional trends in favourability to wood use are also noted. Canadian designers, especially those from the West / North and Central regions, are more favourable to wood use than their American counterparts. That said, favourability in the West United States region is equivalent to the Eastern / Maritimes region in Canada. Favourability to wood use is lower still in the American Midwest, with the lowest levels occurring in the South and Northeast portions of the United States.

Like above, the population of designers can also be segmented into groups based on low, moderate, and high levels of favourability towards wood products. Again, designers who are highly favourable to wood use in buildings four storeys or less are also presently engaged in this sort of activity and are more qualified to do so. Furthermore, more of these designers' philosophies incorporate the use of wood. The vast majority of high favourability designers like seeing wood used structurally in buildings four storeys or less, intend on using the same amount of wood in the future, and would like to learn more about wood. Almost half of the designers in the low favourability segment intend on using less wood in the future, while only some designers in the higher favourability groupings intend on using more. It is interesting to note that, by segmenting on the favourability variable, no trends are seen in concrete use. Rather, wood use only comes at the expense of steel (in the high segment), while steel use is traded off with wood (in the low and moderate segments). In terms of buildings designed, the higher favourability designers concentrate more on residential and farm structures, while the lower favourability designers devote more time to public buildings. Demographically speaking, it can be seen that the West / North and Central regions of Canada contain a high proportion of designers that are very favourable to wood use, while the Southern United States (and Midwestern United States, to a lesser degree) contains a high proportion who are not. Finally, structural engineers, the self-employed, and designers who work in smaller firms seem slightly more favourable to wood use.

The Use of Other Structural Materials:

Steel:

The past share for steel use in buildings four storeys or less is 29.36% [± 3.87%], which is not significantly different from the market share of wood. This translates into a per respondent average of 3.69 [± 1.03] structures that were built in 1993, making steel North America's second most widely used structural material (after wood) in terms of number of buildings designed. Here again, several geographical trends are noted. The market shares for steel use in the seven regions analyzed here are reported, in order of magnitude. The average number of steel buildings designed in 1993 per specifier appear parenthetically alongside the shares.

- Eastern / Maritimes Canada: 35.36% [± 17.11%], (5.56 [± 2.91] buildings);
- Midwest United States: 35.32% [± 9.46%], (4.08 [± 2.33] buildings);
- Northeast United States: 35.25% [± 10.22%], (3.00 [± 1.03] buildings);
- South United States: 33.05% [± 9.08%], (2.79 [± 0.80] buildings);
- Central Canada: 27.78% [± 11.33%], (4.24 [± 2.62] buildings);
- West United States: 19.49% [± 7.37%], (3.63 [± 3.14] buildings);
- West / North Canada: 18.15% [± 10.10%], (4.28 [± 3.37] buildings).

Steel use is highest in the East, decreasing as one moves westward. The highest shares of steel use are seen in the Eastern / Maritimes region of Canada, as well as the Midwest, Northeast, and South United States regions. It is interesting to note that, even in these areas, the market share for steel is still well below that of wood in the high wood use regions. More moderate levels of steel use are seen in Central Canada, with the lowest levels occurring in the West (West United States and West / North Canada). These results seem to indicate that, regionally speaking, there is a very clear trade-off between steel and wood products. That is, steel use is high where wood use is low and vice verse. Also notable is the fact that the number of steel buildings designed in 1993, and their respective variabilities, are much lower than those of wood. This is indicative of the fact that many specifiers design fewer, probably larger, steel structures, relative to wood.

In terms of design preference, steel ranks first with wood following closely behind. The most likely use for steel in buildings four storeys or less is in roof systems, followed by interior partitions and floor systems. Steel is sometimes (though not very often) used in exterior wall systems and exterior cladding, while the least likely application for steel is in interior trim / detail. Finally, designers, for the most part, are very knowledgeable and experienced with steel I-beams, steel beams and decking, steel studs, and metal bar joists (more so than with most wood products). However, they are less familiar with steel tubing, metal cladding, and OWSJ steel decking (though not any less than with most wood products).

Steel possesses several qualities, both positive and negative, according to the specifiers of structural materials in buildings four storeys or less. It should be noted that the ratings that steel received (in either the positive or negative direction) are not as extreme as those obtained for wood products. Furthermore, very few regional differences are observed; steel is perceived fairly consistently across North America. In order of magnitude, the five most highly rated positive qualities for steel are as follows:

- its quality is consistent;
- it is strong;
- it is uniform;
- it is long-lasting;
- it is safe.

Conversely, the five most highly rated negative qualities for steel are as follows:

- it is not warm and inviting;
- it is an expensive material;
- it is not environmentally friendly;
- it is not fire resistant;
- it is expensive to install.

Thus, steel is perceived to be a strong, safe and long-lasting structural alternative of uniform quality. On the other hand, it is expensive (both as a material and to install) and does not guarantee fire resistance. Furthermore, it is thought as environmentally unfriendly, as well as aesthetically sterile and foreboding. By reducing the above product attributes for steel according to similarities in variance structures between respondents, eight sets of common attributes emerge. The three sets of attributes in which respondents' attitudes are most similar are material supply, material properties, and material / building costs. Of these, the first two sets of attributes are considered beneficial to steel use, while the last set is considered a drawback.

In terms of the perceived environmental impact of steel, the above results are confirmed. In fact, steel ranks in last place with regards to environmental friendliness. Despite high scores for recylcability and moderate scores for service life, it does poorly on every other environmental dimension. This is especially pronounced in extracting the raw resource, refining the raw resource, the manufacturing process, energy emissions from steel buildings, and energy efficiency of steel buildings.

Concrete:

The past share for concrete use in buildings four storeys or less is 12.26% [± 2.79%], which is significantly lower than the market share levels of wood and steel. This translates into a per respondent average of 1.55 [± 0.47] structures that were built in 1993, making concrete one of North America's lesser used structural materials (compared to wood and steel) in buildings four storeys or less. Here again, several geographical trends are noted. The market shares for concrete use in the seven regions analyzed here are reported, in order of magnitude. The average number of concrete buildings designed in 1993 per specifier appear parenthetically alongside the shares.

- Eastern / Maritimes Canada: 16.61% [± 13.32%], (2.11 [± 1.42] buildings);
- Central Canada: 15.22% [± 9.09%], (2.33 [± 1.21] buildings);
- South United States: 14.80% [± 6.86%], (1.34 [± 0.63] buildings);
- Midwest United States: 12.68% [± 6.59%], (2.00 [± 1.56] buildings);
- West / North Canada: 11.19% [± 8.26%], (1.48 [± 0.99] buildings);
- West United States: 10.10% [± 5.61%], (1.69 [± 1.12] buildings);
- Northeast United States: 7.31% [± 5.57%], (0.37 [± 0.19] buildings).

Concrete use is highest in the Eastern / Maritimes region, decreasing incrementally as one moves to Central Canada, Southern United States, Midwestern United States, Western / Northern Canada, and Western United States. The lowest share for concrete is seen in the Northeast United States region. It is interesting to note that even the highest use areas for concrete fall below the levels of the lowest use areas for both steel and wood. That said, there does again appear to be a regional trade-off effect between concrete and wood, although it is certainly not as pronounced as in the case of steel. Finally, these results indicate that fewer concrete buildings are designed in every region compared to steel and wood.

In terms of design preference, concrete ranks third; well behind steel and wood and only marginally ahead of masonry. In buildings four storeys or less, concrete is most likely to be used in floor systems. In some instances, it is also used in roof systems, exterior wall systems, and exterior cladding. However, concrete use in interior partitions and interior trim / detail is negligible. Finally, designers, for the most part, seem to be very knowledgeable and experienced with concrete block and concrete slab (more so than with most wood products). However, they are less familiar with beam and column concrete block infill (though not any less than with most wood products) and not very familiar at all with concrete tilt-up and pre-cast concrete.

Concrete also possesses several qualities, both positive and negative, according to the specifiers of structural materials in buildings four storeys or less. It should be noted that concrete's ratings (in either the positive or negative direction), like those of steel, are not as extreme as those obtained for wood products. However, unlike steel, some regional trends are observed here. Canadian designers seem to view concrete more favourably than their American counterparts. In order of magnitude, the five most highly rated positive qualities for concrete are as follows:

- it is fire resistant;
- it is non-combustible;
- it is safe;
- it is durable;
- it is long-lasting.

Conversely, the five most highly rated negative qualities for concrete are as follows:

- it is not warm and inviting;
- it is not simple to install;
- it is expensive to install;
- building costs are high;
- it is an expensive material.

Safety and durability seem to be concrete's strongest attributes. It is perceived as fire resistant, non-combustible, and safe, as well as durable and long-lasting. However, it is also thought of as expensive (both in terms of material and building costs), difficult to install, and aesthetically cold and uninviting. By reducing the above product attributes for concrete according to similarities in variance structures between respondents, six sets of common attributes emerge. The three sets of attributes in which respondents' attitudes are most similar are economic considerations, material properties, and installation concerns. Of these, the first and last sets of attributes are considered drawbacks to concrete use, while the middle set is considered beneficial.

In terms of perceived environmental impact, concrete ranks third. Though not as harmful as steel, concrete does not perform well on most environmental dimensions, including refining the raw resource, the manufacturing process, installing the building, energy emissions from concrete buildings, and energy efficiency of concrete buildings. Concrete's scores are especially poor on the dimension of recycling. That said, it does do moderately well in the area of extracting the raw resource and extremely well in terms of service life.

Masonry:

No significant differences are observed between the use levels of masonry and concrete. The past share for masonry use in buildings four storeys or less is 12.08% [± 2.77%], which is significantly lower than the market share levels of wood and steel. This translates into a per respondent average of 1.94 [± 0.60] structures that were built in 1993, making masonry one of North America's lesser used structural materials (like concrete) in buildings four storeys or less. Here again, several geographical trends are noted. The market shares for masonry use in the seven regions analyzed here are reported, in order of magnitude. The average number of masonry buildings designed in 1993 per specifier appear parenthetically alongside the shares.

- Midwest United States: 16.68% [± 7.38%], (2.11 [± 0.66] buildings);
- Northeast United States: 13.38% [± 7.28%], (1.28 [± 0.49] buildings);
- Central Canada: 13.08% [± 8.53%], (1.69 [± 0.69] buildings);
- South United States: 12.76% [± 6.44%], (1.83 [± 0.58] buildings);
- West United States: 11.68% [± 5.98%], (3.20 [± 2.33] buildings);
- West / North Canada: 6.36% [± 6.39%], (1.45 [± 1.05] buildings);
- Eastern / Maritimes Canada: 3.67% [± 6.73%], (0.52 [± 0.36] buildings).

Masonry use is highest in the Midwest United States. This is followed by more moderate levels in Central Canada and the Northeast, South, and West regions of the United States. On the two coasts of Canada (the West / North and Eastern / Maritimes regions), masonry use is very low. In fact, in these latter two regions, market shares are not significantly different from zero. Like concrete, even the highest use areas for masonry fall below the levels of the lowest use areas for steel and wood. Here also, there appears to be a slight regional trade-off effect between masonry and wood, although it is certainly not nearly as pronounced as in the case of steel. Finally, these results indicate that fewer masonry buildings are designed in every region, compared to steel and wood.

In terms of design preference, masonry ranks fourth; well behind steel and wood and only marginally behind concrete. The most likely uses for masonry in buildings four storeys or less are in exterior wall systems and exterior cladding. It is only sometimes used in interior partitions, and even less frequently in interior trim / detail. Masonry use in roof and floor systems is nonexistent. Finally, designers, for the most part, seem to be very knowledgeable and experienced with unit masonry as a structural material (more so than with most wood products).

Masonry possesses several qualities, both positive and negative, according to the specifiers of structural materials in buildings four storeys or less. That said, it should be noted that the ratings that masonry received (in either the positive or negative direction) are comparatively noncommittal (relative to wood, steel, and concrete). In other words, designers, on average, do not feel strongly about masonry one way or the other. However, like concrete, some regional trends are observed here. Masonry is thought of more favourably in the United States than in Canada. Furthermore, designers in the Eastern portions of each nation look upon the use of masonry in more approving terms. In order of magnitude, the five most highly rated positive qualities for masonry are as follows:

- it is fire resistant;
- it is non-combustible;
- it is attractive in appearance;
- it is easy to maintain;
- it is long-lasting.

Conversely, the five most highly rated negative qualities for masonry are as follows:

- it is not adaptable;
- it is an expensive material;
- it is expensive to install;
- building costs are high;
- its quality is inconsistent.

Like concrete, masonry is thought of as a fire resistant and non-combustible structural alternative. Furthermore, it is long-lasting, easy to maintain, and attractive. On the other hand, masonry, like steel and concrete, is expensive (both as a material and to install). It also lacks consistent quality and adaptability. By reducing the above product attributes for masonry according to similarities in variance structures between respondents, six sets of common attributes emerge. The three sets of attributes in which respondents' attitudes are most similar are material properties, economic considerations, and installation concerns. Of these, the first set of attributes is considered beneficial to masonry use, while the last two sets are considered drawbacks.

In terms of perceived environmental impact, masonry ranks second (very closely behind wood). It scores moderately to very well on every environmental dimension, except recycling. Moderate scores are seen in refining the raw resource, energy emissions from masonry buildings, and energy efficiency of masonry buildings. High scores are seen in the dimensions of extracting the raw resource, the manufacturing process, installing the building, and service life of masonry buildings.

Materials Used in Combination and Other Materials:

Some designers indicated that they often use structural materials in tandem when designing buildings four storeys or less. Steel and masonry are the most frequently cited materials to be used in this manner, followed by wood and concrete. Some of the more popular material combinations include masonry with wood, steel with concrete, and masonry with steel. That said, materials used in combination account for 12.80% [± 2.84%] of the buildings designed in the past (for a per respondent average of 1.41 [± 0.58] buildings designed in 1993). Here again, regional differences are noted. In order of magnitude, material combinations account for the following in the seven regions analyzed here (with the respective average numbers of buildings designed in 1993 per specifier appearing parenthetically):

- Central Canada: 17.37% [± 9.59%], (1.80 [± 1.20] buildings);
- South United States: 17.16% [± 7.28%], (1.18 [± 0.60] buildings);
- Midwest United States: 12.93% [± 6.64%], (1.17 [± 0.68] buildings);
- West / North Canada: 12.32% [± 8.61%], (1.35 [± 1.05] buildings);
- West United States: 11.41% [± 5.91%], (0.82 [± 0.62] buildings);
- Eastern / Maritimes Canada: 8.33% [± 9.89%], (4.22 [± 6.86] buildings);
- Northeast United States: 8.25% [± 5.88%], (1.28 [± 1.26] buildings).

The use of materials in tandem is most popular in Central Canada and Southern United States. Slightly lower levels are seen in West and Midwest regions of the United States, as well as in West / North Canada. Material combinations are least popular in the Eastern regions of Eastern / Maritimes Canada and Northeastern United States.

Finally, it should be noted that the use of materials in combination ranks fifth (behind all other materials used independently) in terms of preference.

The structural use of alternative materials in buildings four storeys or less, apart from a few mentions of aluminum, is negligible. In fact, they account for only 0.14% of past use (for a per respondent average of 0.00 buildings designed in 1993). That said, some alternative non-structural materials are mentioned with respect to specific building applications. For instance, aluminum, vinyl, plastics, gypsum, plaster, drywall, paint, tile, glass, and ceramics are sometimes used for interior trim and detail. Gypsum and drywall are sometimes used for interior partitions. Finally, aluminum, vinyl, stucco, plaster, gypsum, glass, plastics, paint, and curtainwall are occasionally used for exterior cladding.

Summary of Structural Material Use:

Most of the material use levels for wood, steel, concrete, and masonry have been summarized in Table 6.2. Also included are the highest rated positive and negative qualities, design preferences, and environmental friendliness rankings for each material. While all of these findings have been previously discussed, the presentation of results in

Table 6.2: Summary of Structural Material Use.

	Wood	Steel	Concrete	Masonry
Market Share:	33.36 % [± 4.01%]	29.36% [± 3.87%]	12.26% [± 2.79%]	12.08% [± 2.77%]
Average Number of Buildings (1993):	9.78 [± 3.16]	3.69 [± 1.03]	1.55 [± 0.47]	1.94 [± 0.60]
Regions with Lowest Use:	South U.S. Midwest U.S.	West / North Can. West U.S.	Northeast U.S.	East / Maritimes Can. West / North Can.
Regions with Highest Use:	West / North Can. West U.S.	East / Maritimes Can. Midwest U.S. Northeast U.S. South U.S.	East / Maritimes Can. Central Can. South U.S.	Midwest U.S.
Design Preference:	second	first	third	fourth
Highest Positive Qualities of Material:	warm and inviting simple to install attractive inexpensive to install available tradespeople	consistent quality strong uniform long-lasting safe	fire resistant non-combustible safe durable long-lasting	fire resistant non-combustible attractive easy to maintain long-lasting
Highest Negative Qualities of Material:	combustible not fire resistant inconsistent quality inconsistent pricing not long-lasting	not warm and inviting expensive material environ. unfriendly not fire resistant expensive to install	not warm and inviting not simple to install expensive to install high building costs expensive material	not adaptable expensive material expensive to install high building costs inconsistent quality
Environmental Friendliness Rating:	first	fourth	third	second

this manner does allow some of the trade-offs between wood and the other structural materials to be more easily observed. Of particular interest is the regional trade-off that is occurring between wood and steel (and concrete, to a lesser extent). Also notable is the fact that some of the same product attributes turn up, either positively or negatively, in many of the structural materials. That is, wood seems to possess some qualities that other products do not, and vice verse.

Building Design:

Of the 978 respondents in this study, only 553 felt qualified to answer the survey completely. While it is difficult to draw any conclusions from this result, it is safe to say that the proportion of designers across North America who feel qualified to design buildings four storeys or less is at least 56.41%. These architects and structural engineers devote, on average, 79.90 [± 3.40%] of their design workload to buildings four storeys or less. The remainder of the time is fairly evenly split between buildings five storeys or more, nonbuilding structures, and other design endeavours like remodeling, renovation, interior design, and planning.

Of the buildings four storeys or less, an average of 31.85% [± 4.06%] of the design workload is devoted to residential structures. These include detached homes / duplexes (18.15% [± 3.26%]), multifamily dwelling units (9.48% [± 2.48%]), and commercial / residential combinations (4.22% [± 1.70%]). Nonresidential buildings account for 67.14% [± 3.98%] of the design workload, while other activities (as above) make up the remaining 2.01% [± 1.19%]. Simple multiplication can be used to show that residential and nonresidential structures that do not exceed four storeys respectively account for 25.45% and 53.64% (for a total of 79.09%) of all buildings designed (by individuals qualified to design structures four storeys or less). Excluding detached homes / duplexes for the purposes of this study further decreases this total. That is, an average of 64.59% of time is spent designing nonresidential, commercial / residential, and multifamily structures four storeys or less. This section attempts to further examine this total in three parts: residential buildings (including detached homes / duplexes, for the time being), nonresidential buildings, and an analysis of building size. While the use of all structural materials is included in this summary, particular attention is paid to wood products. It should be noted that wood use levels may actually be slightly higher than reported. This is due to the fact that materials used in tandem have been included in the analyses and there is no way of ascertaining how much, if any, wood is being used in these combinations on a per building basis.

Residential Buildings:

Including detached homes / duplexes, residential buildings account for 22.89% [± 3.66%] of the buildings designed in the past, and 27.21% [± 3.95%] of the buildings designed in 1993. It is notable that these figures are comparable to the above proportion of time devoted to residential buildings four storeys or less (31.85% [± 4.06%]), despite the dissimilar nature of the two measures. The proportions of residential buildings designed in the past, as well as the proportions of residential buildings designed in 1993 (seen in parentheses), are broken down in order of magnitude, as follows:

- detached homes / duplexes: 12.02% [± 2.84%], (17.27% [± 3.36%]);
- multifamily dwelling units: 6.86% [± 2.02%], (6.08% [± 2.12%]);
- seniors' residences: 2.28% [± 1.30%], (1.80% [± 1.18%]);
- commercial / residential combinations: 1.73% [± 1.14%], (2.06% [± 1.26%]);
  - ***Total:*** ***22.89% [± 3.66%], (27.21% [± 3.95%]).***

Detached homes / duplexes account for the greatest proportion of residential buildings designed in the past and in 1993. It is interesting to note that the design of single family dwelling units in 1993 is higher than average. At approximately half the level of detached homes / duplexes, multifamily dwelling units account for next highest proportion of residential structures. These are followed by seniors' residences and, lastly, commercial / residential combinations; each of which do not number highly. In terms of design preference, detached homes / duplexes are the most favoured of the residential structures. These are followed by multifamily dwelling units and commercial / residential combinations. Seniors' residences are the least preferred type of residential structure.

It is well known that wood products have a very high and relatively stable share of the detached home / duplex sector. In fact, given the popularity of these structures, it is safe to assume that a significant proportion of the high share of past wood use reported in this study can be explained by single family dwelling units. This result is further substantiated by the large, highly variable, numbers of wood structures built in 1993. For this reason, the market share for wood products (and every other structural material, for that matter) should be reduced if detached homes / duplexes are to be excluded from the analysis. However, the extent to which the shares of wood and other structural materials should be reduced is difficult to ascertain. For wood, one possible solution would be to reduce its market share (33.36%) by a multiplicative factor equivalent to the proportion of single family dwelling units designed in the past (12.02%), for a total of 29.35%. Unfortunately, this probably understates the past share of wood use, given that detached homes / duplexes are not exclusively built out of wood. It can be concluded, though, that the market share for wood products in buildings four storeys or less (excluding detached homes / duplexes) lies somewhere between 29.35% and 33.36%. That said, this study is concerned only with nonresidential, as well as certain residential (multifamily dwelling units, seniors' residences, commercial / residential combinations) structures. For this reason, detached homes / duplexes are excluded from the remainder of the analysis.

The market share for wood products in the multifamily residential sector is very high and stable, and designers are very favourable to wood use in this application. This is true for seniors' residences as well. However, designers are somewhat less favourable to wood used here, with masonry and materials used in combination frequently being used in its place. In the case of commercial / residential combinations, steel has the highest share, followed by materials used in combination. That said, the use of steel in this sector is not seen as particularly stable and designers are somewhat favourable to the use of wood in this application. Unfortunately, the use of wood here, along with concrete and masonry, is comparatively low. Finally, it should be reiterated that the latter two building types, seniors' residences and commercial / residential combinations, do not account for a high proportion of the total design workload.

Nonresidential Buildings:

Nonresidential buildings account for 75.16% [± 3.77%] of the buildings designed in the past, and 70.21% [± 4.06%] of the buildings designed in 1993. It is notable that these figures are comparable to the above proportion of time devoted to nonresidential buildings four storeys or less (67.14% [± 3.98%]), despite the dissimilar nature of the two measures. Other building activities, including nonbuilding structures, remodeling, renovation, interior design, and planning, account for a very small proportion of the buildings designed and are excluded here. With that, the proportions of nonresidential buildings designed in the past, as well as the proportions of nonresidential buildings designed in 1993 (seen in parentheses), are broken down in order of magnitude, as follows:

- industrial buildings / warehouses: 15.51% [± 3.16%], (16.20% [± 3.27%]);
- offices: 13.69% [± 3.00%], (11.25% [± 2.81%]);
- schools: 11.69% [± 2.80%], (11.82% [± 2.87%]);
- public (government) buildings: 8.58% [± 2.44%], (9.62% [± 2.62%]);
- commercial buildings: 6.98% [± 2.22%], (5.15% [± 1.96%)];
- hospitals: 6.28% [± 2.12%], (6.81% [± 2.24%]);
- religious buildings: 4.08% [± 1.73%], (3.21% [± 1.57%]);
- restaurants: 2.32% [± 1.31%], (1.56% [± 1.10%]);
- hotels / motels: 2.29% [± 1.30%], (1.05% [± 0.91%]);
- indoor recreational buildings: 1.89% [± 1.19%], (1.30% [± 1.01%]);
- entertainment facilities: 1.39% [± 1.02%], (1.67% [± 1.14%]);
- farm structures: 0.46% [± 0.59%], (0.57% [± 0.67%]);
    - ***Total:*** ***75.16% [± 3.77%], (70.21% [± 4.06%]).***
- {other building activities: 1.95% [± 1.21%], (2.58% [± 1.41%])}

Industrial buildings / warehouses account for the greatest proportion of nonresidential buildings designed, followed incrementally by offices, schools, and public (government) buildings. Comparatively high proportions are also seen for commercial buildings and hospitals, followed by religious buildings. Restaurants, hotels / motels, indoor recreational buildings, entertainment facilities, and farm structures are not very popular in terms of design, each accounting for less than 3% of the building total (in fact, the proportion of farm structures designed is not significantly different from zero). In terms of design preference, offices are, by far, the most favoured nonresidential structures. These are followed by schools, industrial buildings / warehouses, and public buildings. Commercial and religious buildings also rate relatively highly in this regard, while recreational buildings, hospitals, hotels / motels, entertainment facilities, farm structures, and restaurants do not.

The three types of nonresidential structures in which wood use is highest are farm structures, religious buildings, and restaurants. It is interesting to note that, in each of these applications, concrete use is very low. That said, in the case of farm structures, competition from other materials is minimal. However, the market is very small and considered volatile. In the religious building sector, the market for wood is stable. However, masonry, steel, and materials used in combination are also widely utilized here. The market for wood products in restaurants is also considered stable. That said, competition from steel, as well as masonry and materials used in combination, is fierce. As expected, designers are favourable to the use of wood in these three applications. This is especially pronounced in the cases of farm structures and, to a lesser degree, religious buildings.

In each of the remaining nonresidential building applications, wood use ranks last in terms of use. Furthermore, while wood is infrequently used in offices, hotels / motels, recreational buildings, commercial buildings, and entertainment facilities, its use is extremely low, if not inconsequential, in schools, public buildings, industrial buildings, and hospitals. In the first group of buildings, the use levels for all of the structural materials cluster together with wood ranking lowest in each case. In the second group, the same clustering effect is noted between all of the structural materials except wood. Here, wood use is distinctly lower than any other material. Restated, there seems to be little, if any, competition from wood products at present in the cases of schools, public buildings, industrial buildings, and hospitals.

With the exception of hotels / motels (where steel, concrete, and materials used in combination have approximately equivalent shares), steel is used most frequently in each building type. The market for steel in the nonresidential sector is considered stable in the cases of offices, entertainment facilities, commercial buildings, and industrial buildings. In the cases of public buildings, hospitals, schools, and recreational buildings, the market for steel is considered more volatile. While the market for steel in the hotels / motels sector is also considered volatile, the market for concrete in this sector is seen to have more stability.

Materials used in combination have, in most instances, the second highest share of the market for nonresidential buildings, with either concrete or masonry ranking next. The exceptions are hotels / motels (where materials used in combination have approximately the same share as steel and concrete), public buildings (where concrete use is as high as materials used in combination), and hospitals (where concrete use is higher). In each of these buildings, concrete use is higher than masonry use. Conversely, masonry use is higher than concrete use in recreational buildings, commercial buildings, and schools. In offices, entertainment facilities, and industrial buildings, the frequency of concrete and masonry use is approximately equal. It is interesting to note that, in most instances, the markets for concrete and masonry in the nonresidential sector are not particularly stable.

Not surprisingly, designers are not very favourable to wood use in most of these latter applications. This is especially prevalent in the cases of hospitals and, to a lesser degree, industrial buildings, public buildings, and schools. On average, designers are only slightly opposed to the use of wood in commercial buildings, hotels / motels, and entertainment facilities. On the upside, they are somewhat in favour of wood used in recreational buildings and offices. Finally, it should be noted that the most frequently designed buildings generally use the least amount of wood. These include industrial buildings, offices, schools, public buildings, commercial buildings, and hospitals. To increase wood use in the nonresidential sector, the forest products industry must focus its attention on these buildings.

Building Size:

An approach similar to the ones above can also be taken with an analysis of building size. Specifically, building activity can be categorized by building height and building area. These proportions are summarized below in terms of buildings designed in the past and buildings designed in 1993 (seen in parentheses):

- **BUILDING HEIGHT:**
  - one storey: 43.93% [± 4.37%], (48.18% [± 4.54%]);
  - two storeys: 29.11% [± 4.00%], (29.33% [± 4.13%]);
  - three storeys: 12.08% [± 2.87%], (10.56% [± 2.79%]);
  - four storeys: 5.86% [± 2.07%], (5.11% [± 2.00%]);
  - five storeys or more: 9.02% [± 2.52%], (6.82% [± 2.29%]).

- **BUILDING AREA:**
  - less than 10,000 square metres: 72.21% [± 3.95%], (75.16% [± 3.92%]);
  - 10,000 to 50,000 square metres: 17.38% [± 3.34%], (14.72% [± 3.22%]);
  - more than 50,000 square metres: 10.41% [± 2.69%], (10.12% [± 2.74%]).

One storey buildings are, by far, the most commonly designed structures. These are followed distantly by two storey buildings. Buildings with three storeys and five or more storeys are comparatively less common. Lastly, four storey structures are the least frequently occurring buildings. In terms of design preference, two storey buildings are more favoured than one storey buildings. These are followed by preferences for three storey buildings, buildings five storeys or more, and, lastly, four storey buildings.

Wood use is highest in one and two storey applications, which may be attributable, in part, to the large proportion of detached homes / duplexes that are designed. After two storeys, wood use declines sharply to the point where it is the least used structural material in four storey applications. Designers view wood use in one and two storey applications very favourably. However, they are only slightly approving of wood use in three storey applications, and not very approving of its use in four storey structures.

Wood and materials used in combination have the highest share of the one storey market. These are followed by steel, masonry, and, lastly, concrete. At two storeys, the use of steel and materials in combination exceed the use of wood. However, the share for wood products is still higher than either masonry or concrete. At three storeys, the ever increasing shares of steel and concrete are both greater than the decreasing share of wood. The same is true for materials used in combination and masonry, despite decreases in the use levels of each. Finally, at four storeys, wood use is decidedly low compared to steel, concrete, and materials used in combination. Even the dramatically decreasing share of masonry is greater than wood's share.

In terms of building area, the vast majority of structures designed are less than 10,000 square metres in size. Again, the proportion may be inflated due to the presence of single family dwelling units in the analysis. These are followed very distantly by buildings between 10,000 and 50,000 square metres and, lastly, buildings greater than

50,000 square metres. In terms of design preference, smaller buildings are looked upon more favourably than larger ones.

Wood use is highest in buildings less than 10,000 square metres in size. However, it declines sharply as building sizes increase beyond this level. In structures that are less than 10,000 metres in size, designers view the use of wood favourably. Wood use in buildings that are between 10,000 and 50,000 square metres in size is viewed only somewhat approvingly. Finally, the use of wood in buildings exceeding 50,000 square metres is not looked upon favourably at all.

In buildings 10,000 metres or less in size, the use of steel and materials in combination is slightly higher than the use of wood, concrete, or masonry. At between 10,000 and 50,000 square metres in size, steel use exceeds materials used in combination. The share for concrete increases, although not to the level of steel. Conversely, masonry and wood use decline in buildings this size. However, the decline in the market share of wood products is much more pronounced. Finally, steel very clearly has the market captured for buildings exceeding 50,000 metres in size. This is followed by concrete and materials used in combination, which level off or decrease at this point. Lastly, masonry use decreases to its lowest level, while the share of wood is extremely low.

In both the analyses of building height and building area, one very clear trend emerges. As building size increases, the use of wood products decreases. This decrease in the share of wood is due largely to an increase in the level of steel use as buildings get larger. However, concrete also seems to capture some of wood's market share in larger-scale structures.

Specifiers of Structural Materials:

Findings pertaining to the specifiers of structural materials in buildings four storeys or less, namely architects and structural engineers, are also reported. Six areas have been analyzed here, including demographic characteristics, the workplace environment, educational issues, promotional methods, design issues, and the material specification process. Each is discussed in turn.

Demographic Characteristics:

In Canada, most specifiers are situated in Ontario, Quebec, British Columbia, and Alberta. In the United States, the highest proportions of specifiers are seen in the Pacific, East North Central, South Atlantic, and Middle Atlantic regions. Typically, specifiers are male, Caucasian, and between thirty-one and fifty years of the age (for a mean age of 45.95 years). Obviously, there are exceptions to these demographics. However, the overwhelming majority of specifiers seem to fall into these categories.

The Workplace Environment:

On average, specifiers have been in practice for 18.71 [± 0.95] years, and at their present place of work for 11.25 [± 0.70] years. The latter distribution is skewed towards a shorter time frame which, coupled with the above parameters, seems to indicate that their is a great deal of movement within the design professions. In terms of their careers as designers, the most commonly cited structures that specifiers and their respective firms are notable for are schools and detached homes, followed by offices, public buildings, and stores.

The average number of employees, primary designers, and secondary designers per firm are 247.65, 17.43, and 3.82, respectively. No confidence intervals are reported here due to the massive amounts of variation seen in this data. That said, 40.61% [± 4.19%] of the specifiers are self-employed. Approximately 60% of the respondents are employed in small to medium-sized firms with less than twenty employees and five primary designers. Large firms, consisting of more than 100 employees, account for only 15% of the responses. Conversely, one quarter of the respondents work alone, while there are generally no more than thirty primary designers in any one given firm. These results are confirmed in an analysis of revenues generated per firm. Approximately 60% of the firms sampled are small to medium-sized (billing less than $2,000,000 per year), while only 13% are large (billing more than $10,000,000 per year). Furthermore, while a significant portion of these billings can be attributed to buildings four storeys or less, very little business is generated by wood buildings four storeys or less.

Given that, the average number of employees per firm that design buildings four storeys or less is 10.44 [± 2.25]. An average of only 3.60 [± 0.97] design wood buildings four storeys or less, while 1.48 [± 0.49] specialize in these types of structures. Approximately 95% of all firms have at least one employee on staff (80% having less than ten) who designs buildings four storeys or less. However, only 40% of the firms have a designer on staff devoted to timber design, while 75% of the firms have a designer on staff who occasionally specifies wood in buildings four storeys or less. Most companies do not employ a secondary designer (i.e., a structural engineer in an architectural firm, and vice verse), while those that do, usually employ only one or two. In other words, most of the communication that takes place between architects and structural engineers involves two or more companies.

Finally, very few differences are noted between the workplace environments of architects and structural engineers. One exception is the number of employees that design buildings four storeys or less. The average number of architects per firm involved in this type of design (11.90 [± 2.44]) is significantly higher than the number of structural engineers (7.00 [± 3.81]). Paradoxically, the firms in which structural engineers work appear to be slightly larger than those of architects, although this cannot be statistically confirmed.

Educational Issues:

In general, specifiers learn about structural materials in two places: at school and at work. That said, specifiers seem to learn more and more about the use of structural materials as their careers progress from school, to on the job training, and finally to work experience. In fact, 98.43% [± 1.08%] of the specifiers agree that most of what they have learned with regards to product information has been on the job. Furthermore, 75.51% [± 3.80%] state that most of what they have learned with regards to design concepts has been at work, as well. However, 61.39% [± 4.19%] of the designers claim that their education has had an effect on the structural materials that they specify, with 15.79% [± 3.16%] stating that they only use materials that they learned about in school. One other very significant trend is noted between learning at school or at work. At the workplace, there are very few differences in the extent to which knowledge of each structural material (wood, steel, concrete, and masonry) is gained. However, at school, very significant differences emerge between the intensities with which the use of each structural material is taught.

For this reason, the issue of design education, as it pertains to learning about structural materials, must be further explored. By far, the most common form of schooling among designers is university training, with a significant portion of designers attending at the post-graduate level. In comparison, colleges and technical / trade schools are relatively uncommon. In fact, more designers rely on apprenticeship training and/or continuing education. For the most part, structural engineers think of design education as being technically oriented. Architects, on the other hand, view schooling in more artistic and practical terms.

In architectural school, the proportions of time spent learning about steel (29.73% [± 4.52%]), concrete (25.78% [± 4.33%]), and wood (26.18% [± 4.35%]) are statistically similar. However, masonry accounts for a significantly lower portion of the design curriculum (16.29% [± 3.66%]). In other words, architects are taught about steel, concrete, and wood in equal measures, while the use of masonry taught less frequently. This all changes on the job as masonry quickly catches up to the other structural materials. Here, no significant differences are observed between materials in terms of knowledge gained. That is, architects devote approximately the same amount of time at work to learning about steel, concrete, wood, and masonry.

A very different picture emerges in the case of structural engineers. Statistically equal portions of time are allotted to teaching the use of steel (40.15% [± 7.57%]) and concrete (39.30% [± 7.54%]). However, significantly lower proportions of time are spent learning about wood (13.63% [± 5.30%]) and masonry (6.33% [± 3.76%]). In other words, a structural engineer's design education is comprised of learning primarily about the use of steel and concrete, with much less time devoted to wood and masonry. Although the situation for wood is not as bleak as masonry's, this low level of timber engineering training certainly does not benefit the market position of wood products in the nonresidential sector. While significant gains are made, in terms of learning more about wood and masonry at work, structural engineers still seem to possess a little more knowledge about the use of steel and concrete. That is, in terms of knowledge acquisition on the job, steel and concrete are again dominant, albeit slightly. Like above, this does not bode particularly well for the forest products industry.

Promotional Methods:

One method of informing specifiers about new structural products and systems is by means of the vast array of promotional methods that are presently in place (a description of the various methods can be seen in the Education / Promotion section of Chapter 4). For specifiers, the most common forms of obtaining product information on the job are by reading materials, manuals / data files, and corporate promotion. These are followed by word of mouth, personal promotion, association promotion, and continuing education. Physical examples, proactive marketing, and computerized information are relatively uncommon methods of learning about new structural products and systems. Generally speaking, the most common promotional methods are also the most utilized. Two exceptions are continuing education and physical examples, where use seems to be much higher than occurrence.

Of greater importance, perhaps, is the influence that each of these promotional methods have on specifiers in terms of exploring and/or using a new product or system. Manuals / data files are thought of as the most influential methods of learning, followed by reading materials. Word of mouth and physical examples are also relatively effective means of educating specifiers about the structural materials. These are followed by continuing education, personal promotion, and, to a lesser extent, corporate promotion. Lastly, association promotion, proactive marketing, and computerized information do not seem to be very influential at all. It is interesting to note that, while corporate and association promotion are relatively common promotional methods, they do not seem to be very influential. On the other hand, relatively uncommon methods, like word of mouth, continuing education, and physical examples, are, in fact, effective means of obtaining product information.

For the most part, structural engineers and architects are very similar with regards to methods of learning about new products and systems. However, some subtle differences are noted. For example, the two most common methods of learning for architects are reading materials, followed by manuals / data files; each of which is equally influential. For structural engineers, reading materials are not as common nor influential as manuals / data files. Personal promotion is more common and influential among architects, while the same can be said about continuing education among structural engineers. Word of mouth is more influential to architects, while computerized information, although relatively uncommon, is more widely accepted by structural engineers. Finally, physical examples are more common, and much more influential, to architects. However, structural engineers do find some value in demonstrations of this nature.

That said, marketing programs aimed at increasing wood use among structural engineers and architects should include some form of reading material, manual, or data file. Strategies directed specifically at structural engineers should also incorporate some type of continuing education program, coupled with physical examples. In the case of architects, the similar use of physical examples and continuing education, coupled with a program of personal promotion, is recommended. Finally, it is noteworthy that both professional groups place a great deal of importance on word of mouth. In this sort of climate, new and well-regarded products and systems are more likely to succeed in the marketplace.

Design Issues:

Several miscellaneous characteristics pertaining to the process of design and construction are also reported. For instance, architects devote a significantly higher proportion of time to designing buildings four storeys or less compared to structural engineers (82.49% [± 3.76%] for architects vs. 60.86% [± 7.54%] for structural engineers). No such differences are observed in the proportion of designers whose design philosophies are conducive to the use of wood (76.33% [± 3.70%] for the entire population of designers, irrespective of profession). The same holds true for the proportion of designers who have been sued in their professional careers (8.21% [± 2.35%] for the entire population of designers).

A comparison between the methods of working stress design and the more recently developed limit states design reveals some very notable trends between professional groups. For example, structural engineers are much more familiar with the limit states method in steel and concrete design. The same holds true for architects in the case of masonry. Interestingly, neither professional group is well-versed in the limit states method as it pertains to wood design. For the most part, both structural engineers and architects are equally reliant on outdated working stress methods when designing timber structures. In terms of construction methods, 71.23% [± 6.99%] of structural engineers state that they are equally familiar with both post and beam and light frame methods. Significantly fewer architects, 51.52% [± 4.95%] indicate likewise. Of the remaining structural engineers, 12.33% [± 5.08%] are more familiar with post and beam construction, while 16.14% [± 5.68%] are more familiar with light frame methods. In the case of architects, only 6.61% [± 2.46%] are more familiar with post and beam construction, while fully 41.87% [± 4.88%] are more familiar with light frame methods. Not surprisingly, all of the above results seem to indicate that structural engineers are more well-rounded and advanced than architects in their knowledge of design and construction techniques. Given this, it is surprising to find that structural engineers so infrequently use the newer limit states methods for timber engineering.

The importance of various design considerations in the selection of structural materials in buildings four storeys or less is also reported. Unfortunately, there seems to be little differentiation between the factors affecting the specification of materials. In most cases, approximately 90% of the designers feel that the factor in question is, in the least, important. In more than half of the cases, at least 50% of the designers feel the factor is very or extremely important in selecting the appropriate structural material. That said, the most critical design considerations in terms of specifying structural materials are as follows:

- architectural considerations (light, space, sound, function, etc.);
- the cost of installing the material;
- whether or not the product has a proven record;
- material strength;
- material longevity;
- the fire performance of the material;
- preference of the architect;
- preference of the structural engineer.

Conversely, the least important design considerations affecting the material selection process are as follows:

- proximity to other buildings;
- product guarantees / warranties;
- environmental considerations;
- availability of tradespeople;
- building resale value;
- preference of the contractor.

Unfortunately, wood products do not rate highly on many of the design considerations considered most important in the material specification process. These include architectural considerations, material strength, material longevity, and the fire performance of the material. On the upside, some of the more established wood products do have proven records and the cost of installing timber structures is low. Wood also performs poorly on factors of slightly lesser importance, like material consistency / quality, design considerations, and consistency of supply (not reported here). However, wood products do rate highly on the dimensions of material costs, value, appearance, and ease of installation. Lastly, wood seems to perform well on some of the least important factors, like environmental considerations and availability of tradespeople. These results should, indeed, be cause for concern in the forest products industry. Many of the factors considered most critical to designers when specifying materials, are also the ones in which wood products are not very well perceived.

It is interesting to note that two of the highly rated considerations include the preferences of the architect and the structural engineer. An analysis of these two professional groups, like the one above, yields almost identical results (i.e., most design considerations are important to both architects and structural engineers in the specification of structural materials). However, differences are noted with respect to sets of considerations that are thought of similarly (in terms of variance structures of the importance ratings among respondents). Structural engineers are most similar in rating the importance of engineering considerations (material strength, longevity, consistency, and quality), followed by product attributes (guarantees, warranties, environmental impact, fire performance, and proven records), and economic considerations (material costs, value, and supply). Architects are most similar in rating the importance of building / economic considerations (material costs, value, and supply, guarantees, warranties, proven records, building resale value, proximity to other buildings, and occupancy), followed by engineering considerations (as above), and installation concerns (preference of contractors, availability of tradespeople, cost and ease of installation). Because an argument can be made that each of the above considerations is important to structural engineers and architects, these sets (especially the first sets, which account for more variation) represent the most efficient means of conveying product information, in terms of reaching a relatively large and homogenous audience with a minimum of effort and a high degree of appeal. In other words, marketing strategies aimed at increasing wood use among structural engineers should put the emphasis on the "material". The negative perceptions that they may have towards the various material properties of wood should be addressed (engineering concerns and product attributes), while the cost advantages of wood products should also be stressed (economic considerations). Marketing strategies directed at architects should emphasize the "building". A campaign of this nature should articulate the economic advantages, as well as the ease of installation, inherent in timber design (building / economic concerns and installation concerns). It should also attempt to avert some of the fears that they may have toward wood's perceived lack of engineering qualities (engineering concerns).

The Material Specification Process:

Two very distinct paradigms emerge by asking structural engineers and architects to identify the main specifier of structural materials in buildings four storeys or less. As expected, the majority of designers in each professional group feel that they are the principal specifiers. Almost half of the structural engineers believe that they are the main specifiers of structural materials, with architects accounting for less than one-third of the responses. Even more peripheral are the roles of owners / developers and clients, who are thought of as the principal specifiers less than 10% of the time. Conversely, two-thirds of the architects feel that they are the main specifiers of structural materials in buildings four storeys or less, with structural engineers accounting for just over one-quarter of the responses. The roles of the remaining parties are thought of as inconsequential by architects.

That said, there is remarkable agreement between professional groups on two issues of material specification (parameters for the entire population are reported as no significant differences are noted). First, designers claim that 51.59% [± 4.42%] of the buildings that they have worked on in the past had its structural components independently specified by them. Second, the vast majority of the designers (78.70% [± 3.56%]) claims that the main specifier does not work independently in the material selection process. In this paradigm of working co-operatively, there seems to be more agreement between architects and structural engineers. While both parties again consider themselves to be the main specifiers, they do acknowledge that the respective other professional group (i.e., structural engineers or architects) makes much more of an important contribution to the process of material selection (although structural engineers seem to be more democratically-minded than architects in this regard). Despite the contributions of other parties not being nearly as high as architects' and structural engineers', they too figure more prominently in this model. For structural engineers, owners / developers are seen as being somewhat more influential than clients and building contractors. For architects, all three of these parties contribute approximately equally to the specification process.

It is difficult to ascertain exactly how structural materials are specified. Typically, material selection is initiated by either an architect or a structural engineer, and is sometimes carried out independently. However, material selection, for the most part, involves input from several parties. Structural engineers and architects play very key roles in the material specification process, while the contribution of other parties, like owners / developers, clients, and building contractors, is more peripheral (albeit of some importance). It is impossible to tell whether structural engineers or architects are the "main" specifiers of structural materials in buildings four storeys or less. Each provides different inputs to the specification process, which, no doubt, affect the decision of which material to ultimately use. That said, the most likely model for material specification is a dynamic one. In other words, no one single paradigm can be used to describe this complicated process. Rather, it changes from situation to situation, and from building to building. However, in most cases, both architects and structural engineers play significant roles in the material specification process.

Recommendations for Increasing Wood Use in the Nonresidential Sector:

While nothing by way of a marketing plan has been developed, some generalized recommendations for increasing wood use in the nonresidential sector are offered here. It is up to interested forest products companies to create and implement specific marketing strategies aimed at increasing wood use in this market. That said, this analysis has identified several segments where wood use varies. These segments represent the most logical starting point for parties interested in entering this market.

For the purposes of this report, the definition of nonresidential buildings extends to include multifamily dwelling units, seniors' residences, and commercial / residential combinations. The rationale behind this approach is simply that, in terms of design and construction, these residential structures are very similar to buildings in the nonresidential sector. However, the inclusion of these residential structures in the analysis, along with detached homes, has artificially inflated the market share value for wood used solely in nonresidential applications. It is safe to say that, if these residential structures were removed from the analysis, the market situation for wood products would not appear nearly as promising. Given this, the market share for wood in multifamily dwelling units and seniors' residences is seen to be high and stable. Furthermore, while wood use in commercial / residential combinations is only moderate (second only to steel), the size of this market is presently inconsequential. The remaining buildings are, in the real sense of the word, nonresidential. In other words, most barriers to wood use truly occur in the nonresidential sector.

In the nonresidential sector, only religious buildings, restaurants, and farm structures have high levels of wood use associated with them. Furthermore, despite some competition from alternative structural materials, the markets for wood in religious buildings and restaurants are relatively stable. Unfortunately, both of these markets, especially the restaurant sector, are comparatively small. In the case of farm structures, a higher degree of volatility is observed. However, the size of this market is negligible and, as such, probably should be excluded from the analysis. For these reasons, religious buildings, restaurants, and farm structures are not likely targets for efforts aimed at increasing wood use in the nonresidential market.

In each of the remaining nonresidential structures, wood use ranks lowest. This is especially prevalent in schools, hospitals, industrial buildings, and public buildings where steel is, by far, the most commonly used structural material. However, only industrial buildings display any stability in terms of steel use. Furthermore, while the shares for concrete and masonry are only moderate in these buildings, they still exceed those of wood. In terms of size, each of these markets is comparatively large, with industrial buildings, schools, and public buildings being particularly widespread. These sizable and volatile markets represent an immense opportunity for the forest products industry. Codes permitting, these are the buildings in which the most gains can be made in terms of increasing wood use in the nonresidential sector (some building codes may restrict the use of wood in certain applications like hospitals and schools, in which case efforts should be directed at lobbying codes officials). Schools and public buildings are likely the most lucrative sectors due to the fact that their markets are large and volatile (measured in terms of consistency of material use). Because market erosion of steel's share is less likely in industrial buildings, this sector represents more of a challenge. Finally, while hospitals are not as prevalent as the other structures, their market is sizable enough that it should not be ignored.

Wood use again ranks lowest in offices, commercial buildings, hotels / motels, indoor recreational buildings, and entertainment facilities. That said, the market share for wood products is not nearly as low as in the aforementioned buildings. Here, too, steel is the most commonly used structural material, with the exception of hotels / motels (where concrete use is slightly higher). In the remaining buildings, the shares for concrete and masonry are moderate, although they still exceed those of wood (albeit, not by much). Only recreational buildings are seen as being volatile. Concrete has a stable market share in hotels / motels, while markets for steel are seen as being stable in all of the remaining structures. In terms of size, the market for offices is very large, while the market for commercial buildings is somewhat smaller. Hotels / motels, indoor recreational buildings, and entertainment facilities are, in comparison, not very widespread. The high degrees of stability seen in these buildings, coupled with the fact that wood products have already captured some of their market shares, indicates that further gains in market share would be difficult. That said, the office sector is vast and varied, and should definitely not be ignored.

The same is true for commercial buildings, to a lesser degree. However, efforts aimed at increasing wood use in hotels / motels, indoor recreational buildings, and entertainment facilities may prove unproductive due to the fact that their markets are very modest in size.

It should also be noted that the market share for wood products decreases as the size of buildings increase. Wood is frequently used in one and two storey buildings. At three storeys, the share for wood products is moderate, dropping to a very low level in buildings exceeding this height. The same is true in the case of building area. While wood use is relatively high in buildings that are less than 10,000 square metres in size, it is very low in buildings exceeding this area. In each case, the market share for wood is captured by steel (as well as concrete and masonry, to a lesser degree) as buildings get larger. That said, larger-scale buildings (i.e., three storeys or greater in height and more than 10,000 square metres in area) represent an opportunity for the forest products industry to expand the share of wood products in the nonresidential market.

Several segments of the design population, in which the use of wood products in the nonresidential sector varies, have been identified. Some of these are accessible, while others are not. Clearly, the geographical segments obtained in this analysis are accessible. Wood use is seen as low in the Midwest and Southern regions of the United States, as well as in Central Canada. Its use is more moderate in Northeastern United States and Eastern / Maritimes Canada, and high in the Western regions of the United States and Canada. In terms of the workplace, two accessible segments have emerged. Designers who are not self-employed, but rather work for a company, are less likely to use wood in nonresidential structures. Furthermore, designers who work in larger firms also use wood less often in these applications. Other, less accessible, workplace segments of low wood users include designers who are younger, designers who devote less time to buildings four storeys or less, and designers who tend not to specify structural materials independently. Although, these segments are not very useful for marketing purposes, some interesting conclusions can be drawn. For instance, it seems that designers become more open to the use of wood products in buildings four storeys or less the older and more experienced they get. The last result suggests that the more people involved in the material selection process, the less likely it is that wood will be specified. In other words, it seems that many of the parties involved in the material specification process (architects, structural engineers, and, to a lesser extent, owners / developers, clients, and building contractors) have negative perceptions of wood that must be averted.

Four methods of overcoming the barriers to wood use in nonresidential construction are suggested. The first method involves a series of individually tailored promotional campaigns aimed at increasing wood use in each of the accessible, low use segments (Midwest and South United States, Central Canada, designers working for large firms). If nothing else, these campaigns should address some of the fears and perceptions that specifiers have towards the use of wood products in nonresidential buildings (specifically in the applications of interior partitions, roof systems, floor systems, exterior wall systems, and exterior cladding).

The second method recommended to capture market share in the nonresidential sector involves similar promotional strategies aimed at the accessible moderate use segments (Northeastern United States, Eastern / Maritimes Canada, designers working in medium-sized firms). However, the tone of these campaigns should be less intense. Here, the advantages to wood use in nonresidential design should be stressed, especially in the context of larger-scale applications, like schools, public buildings, industrial buildings, hospitals, offices, and commercial buildings. That said, the negative perceptions that specifiers have towards the use of wood products should not be ignored.

The third campaign involves appealing to the high use segments (West United States, West / North Canada, self-employed designers, designers working in small firms) in hopes that this would result in the successful implementation of a "pull" or "user-demand" strategy. Here, the benefits of wood use need not be sold to designers, although they may still be reminded. Rather, they should somehow be upheld as unconventional and avant-garde; designers whose buildings can be used as an example to the rest of the design community. Furthermore, if these experienced proponents of wood use are willing to be made available, they could serve as invaluable sources of information to less experienced designers. This, in turn, could effectively create "word of mouth" channels pertaining to the use of wood in a nonresidential context. Although this may be overstating the case somewhat, this might just be the kind of approach required to increase the share of wood products in both the high and low use segments.

Finally, the last method for increasing wood use in the nonresidential sector is not an appeal to specifiers at all. Rather, it is essential that the forest products industry lobby structural engineering schools across North America to offer more courses in timber design. The results here clearly indicate that, compared to steel and concrete, the use of wood is not commonly taught in most engineering curricula. Furthermore, little is learned about the newly developed method of limit states design, as it pertains to wood. Obviously, in terms of capturing market share in the nonresidential sector, this is a major problem. Wood cannot possibly be specified by structural engineers who possess little or no knowledge of its use.

While architects and structural engineers have similar objectives in terms of building design, their professions are very different. It is the job of the architect to conceptualize the design of a building, while the structural engineer helps to realize this design by ensuring the structural integrity of the building. As such, both professions have different sets of wants and needs in terms of structural material use. However, for the most part, both professional groups play integral roles in the material specification process and, as such, should both be targeted. That said, promotional campaigns aimed at architects and structural engineers should vary accordingly. For both professions, efforts to increase the use of wood in the nonresidential sector should include some form of reading material, manual, and/or data file. However, the results of this analysis clearly indicate that specifiers prefer not to have these materials put out and/or sponsored by industry associations (although not included in the study, an alternative source for these materials might be non-aligned institutes and/or academia). Strategies aimed specifically at structural engineers should also incorporate a continuing education program and demonstration buildings. Likewise for architects, the use of physical examples, coupled with continuing education, is recommended. However, it is also important that companies employ staffs of sales people and technical representatives who are readily available to support and assist architects in their design decisions.

The emphasis of marketing strategies directed at structural engineers should be on the "material". The most efficient marketing program would include information which addresses the negative perceptions that they have towards the engineering and material properties of wood products, as well as the economic advantages of using wood. For architects, marketing programs should put the emphasis on the "building". The most efficient strategy would include information pertaining to the cost advantages and installation ease inherent in timber design, while addressing the various engineering and material concerns that they have, at the same time.

Marketing campaigns can be approached in two ways: by promoting the advantages of using a product and/or by showing how problems associated with a product either are not valid or can be overcome. Given this, marketers may want to stress any or all of the following perceived benefits and drawbacks to using wood products in campaigns designed to promote wood use among architects and structural engineers in the nonresidential sector. In terms of material specification, the most important perceived advantages to wood use are as follows:

- it is warm, inviting, and comfortable;
- it is attractive in appearance;
- it is functional;
- it is inexpensive to buy and install;
- building costs are low;
- certain wood products have proven records..

Perceived advantages to wood use that are considered less critical include the following:

- it is adaptable;
- it is simple to install;
- it is simple and gratifying to design with;
- tradespeople are readily available;
- it is easy to obtain / readily available;
- it is an environmentally friendly alternative.

Conversely, marketing campaigns should also address the many perceived drawbacks to wood use. In terms of material specification, the perceived disadvantages considered most damaging to wood use are as follows:

- it is a combustible material;
- it is not fire resistant;
- fire protection is difficult to build in;
- it is not strong;

- it is not long-lasting;
- it deteriorates / rots;
- certain, more recently developed, wood products do not have proven records;
- it is not priced consistently;
- its supply is inconsistent.

Other, less critical, perceived disadvantages to wood use include the following:

- it is not safe;
- it shrinks and swells;
- it lacks consistent quality / uniformity;
- it lacks durability;
- it is difficult to maintain;
- it is time-consuming to design with;
- calculations and design of connection is difficult;
- building and fire codes are sometimes difficult to understand;
- liability and building insurance is more expensive when wood is used.

The inclusion of any or all of these perceived benefits and drawbacks in marketing campaigns aimed at increasing wood use among architects and structural engineers in the nonresidential sector would likely prove fruitful in capturing market share. It should be noted that some geographical differences are seen in the extent to which designers feel that these attributes are beneficial / detrimental to wood use. Parties interested in exploring specific regions of North America are directed to the *Regional Attributes Grid* (Table 5.3). Marketers may also choose to incorporate some of the perceived disadvantages to using alternative structural materials, like steel, concrete, and masonry (Tables 4.9 and 6.2). In any event, specifically tailored marketing campaigns designed to promote the use of wood in the nonresidential sector should not only stress the advantages of wood use, but also alleviate the fears and negative perceptions that designers have towards wood products. In some instances, abating the fears of specifiers may prove challenging because some of their negative perceptions are, in fact, warranted. Here, the forest products industry must initiate and deliver research, coupled with concentrated promotional campaigns, to overcome these barriers to wood use. In cases where the negative perceptions are simply untrue, the marketing problem may prove simpler. Here, marketing plans designed to dispel these misconceptions must be implemented.

Future Research:

It is hoped that this research will serve as a valuable database for many forest products firms who are presently involved with, or planning to enter, the market for wood products used structurally in the construction of nonresidential buildings. In other words, the results obtained here can serve as a useful tool or starting point in the development of specifically tailored marketing plans (both company-specific and industry-wide) necessary for the forest products industry to increase its share of this sizable market. Results may also be used to establish the benchmark data necessary for interested parties to perform future time series analyses pertaining to the diffusion of wood products into this market.

Analysis of this data is, by no means, exhausted. The sheer magnitude of information collected in this study has precluded in-depth investigations of, among other topics, the factors which contribute to the specification of structural materials in nonresidential construction, wood use in nonresidential construction (excluding residential structures), the processes of design and material specification, and educational issues. Furthermore, it is believed that other logical and accessible design segments can be identified (to facilitate the development of specifically tailored marketing strategies which promote the use of wood) with the continued use of multivariate statistical techniques. Each of these subject areas remains to be explored.

Concluding Remarks

At present, the markets for wood products in the North American nonresidential construction sector appear unfavourable. For the most part, architects and structural engineers tend to specify alternative structural materials in these applications, especially as buildings increase in size. This is most prevalent in hospitals, industrial buildings, public buildings, and schools, but also true, to a lesser extent, in entertainment facilities, commercial buildings, recreational buildings, hotels / motels, and offices. Steel is, by far, the most favoured building material in these structures, although concrete and masonry use invariably exceeds that of wood, as well. As such, these buildings represent the greatest opportunity for the forest products industry to capture market share from competitor materials. This is especially true in the southern and central regions of the continent, where wood use is low to moderate.

These findings are mitigated, somewhat, by the fact that wood use in some smaller-scale nonresidential applications, like farm structures, religious buildings, and restaurants, is healthy. However, these buildings represent a comparatively modest proportion of the total design workload. As well, markets continue to be robust in residential applications which have traditionally used wood products: detached homes, multifamily dwelling units, seniors' residences, and commercial / residential combinations. However, a reliance on these sectors would likely serve to limit the industry expansion that is seen as critical at this time. This would be nothing short of a missed opportunity, given that there exists a vast array of wood products, both specialty-engineered and commodity-based, ideally suited for many structural uses in the nonresidential sector.

The results of this analysis, as they pertain to wood use in the nonresidential construction market, are particularly surprising because specifiers seem very aware of the fact that wood possesses several positive qualities. It is thought of as a warm, inviting, and comfortable material that is attractive in appearance. It is also inexpensive to buy and install, functional, simple and adaptable. More importantly, perhaps, in this age of environmental awareness, wood is a comparatively benign structural alternative.

Unfortunately, for the most part, architects and structural engineers across North America also have certain negative perceptions about wood. Issues pertaining to fire, like wood's combustibility, its lack of fire resistance, and the requirements of fire protective design, are its most commonly cited drawbacks. However, wood is also thought of as a material which lacks strength, durability, and uniform quality. Buildings made of wood are said to deteriorate and rot, which may contribute to the notion that they are not long-lasting. Finally, the price and supply channels for wood products are seen as being inconsistent. Although these apprehensions do not seem to be much of a problem in the residential sector, they do seem to outweigh wood's positive qualities in numerous aspects of nonresidential construction. As such, wood products are not commonly specified in many nonresidential buildings four storeys or less.

This type of information can be used in the development of marketing strategies aimed at increasing wood use in the nonresidential construction sector in one of two ways: by promoting the advantages of wood or by showing how the problems associated with wood are either invalid or surmountable. Given this, three types of promotional campaigns are recommended for overcoming the barriers to wood use in this market. The first, aimed at segments that use little or no wood, would be an intensive campaign addressing the fears and perceptions that they have towards its use. The second strategy would be directed at moderate users of wood products. It would stress the advantages to wood use, especially in a nonresidential context. The third campaign would be aimed at those specifiers who already incorporate wood in their designs and would, effectively, serve to remind them of the advantages inherent in timber design. Hopefully, this type of approach, by way of example and word of mouth, would induce the low use segments to consider wood for future designs.

Reading materials, manuals, and/or data files are the most effective means of communicating this type of promotional information to designers. Specifiers also place value on physical demonstration buildings, programs of continuing education, and personal promotion. That said, it is important to bear in mind that architects and structural engineers, although both integral to the material specification process, have very different objectives in terms of building design. As such, marketing campaigns, aimed at both of these professional groups, should vary accordingly.

Wood can and should be used widely in a nonresidential context. This has always been the case throughout history, from Japanese temples to Egyptian tombs to the long houses of First Nations peoples. Even today, one need only look to the example of Europe to see the extent to which wood is successfully used in nonresidential applications to achieve attractive, functional, and expansive architectural spaces. These can be seen in the timber designs of

Switzerland's Julius Natterer and in the Hungarian *Architettura Organica* (organic architecture) movement, to name but two examples. However, apart from a few isolated examples, this is not true of North America.

It is hoped that the results obtained in this study offer an unbiased assessment of the market situation for wood products used structurally in the North American nonresidential sector. The information generated in this report, pertaining to the attitudes and perceptions of specifiers as well as the characteristics of the nonresidential sector, will hopefully serve as a useful benchmark database for parties interested in pursuing this market. Knowledge of this type is absolutely critical in ensuring an effective entry into the marketplace, competitiveness within it, and ultimately, long-term success. Coupled with the recommendations offered here, this strategic information can be used as a guide in the development and implementation of specifically tailored marketing strategies which serve to penetrate this lucrative market and increase the share of wood use.

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APPENDIX A:

MINUTES FROM THE MEETING WITH INDUSTRY ADVISORY PANEL (FEBRUARY 21ST, 1992)

MEETING WITH INDUSTRY ADVISORY PANEL
February 21, 1992

Re:

Analysis of the Specifiers of Materials in Commercial Construction -- Phase I; and Future direction for Phase II.

Present:

Bob Lindstrom *(Fletcher Challenge Canada)*
Kenneth Lau *(MacMillan Bloedel Limited)*
Bob Stevens *(Forintek Canada Corporation)*
Roger Levasseur *(Canadian Wood Council)*
Steve Taylor *(School of Architecture, U.B.C.)*
Dave Barrett *(Faculty of Forestry, U.B.C.)*
David Cohen *(Faculty of Forestry, U.B.C.)*
Robert Kozak *(Ph.D. Candidate, U.B.C.)*

Discussion: *"Where next?"*

Eastern schools, such as *McMaster* and *Queens*, have NO courses in timber engineering/design. *(Roger)*

Important to include wood design in certification course for architects and engineers (which allows them to approve of construction plans, Code 3). *Forintek* provides space for the course in exchange for 4-5 hours of teaching time. *(Bob S. and Steve)*

MacMillan Bloedel puts the focus on architects. It is important that they are in with the architects before the decision of material selection is made to eliminate doubts that wood is not a suitable building material. *(Kenneth)*

It is important to determine the percentage of buildings where architects have control of design. This figure was estimated at 10%, although the *Architecture Institute* would have more accurate information. *(Steve)*

There is the added problem of engineers acting as architects (ie, engineers designing buildings with draughtsmen in the back room). *(Steve)*

Must determine what the client-base or breakdown is in terms of people controlling the job. *(Steve)*

The term specification is over-simplified. In other words, specification refers to choosing individual materials or systems. Design is much more complicated...there is a system or a strategy to building as a whole. The question of choosing wood is much more philosophical than that of specification (for instance, the *Forintek* building is not great because it is made of wood -- it is great because of more attitudinal reasons, including the fact that, by using wood, one is able to split large forces into smaller ones). This is a philosophical use of timber as opposed to the more classical use; one which *Natterer* uses. We must gauge respondents on the basis of structural strategies. *(Steve)*

The importance of pilot studies and pretests was stressed. *(David C.)*

The importance of identifying market size in terms of structural components was stressed. For example components may only account for 25% of the value of a structure. *(Roger)*

The example of *McDonald's Restaurant* was brought up. Where does the decision making process (in terms of material specification) take place in this company? *(Roger)*

The scope of the survey must be narrowed. The market must be segmented (to people who are involved with smaller buildings) to obtain higher quality results. *(Bob L.)*

C.W.C. is finding that, generally, smaller projects are designed by smaller design firms. There is a relationship between size of a firm and commercial construction involvement. *(Roger)*

Architectural mailing lists available from *CANDATA (Southam)* and from magazines, such as *Architecture* and *Architecture Record.* *(Roger)*

The survey should determine the size of the market where architects specify materials and buildings can be made of wood. Also, how big is the *turnkey/prefab market* and who specifies *turnkey* structures? *(Kenneth)*

Must have a clear idea of what the survey is about. Must define the objectives of the survey. *(Steve)*

Engineering firms take what is offered to them. A wood building is generally left to the younger, junior staff, who would otherwise be out of work. *(Steve)*

C.W.C. has the names of design firms in North America that work in wood. *(Roger)*

The information that the *C.W.C.* requires from this survey is what types of design tools are needed to design in wood? *(Roger)*

The information that *Forintek* requires from this survey is performance requirements, and product and technology requirements. *(Bob S.)*

The information that *industry* requires from this survey is *how can they do a better job of communication to specifiers and have they heard of the products that are available to them?* *(Kenneth)*

To this end, *MacMillan Bloedel* holds lunchtime seminars (which are relatively inexpensive) in an attempt to familiarize the specifiers with the products that are available. *(Kenneth)*

The question of who should take the lead in which area was raised. What should associations like *COFI*, the *C.W.C.*, and *Forintek* be involved with? *(Bob S.)*

Industry believes that some things have to be from a company perspective. For example, what the dimension of the market is and promotional schemes. *(Bob L.)*

Forintek believes that there should be no special interest groups. *(Bob S.)*

Associations are working on behalf of the *industry's* interest. Unfortunately, *industry* has not defined its needs, specifically in the area of opportunities to market wood products in engineered applications. *Industry* and *groups* must be brought together through networking and common goal objectives. *(Dave B.)*

Must differentiate between company-specific issues and common goal issues. The determining factor is whether or not the issue is a competitive market issue. Proprietary issues need a lead time, while generic issues do not. *(Bob L.)*

Products that are 25 years old still have an important place in the market. We must stop looking at solid wood products as a commodity. *(Dave B.)*

Technical knowledge is of utmost importance to engineers and architects. *(Dave B.)*

A survey needs to ask questions on how architects and engineers perceive commodity products, such as *lumber* and *LVL*. Which products are ideally suited for specific projects? *(Dave B.)*

There are 100 seminars in the United States discussing the issue of ingrade data. *(Dave B.)*

The materials that wood is competing with has only a domestic market, not overseas. *(Steve)*

The masonry industry has a sense of urgency. We must learn their methods (what is the competition doing?). We must rank information collected on wood with respect to other competitor products (rank order, list). We must also collect comments from respondents on the effectiveness of handouts, case studies, and the like. *Case studies* at the *Masonry Institute* (contact *Bruce Peter*) are grass-roots and down to earth, but have specific details. *(Steve)*

We must also observe cultural differences. There is a different customer base here than there is overseas, for both the *residential* and *non-residential* market. *(Steve)*

Are environmental issues driving issues in a context of sustainable yield? How important is the concept of environmentally friendly? *(Bob S.)*

The need for long-term education is obvious. This project must concentrate on the short-term. *(Roger)*

We must also disseminate information to the largest amount of people possible. Presently, *Phase I* can be made public. However, *Phase II* must be proprietary for now. *(All)*

APPENDIX B:

FACSIMILE SURVEY SENT TO INDUSTRY ADVISORY PANEL (FOCUS FOR THE MAIL SURVEY)

FOCUS FOR MAIL SURVEY

Please fax this form back to David Cohen, (604) 822-9104

Please indicate the **three (3)** most important research results (essential), and the three least important (needless) research results for you and you organization.

Essential		Needless
______	Familiarity and opinions towards specific EWP	______
______	Familiarity and opinions towards commodity wood products	______
______	Design philosophy and whether it is amenable to wood	______
______	Market size in terms of $, square footage, & # of design firms	______
______	Market structure...types of design firms; who within firm designs buildings suitable for wood	______
______	Most appropriate current promotional, service, and training methods (for all construction materials)	______
______	Process that firms use to choose structural materials for commercial construction	______
______	Product positioning (with concrete & steel) for specific uses	______
______	Best means for educating existing architects and engineers about design using wood	______
______	Most suitable design tools to encourage switch to wood use	______
______	Need and desire for technical information & knowledge about existing solid wood commodities	______
______	Impact of perceptions and realities of laws, codes, insurance premiums as constraints on wood use	______
______	Existing & expected importance of environmental impact of construction & use of building	______
______	Other: ______________________________	______

APPENDIX C:

DETAILED DISTRIBUTION OF SAMPLE UNITS

Detailed Distribution of Sample Units by Stratum, Collapsed Region, Country, and Professional Group.

	Architects	Structural Engineers		Architects	Structural Engineers
United States:	**2,999**	**1,322**	Middle Atlantic:	447	229
West:	*759*	*349*	- New Jersey	106	54
Pacific:	596	280	- New York	224	102
- Alaska	8	6	- Pennsylvania	117	73
- California	410	207	*South:*	*930*	*406*
- Hawaii	47	17	West South Central:	270	124
- Oregon	40	13	- Arkansas	18	5
- Washington	91	37	- Louisiana	36	18
Mountain:	163	69	- Oklahoma	24	6
- Arizona	43	8	- Texas	192	95
- Colorado	48	26	East South Central:	105	61
- Idaho	10	6	- Alabama	34	21
- Montana	9	4	- Kentucky	22	8
- Nevada	12	7	- Mississippi	10	7
- New Mexico	20	12	- Tennessee	39	25
- Utah	17	5	South Atlantic:	555	221
- Wyoming	4	1	- Delaware	6	5
Midwest:	*653*	*246*	- District of Columbia	36	2
West North Central:	220	82	- Florida	127	59
- Iowa	28	5	- Georgia	85	30
- Kansas	35	21	- Maryland	71	36
- Minnesota	71	21	- North Carolina	82	28
- Missouri	59	25	- South Carolina	39	17
- Nebraska	17	8	- Virginia	101	39
- North Dakota	6	2	- West Virginia	8	5
- South Dakota	4	0	**Canada:**	**1,000**	**500**
East North Central:	433	164	*West / North:*	*235*	*130*
- Illinois	136	52	- Alberta	88	57
- Indiana	36	20	- British Columbia	140	66
- Michigan	97	30	- Northwest Territories	5	4
- Ohio	97	43	- Yukon	2	3
- Wisconsin	67	19	*Central:*	*416*	*210*
Northeast:	*657*	*321*	- Manitoba	37	17
New England:	210	92	- Ontario	357	170
- Connecticut	63	21	- Saskatchewan	22	23
- Maine	7	8	*East / Maritimes:*	*349*	*160*
- Massachusetts	113	44	- New Brunswick	11	12
- New Hampshire	10	9	- Newfoundland	7	9
- Rhode Island	10	3	- Nova Scotia	26	16
- Vermont	7	7	- Prince Edward Island	9	7
			- Quebec	296	116

APPENDIX D:

SURVEY INSTRUMENT
(MAIL QUESTIONNAIRE SENT TO ARCHITECTS)

AN ANALYSIS OF THE NORTH AMERICAN SPECIFIERS OF BUILDING MATERIALS IN SMALL TO MEDIUM SIZED CONSTRUCTION

Department of Wood Science

Faculty of Forestry

The University of British Columbia

Section I

We would like to begin by asking you some general questions about the buildings that you design.

1. IS YOUR DESIGN WORKLOAD DEVOTED ***ENTIRELY*** TO:

a. buildings 5 storeys or more	❑ No	❑ Yes
b. single family dwelling units (detached homes) and/or duplexes	❑ No	❑ Yes
c. nonbuilding structures (dams, tunnels, bridges, etc.)	❑ No	❑ Yes
d. two or more of the above	❑ No	❑ Yes

✋ STOP!!! The remainder of this survey concerns ***buildings 4 storeys or less*** (unless otherwise indicated). If you have answered ***Yes*** to any of ***Question 1***, or do not feel qualified to answer questions on this subject matter, or did not do any design work in the calendar year 1992, please pass the survey on to someone who meets these requirements. If this is not possible, please proceed to Section VII (Personal Information) at the end of this survey.

2. ESTIMATE THE PERCENT OF YOUR DESIGN WORKLOAD DEVOTED TO:

   a. buildings 4 storeys or less (including detached homes/duplexes) ______%

   b. buildings 5 storeys or more ______%

   c. nonbuilding structures ______%

   d. other (*please specify*) ______%

   ____________________ 100 %

3. OF THE BUILDINGS 4 STOREYS OR LESS, ESTIMATE THE PERCENT OF YOUR DESIGN WORKLOAD DEVOTED TO:

   a. single family dwelling units (detached homes/duplexes) ______%

   b. multifamily dwelling units (apartments, condominiums) ______%

   c. nonresidential buildings (commercial, industrial, etc.) ______%

   d. commercial/residential combinations ______%

   e. other (*please specify*) ______%

   ____________________ 100 %

4a. OF THE BUILDINGS 4 STOREYS OR LESS THAT YOU HAVE DESIGNED IN THE PAST, APPROXIMATELY WHAT PROPORTION HAVE USED THE FOLLOWING AS STRUCTURAL COMPONENTS?

	4a. ⇩	4b. HOW MANY OF EACH DID YOU DESIGN IN 1993? ⇨	4c. PLEASE RANK FROM 1 TO 3 THE MATERIALS THAT YOU PREFER TO DESIGN WITH.
a. primarily steel	______%	a._____	a._____
b. primarily concrete	______%	b._____	b._____
c. primarily wood	______%	c._____	c._____
d. primarily masonry	______%	d._____	d._____
e. other (*please specify*) ____________________	______%	e._____	e._____
f. a combination of the above (*please specify*) ____________________ ____________________	______%	f._____	f._____
	100 %		

5. FOR EACH OF THE FOLLOWING THREE CATEGORIES (*END USE*, *BUILDING HEIGHT*, AND *BUILDING AREA*), PLEASE ESTIMATE THE PROPORTION OF THE TOTAL NUMBER OF BUILDINGS THAT YOU HAVE DESIGNED ***IN THE PAST*** AND ***IN THE CALENDAR YEAR 1993*** FOR EACH BUILDING TYPE LISTED.

Some of these buildings may not be applicable to you. ***Please leave these blank.***

Building Type	Proportion Designed In The Past	Proportion Designed In 1993
End Use:		
a. offices	______	______
b. stores/shopping plazas/malls	______	______
c. industrial buildings/warehouses	______	______
d. hospitals	______	______
e. schools	______	______
f. hotels/motels	______	______
g. restaurants	______	______
h. public (government) buildings	______	______
i. indoor recreational buildings	______	______
j. entertainment facilities	______	______
k. religious buildings	______	______
l. farm structures	______	______
m. multifamily dwelling units	______	______
n. seniors' residences	______	______
o. detached homes/duplexes	______	______
p. commercial/residential combinations	______	______
q. other (*please specify*) ________________	______	______
	100 %	100 %
Building Height:		
r. 1 storey	______	______
s. 2 storeys	______	______
t. 3 storeys	______	______
u. 4 storeys	______	______
v. 5 storeys or more	______	______
	100 %	100 %
Building Area (in 000's):		
w. less than 110 ft^2 (10 m^2)	______	______
x. between 110 - 540 ft^2 (10 - 50 m^2)	______	______
y. more than 540 ft^2 (50 m^2)	______	______
	100 %	100 %

6. FOR EACH OF THE ABOVE THREE CATEGORIES (*END USE, BUILDING HEIGHT, BUILDING AREA*), PLEASE RANK THE THREE BUILDING TYPES THAT YOU ***PREFER*** TO DESIGN.

List in order of preference. If three do not apply, list as many as you can.

- **End Use** (a through q): 1. ______ 2. ______ 3. ______
- **Building Height** (r through v): 1. ______ 2. ______ 3. ______
- **Building Area** (w through y): 1. ______ 2. ______ 3. ______

7. **WAIT!!!** **PLEASE DO NOT PASS OVER THIS QUESTION, IT IS REALLY VERY SIMPLE TO COMPLETE.**

FOR EACH BUILDING CATEGORY (*AREA, HEIGHT, AND END-USE*), CHECK ***ONLY*** THOSE BUILDINGS THAT YOU HAVE DESIGNED IN THE PAST.

FOR EACH BUILDING SELECTED, PLEASE INDICATE HOW OFTEN YOUR DESIGNS INCORPORATE STEEL, CONCRETE, WOOD, MASONRY, ANOTHER MATERIAL, OR A COMBINATION OF THE ABOVE MATERIALS AS THE MAJOR STRUCTURAL COMPONENTS USING THE FOLLOWING KEY:

1 -- ALWAYS use this material *2 -- VERY OFTEN use this material*
3 -- SOMETIMES use this material
4 -- RARELY use this material *5 -- NEVER use this material*

Remember, only buildings 4 storeys or less that you have designed are considered here.

	ALWAYS			NEVER
BUILDING AREA:				
❑ Less than 110,000 ft^2 (10,000 m^2)				
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ 110,000 to 540,000 ft^2 (10,000 to 50,000 m^2)					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ More than 540,000 ft^2 (50,000 m^2)					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
END USE:					
❑ Offices					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ Stores/Shopping Plazas/Malls					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5

	ALWAYS				NEVER
BUILDING HEIGHT:					
❑ One Storey					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ Two Storeys					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ Three Storeys					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ Four Storeys					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ Industrial Buildings/Warehouses					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5

	Always				Never
❑ **Hospitals**					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ **Hotels/Motels**					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ **Public (Government) Buildings**					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ **Entertainment Facilities**					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ **Farm Structures**					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ **Low-Rise Multifamily Dwelling Units**					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5

	Always				Never
❑ **Schools**					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ **Restaurants**					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ **Indoor Recreational Buildings**					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ **Religious Buildings**					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ **Seniors' Residences**					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5
❑ **Commercial/Residential Combinations**					
steel	1	2	3	4	5
concrete	1	2	3	4	5
wood	1	2	3	4	5
masonry	1	2	3	4	5
combination	1	2	3	4	5
other	1	2	3	4	5

Section II

We would like to ask you some questions with regards to the structural materials used in buildings 4 storeys or less.

1. FOR EACH OF THE FOLLOWING STATEMENTS, PLEASE STATE WHICH STRUCTURAL MATERIAL, STEEL, CONCRETE, WOOD, OR MASONRY, BEST FULFILLS THE QUALITY DESCRIBED. WHICH MATERIAL DOES NOT?
   For each statement, indicate which material best fulfills the quality described with a ✓. Indicate which material does not with a ✖.

	Steel	Concrete	Wood	Masonry
material is attractive in appearance	______	______	______	______
material is warm and inviting	______	______	______	______
material is simple to design with	______	______	______	______
material is strong	______	______	______	______
material is durable	______	______	______	______
material is adaptable	______	______	______	______
material is uniform	______	______	______	______
material is of consistent quality	______	______	______	______
material is long-lasting	______	______	______	______
material is simple to install	______	______	______	______
material is inexpensive to install	______	______	______	______
material is easy to maintain	______	______	______	______
material is fire resistant	______	______	______	______
material is non-combustible	______	______	______	______
material is safe	______	______	______	______
material is inexpensive	______	______	______	______
material is competitively priced	______	______	______	______
material is priced consistently	______	______	______	______
material is easy to obtain	______	______	______	______
material is readily available	______	______	______	______
supply of material is consistent	______	______	______	______
material has good value for the money	______	______	______	______
tradespeople are readily available	______	______	______	______
building costs are low	______	______	______	______
building codes are easy to understand	______	______	______	______
fire codes are easy to understand	______	______	______	______
material is environmentally friendly	______	______	______	______

2. WHICH STRUCTURAL MATERIAL ARE YOU MOST LIKELY TO DESIGN WITH FOR THE FOLLOWING SYSTEMS (*a through f*) IN BUILDINGS 4 STOREYS OR LESS?
   Check one for each component listed. In the case of material combinations, check as many as are applicable.

	Steel	Concrete	Wood	Masonry	Other (Please Specify)
a. roof systems	❑	❑	❑	❑	❑ ______________
b. floor systems	❑	❑	❑	❑	❑ ______________
c. exterior wall systems	❑	❑	❑	❑	❑ ______________
d. interior partitions	❑	❑	❑	❑	❑ ______________
e. exterior cladding	❑	❑	❑	❑	❑ ______________
f. interior trim/detail	❑	❑	❑	❑	❑ ______________

3a. HOW KNOWLEDGEABLE AND EXPERIENCED ARE YOU WITH THE FOLLOWING STRUCTURAL AND NONSTRUCTURAL WOOD PRODUCTS AND SYSTEMS?

Please circle one number in each category (Knowledge & Experience) for every product listed using the following key:

1 -- NOT AT ALL KNOWLEDGEABLE/EXPERIENCED with this product
2 -- NOT VERY KNOWLEDGEABLE/EXPERIENCED with this product
3 -- SOMEWHAT KNOWLEDGEABLE/EXPERIENCED with this product
4 -- VERY KNOWLEDGEABLE/EXPERIENCED with this product

	Knowledge				Experience			
Structural Applications:								
a. dimension lumber (joists)	1	2	3	4	1	2	3	4
b. timbers	1	2	3	4	1	2	3	4
c. lumber studs	1	2	3	4	1	2	3	4
d. composite lumber (e.g., Timber Strand)	1	2	3	4	1	2	3	4
e. glu-lam beams (glued-laminated timber)	1	2	3	4	1	2	3	4
f. wood I-beams (I-joists)	1	2	3	4	1	2	3	4
g. laminated veneer lumber (LVL)	1	2	3	4	1	2	3	4
h. parallel strand lumber (PSL)	1	2	3	4	1	2	3	4
i. stressed skin panels	1	2	3	4	1	2	3	4
j. parallel chord trusses	1	2	3	4	1	2	3	4
k. pitched roof trusses	1	2	3	4	1	2	3	4
l. floor trusses	1	2	3	4	1	2	3	4
Non-structural Applications:								
m. siding/plank decking	1	2	3	4	1	2	3	4
n. plywood	1	2	3	4	1	2	3	4
o. oriented strand board (OSB)	1	2	3	4	1	2	3	4
p. medium density fibre board (MDF)	1	2	3	4	1	2	3	4
q. particle board	1	2	3	4	1	2	3	4
r. wafer board	1	2	3	4	1	2	3	4

3b. PLEASE ANSWER THE ABOVE QUESTION AGAIN FOR THE FOLLOWING STEEL, CONCRETE, AND MASONRY PRODUCTS AND SYSTEMS.

	Knowledge:				Experience:			
a. metal bar joists	1	2	3	4	1	2	3	4
b. steel I-beams	1	2	3	4	1	2	3	4
c. steel beams & deck	1	2	3	4	1	2	3	4
d. OWSJ & steel deck	1	2	3	4	1	2	3	4
e. steel studs	1	2	3	4	1	2	3	4
f. metal cladding	1	2	3	4	1	2	3	4
g. steel tubing	1	2	3	4	1	2	3	4
h. concrete tilt-up	1	2	3	4	1	2	3	4
i. concrete slab	1	2	3	4	1	2	3	4
j. concrete block	1	2	3	4	1	2	3	4
k. beam & column with concrete block infill	1	2	3	4	1	2	3	4
l. pre-cut concrete	1	2	3	4	1	2	3	4
m. unit masonry	1	2	3	4	1	2	3	4

Section III

> Now, we would like to ask you a few questions about wood and how it pertains to designing buildings 4 storeys or less.

1. DO YOU PRESENTLY DESIGN BUILDINGS 4 STOREYS OR LESS USING WOOD AS THE MAIN STRUCTURAL COMPONENT?

   ❑ Yes ❑ No

2. DO YOU INTEND ON USING MORE OR LESS WOOD IN FUTURE DESIGNS?

   ❑ More ❑ Less ❑ The Same

3. IN GENERAL, DO YOU LIKE SEEING WOOD USED AS A STRUCTURAL MATERIAL IN NON-RESIDENTIAL BUILDINGS 4 STOREYS OR LESS?

   ❑ Yes ❑ No ❑ Sometimes

4. DO YOU FEEL THAT YOU ARE QUALIFIED TO DESIGN BUILDINGS 4 STOREYS OR LESS IN WOOD?

   ❑ Yes ❑ No

5. HOW FAVOURABLE ARE YOU TO THE USE OF WOOD AS A STRUCTURAL MATERIAL IN THE FOLLOWING APPLICATIONS?
   Check one box for each application.

	Very Favourable	Favourable	Neutral	Not Favourable	Not At All Favourable
End Use:					
a. offices	❑	❑	❑	❑	❑
b. stores/shopping plazas	❑	❑	❑	❑	❑
c. industrial buildings/warehouses	❑	❑	❑	❑	❑
d. hospitals	❑	❑	❑	❑	❑
e. schools	❑	❑	❑	❑	❑
f. hotels/motels	❑	❑	❑	❑	❑
g. restaurants	❑	❑	❑	❑	❑
h. public (government) buildings	❑	❑	❑	❑	❑
i. indoor recreational buildings	❑	❑	❑	❑	❑
j. entertainment facilities	❑	❑	❑	❑	❑
k. religious buildings	❑	❑	❑	❑	❑
l. farm structures	❑	❑	❑	❑	❑
m. low-rise multifamily dwelling units	❑	❑	❑	❑	❑
n. seniors' residences	❑	❑	❑	❑	❑
o commercial/residential combinations	❑	❑	❑	❑	❑
Building Height:					
p. 1 storey	❑	❑	❑	❑	❑
q. 2 storeys	❑	❑	❑	❑	❑
r. 3 storeys	❑	❑	❑	❑	❑
s. 4 storeys	❑	❑	❑	❑	❑
Building Area (in 000's):					
t. less than 110 ft^2 (10 m^2)	❑	❑	❑	❑	❑
u. between 110 - 540 ft^2 (10 and 50 m^2)	❑	❑	❑	❑	❑
v. more than 540 ft^2 (50 m^2)	❑	❑	❑	❑	❑

6. PLEASE INDICATE YOUR LEVEL OF AGREEMENT OR DISAGREEMENT WITH THE FOLLOWING STATEMENTS.
Circle one response per statement.

	Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
Buildings 4 storeys or less made primarily of wood are...					
...easy to build	1	2	3	4	5
...inexpensive to build	1	2	3	4	5
...long-lasting	1	2	3	4	5
...attractive	1	2	3	4	5
...comfortable	1	2	3	4	5
...functional	1	2	3	4	5
...sound-proof	1	2	3	4	5
...well lit	1	2	3	4	5
...well insulated	1	2	3	4	5
Designing with wood is...					
...simple	1	2	3	4	5
...gratifying	1	2	3	4	5
...time consuming	1	2	3	4	5
With wood...					
...fire codes are simple to understand	1	2	3	4	5
...building codes are simple to understand	1	2	3	4	5
...design calculations are simple	1	2	3	4	5
...design of connections between members is simple	1	2	3	4	5
...fire protection is easily built in	1	2	3	4	5
...rot/pest damage is overwhelming	1	2	3	4	5

7. ON AVERAGE, COMPARING WOOD TO OTHER MATERIALS (STEEL, CONCRETE, MASONRY) USED IN BUILDINGS 4 STOREYS OR LESS...

	more	less	the same
...the material cost is	☐	☐	☐
...the design costs are	☐	☐	☐
...the cost of installation is	☐	☐	☐
...labour costs are	☐	☐	☐
...finishing costs are	☐	☐	☐
...the total building cost is	☐	☐	☐
...the number of designers required is	☐	☐	☐
...the number of specifiers involved is	☐	☐	☐
...the number of contracting crews required is	☐	☐	☐
...the number of construction workers/tradespeople required is	☐	☐	☐
...the number of structural engineers is	☐	☐	☐
...the availability of skilled tradespeople is	☐	☐	☐

8. FOR EACH OF THE FOLLOWING STATEMENTS, PLEASE CIRCLE TRUE (T) OR FALSE (F) AS THEY PERTAIN TO WOOD USED IN BUILDINGS 4 STOREYS OR LESS.

T	F	Wood withstands: dead loads well
T	F	live loads well
T	F	Wood withstands: seismic (earthquake) loads well.
T	F	wind loads well.
T	F	When wood is used structurally, building insurance is: easy to obtain.
T	F	inexpensive.
T	F	When wood is used structurally, liability insurance is: easy to obtain.
T	F	inexpensive.
T	F	Building failures are more common with wood than with other materials.
T	F	Design errors and omissions are more common with wood than with other materials.
T	F	Wood fulfills: the space requirements of buildings well.
T	F	the functional requirements of buildings well.
T	F	Wood fulfills: the light requirements of buildings well.
T	F	the structural requirements of buildings well.
T	F	When wood is used structurally, lawsuits and litigation occur more frequently than usual as a result of building failures, errors and omissions, etc.

9. HOW LIKELY ARE YOU TO USE WOOD IN THE FOLLOWING APPLICATIONS IN BUILDINGS 4 STOREYS OR LESS?

	Very Likely	Likely	Not Very Likely	Not At All Likely
a. roof systems	❑	❑	❑	❑
b. floor systems	❑	❑	❑	❑
c. exterior wall systems	❑	❑	❑	❑
d. interior partitions	❑	❑	❑	❑
e. exterior cladding	❑	❑	❑	❑
f. interior trim/detail	❑	❑	❑	❑

10a. BELOW IS A LIST OF SOME OF THE REASONS WHY WOOD IS NOT COMMONLY USED IN NON-RESIDENTIAL DESIGN PLEASE CHECK WHAT YOU BELIEVE TO BE THE ***THREE GREATEST DRAWBACKS*** TO USING WOOD IN THIS TYPE OF APPLICATION.

Check any three.

❑ it is costly
❑ it burns
❑ it is not strong
❑ it is not durable
❑ it shrinks and swells
❑ it deteriorates/rots
❑ its quality is inconsistent
❑ other (*please specify*) ____________________
____
❑ it is a variable material
❑ it is prone to damage by pests/fungi
❑ it is difficult to design with

10b. WOULD YOU WANT TO LEARN HOW SOME OF THE AFOREMENTIONED PROBLEMS CAN BE OVERCOME?

❑ Yes ❑ No ❑ Already Know How

Section IV

We would like to ask a few questions on the process of learning about building materials and design.

1. WHICH OF THE FOLLOWING BEST DESCRIBES YOUR EDUCATIONAL BACKGROUND IN THE FIELD OF DESIGN?
   Check all that apply.

   - ❑ university (undergraduate)
   - ❑ university (post-graduate)
   - ❑ continuing education
   - ❑ college
   - ❑ technical/trade school
   - ❑ other (*please specify*) ____________________
   - ❑ on the job/apprenticeship training
   - ❑ no formal program

2. PLEASE CHECK THE WORD YOU FEEL BEST DESCRIBES THE ORIENTATION OF YOUR DESIGN EDUCATION.
   Check one only.

   - ❑ scientific
   - ❑ technical
   - ❑ business
   - ❑ artistic
   - ❑ practical

3a. HAS YOUR DESIGN EDUCATION HAD AN IMPACT ON THE STRUCTURAL MATERIALS THAT YOU SPECIFY IN YOUR WORK TODAY?

❑ Yes ❑ No

3b. IN BUILDINGS 4 STOREYS OR LESS, DO YOU ONLY SPECIFY STRUCTURAL MATERIALS THAT YOU LEARNED ABOUT DURING YOUR DESIGN EDUCATION?

❑ Yes ❑ No

4a. WITH REGARDS TO DESIGN CONCEPTS, HAS MOST OF WHAT YOU HAVE LEARNED BEEN FROM YOUR EDUCATION OR YOUR JOB?

❑ Education ❑ Job

4b. WITH REGARDS TO PRODUCT INFORMATION, HAS MOST OF WHAT YOU HAVE LEARNED BEEN FROM YOUR EDUCATION OR YOUR JOB?

❑ Education ❑ Job

5. OF THE TIME SPENT LEARNING ABOUT STRUCTURAL MATERIALS DURING YOUR DESIGN EDUCATION, WHAT PROPORTION WAS DEDICATED TO THE FOLLOWING?

   a. steel ______%
   b. concrete ______%
   c. wood ______%
   d. masonry ______%
   e. other (*please specify*) ______%
   ____________________ 100 %

6. ON A SCALE OF 1 TO 4, PLEASE RATE THE FOLLOWING 3 METHODS OF ACQUIRING KNOWLEDGE AS THEY PERTAIN TO EACH OF THE STRUCTURAL MATERIALS LISTED.
   Circle one number for each category and every material listed using the following key:

   1 -- NO KNOWLEDGE of this material gained
   2 -- LITTLE KNOWLEDGE of this material gained
   3 -- SOME KNOWLEDGE of this material gained
   4 -- MUCH KNOWLEDGE of this material gained

	Your Education:				Your On The Job Training				Your Work Experience			
a. steel	1	2	3	4	1	2	3	4	1	2	3	4
b. concrete	1	2	3	4	1	2	3	4	1	2	3	4
c. wood	1	2	3	4	1	2	3	4	1	2	3	4
d. masonry	1	2	3	4	1	2	3	4	1	2	3	4

7a. THE FOLLOWING LIST REPRESENTS SOME OF THE MANY WAYS IN WHICH INFORMATION ABOUT NEW PRODUCTS/SYSTEMS/SERVICES CAN BE OBTAINED ON THE JOB. PLEASE CHECK THE ONES THAT ***YOU USE*** TO LEARN ABOUT NEW STRUCTURAL MATERIALS/PRODUCTS. PLEASE ALSO CHECK THE ONES THAT ARE ***MOST COMMON*** IN YOUR PLACE OF WORK AND ***MOST INFLUENTIAL*** IN GETTING YOU TO TRY A NEW PRODUCT.

In each case, check as many as are applicable.

	You Use	Most Common	Most Influential
a. Reading Materials e.g., trade magazines, trade journals, trade books, text books, technical research, etc.	☐	☐	☐
b. Manuals/Data Files e.g., design manuals, codes manuals, service manuals, fire protection manuals, span books, construction data files, etc.	☐	☐	☐
c. Corporate (Company-specific) Promotion e.g., product manuals, company information packages/updates, product brochures/mailouts, third party testimonials, advertisements, etc.	☐	☐	☐
d. Association (Industry-wide) Promotion e.g., newsletters, updates, mail-outs, etc.	☐	☐	☐
e. Personal Promotion e.g., personal sales calls and visits, customer service representatives, company/association representatives handling technical inquiries, company consultations, etc.	☐	☐	☐
f. Continuing Education e.g., information seminars, product seminars, short courses, lecture series, guest speakers, etc.	☐	☐	☐
g. Word of Mouth e.g., friends, peers, co-workers, clients, contractors, tradespeople, etc.	☐	☐	☐
h. Proactive Marketing Tactics e.g., associations/companies costing projects, associations/companies submitting designs and drawings, etc.	☐	☐	☐
i. Physical Examples e.g., demonstration buildings, new buildings, exhibits, trade shows, case studies, etc.	☐	☐	☐
j. Computerized Information e.g., on-line databases, bulletin boards, design software, etc.	☐	☐	☐
k. Other (*please specify*) ____________________ ____________________ ____________________	☐	☐	☐

7b. PLEASE LIST UP TO 3 OF THE ABOVE METHODS OF LEARNING (a *through* k) WHICH RESULTED IN YOU ...

...***EXPLORING*** THE USE OF A NEW AND/OR UNFAMILIAR PRODUCT AS A STRUCTURAL MATERIAL IN BUILDINGS FOUR STOREYS OR LESS?

1. ______ 2. ______ 3. ______

...***USING*** A NEW AND/OR UNFAMILIAR PRODUCT THAT YOU ORDINARILY WOULD NOT USE AS A STRUCTURAL MATERIAL IN BUILDINGS FOUR STOREYS OR LESS?

1. ______ 2. ______ 3. ______

8a. IN 1993, DID YOU DESIGN A BUILDING 4 STOREYS OR LESS THAT USED WOOD AS ITS MAJOR STRUCTURAL COMPONENT?

❑ Yes ⇩

8b. IF *YES*, WHICH OF THE FOLLOWING WOULD HAVE ENCOURAGED YOU TO CHANGE YOUR MIND AND USE ANOTHER STRUCTURAL MATERIAL?

Check as many as are applicable.

❑ No ⇩

8b. IF *NO*, WHICH OF THE FOLLOWING WOULD HAVE ENCOURAGED YOU TO CHANGE YOUR MIND AND USE WOOD?

Check as many as are applicable.

If Yes		If No
go to # 9 ← ❑	would not have used another structural material	❑ → go to # 9
❑	a magazine/journal article	❑
❑	simpler codes	❑
❑	better text books	❑
❑	more technical research	❑
❑	a product seminar	❑
❑	a product mailout/brochure	❑
❑	an advertisement	❑
❑	better design tools (manuals, software, etc.)	❑
❑	an association newsletter	❑
❑	a submitted design/drawing	❑
❑	a personal sales call/visit	❑
❑	a lecture/seminar	❑
❑	a peer/co-worker	❑
❑	an example/demonstration building	❑
❑	a trade show/exhibit	❑
❑	a case study	❑
❑	other (*please specify*)	❑

____

____

9a. WOULD YOU WANT TO LEARN MORE ABOUT DESIGNING WITH WOOD IN MEDIUM TO LARGE SCALE APPLICATIONS?

❑ Yes ❑ No ⇩

9b. IF *NO*, PLEASE STATE WHY NOT.

Check one.

❑ too busy ❑ already know how to use wood ❑ not part of my job

❑ not interested ❑ wood not used in this area ❑ wood not used in this firm

❑ other (*please specify*) ______________________________

____

Section V

Now we would like to ask a few questions on the design process and philosophy in buildings 4 storeys or less.

1a. IN YOUR EXPERIENCE, WHO IS THE MAIN SPECIFIER OF STRUCTURAL MATERIALS IN BUILDINGS FOUR STOREYS OR LESS?
Check only one.

❑ architects ❑ building contractors ❑ clients

❑ structural engineers ❑ owners/developers ❑ other (*please specify*) ______________________

1b. IS THIS SPECIFICATION OF MATERIALS BY THIS PARTY DONE INDEPENDENTLY?

❑ Yes ❑ No ⇩

1c. IF *NO*, HOW IS THE SPECIFICATION OF MATERIALS APPORTIONED (*OUT OF A TOTAL SCORE OF 100*)?

a. architects ______

b. structural engineers ______

c. building contractors ______

d. owners/developers ______

e. clients ______

e. other (*please specify*) ______

______________________ 100

2. APPROXIMATELY WHAT PROPORTION OF BUILDINGS THAT YOU HAVE WORKED ON IN THE PAST HAVE HAD ITS STRUCTURAL COMPONENTS INDEPENDENTLY SPECIFIED BY YOU? ______%

3. FOR EACH OF THE FOLLOWING MATERIALS, PLEASE INDICATE WHICH DESIGN METHODS YOU WOULD GENERALLY USE.
Check one for each material. Skip any material that you do not design with.

	Working Stress Design	**Reliability Based/ Limit States Design**	**Other (*Please Specify*)**
steel	❑	❑	❑ ______________________
concrete	❑	❑	❑ ______________________
wood	❑	❑	❑ ______________________
masonry	❑	❑	❑ ______________________

4. WHICH OF THE FOLLOWING TYPES OF CONSTRUCTION ARE YOU MORE FAMILIAR WITH?

❑ post and beam construction ❑ light frame construction ❑ equally familiar with both

5. WOULD YOU SAY THAT YOUR DESIGN PHILOSOPHY IS CONDUCIVE TO THE USE OF WOOD AS A STRUCTURAL MATERIAL IN BUILDINGS 4 STOREYS OR LESS

❑ Yes ❑ No

6a. HOW IMPORTANT ARE THE FOLLOWING CONSIDERATIONS WHEN SELECTING STRUCTURAL MATERIALS FOR BUILDINGS 4 STOREYS OR LESS?

Check one box for each consideration.

	Not At All Important	Slightly Important	Important	Very Important	Extremely Important
a. preference of architect	❑	❑	❑	❑	❑
b. preference of structural engineer	❑	❑	❑	❑	❑
c. preference of owner/developer	❑	❑	❑	❑	❑
d. preference of contractor	❑	❑	❑	❑	❑
e. availability of tradespeople	❑	❑	❑	❑	❑
f. appearance of material	❑	❑	❑	❑	❑
g. design considerations [1]	❑	❑	❑	❑	❑
h. architectural considerations [2]	❑	❑	❑	❑	❑
i. environmental considerations [3]	❑	❑	❑	❑	❑
k. material strength	❑	❑	❑	❑	❑
l. material longevity	❑	❑	❑	❑	❑
m. material consistency/quality	❑	❑	❑	❑	❑
n. material adaptability	❑	❑	❑	❑	❑
o. ease of installation	❑	❑	❑	❑	❑
p. cost of installation	❑	❑	❑	❑	❑
q. building occupancy	❑	❑	❑	❑	❑
r. proximity to other buildings	❑	❑	❑	❑	❑
s. building resale value	❑	❑	❑	❑	❑
t. material costs	❑	❑	❑	❑	❑
u. material value	❑	❑	❑	❑	❑
v. material supply	❑	❑	❑	❑	❑
w. fire performance of material	❑	❑	❑	❑	❑
x. product guarantees/warranties	❑	❑	❑	❑	❑
y. proven record for product	❑	❑	❑	❑	❑

1 -- Design considerations refer to simplicity of design, understandability of codes, amount of time required, etc.

2 -- Architectural considerations refer to light, space, sound, function, etc.

3 -- Environmental considerations refer to global impact due to material use.

6b. PLEASE STATE ANY CONSIDERATIONS THAT ARE IMPORTANT TO YOU WHEN SPECIFYING STRUCTURAL MATERIALS THAT WE HAVE NEGLECTED TO MENTION:

____

____

____

____

____

____

Section VI

Now we would like to hear your opinion on environmental issues as they pertain to the use of building materials.

1. THE USE OF BUILDING MATERIALS IMPACTS THE GLOBAL ENVIRONMENT IN MANY WAYS. PLEASE RATE STEEL, CONCRETE, WOOD, AND MASONRY ON EACH OF THE FOLLOWING DIMENSIONS ACCORDING TO HOW HARMFUL YOU FEEL THEY ARE TO THE ENVIRONMENT.

	Very Harmful	Harmful	Harmless	Completely Harmless	Never Thought About It
Extracting the Raw Resource:					
steel	❑	❑	❑	❑	❑
concrete	❑	❑	❑	❑	❑
wood	❑	❑	❑	❑	❑
masonry	❑	❑	❑	❑	❑
Refining the Raw Resource:					
steel	❑	❑	❑	❑	❑
concrete	❑	❑	❑	❑	❑
wood	❑	❑	❑	❑	❑
masonry	❑	❑	❑	❑	❑
The Manufacturing Process:					
steel	❑	❑	❑	❑	❑
concrete	❑	❑	❑	❑	❑
wood	❑	❑	❑	❑	❑
masonry	❑	❑	❑	❑	❑
Transporting the Building Material:					
steel	❑	❑	❑	❑	❑
concrete	❑	❑	❑	❑	❑
wood	❑	❑	❑	❑	❑
masonry	❑	❑	❑	❑	❑
Installing the Building:					
steel	❑	❑	❑	❑	❑
concrete	❑	❑	❑	❑	❑
wood	❑	❑	❑	❑	❑
masonry	❑	❑	❑	❑	❑
Energy Emissions from the Building:					
steel	❑	❑	❑	❑	❑
concrete	❑	❑	❑	❑	❑
wood	❑	❑	❑	❑	❑
masonry	❑	❑	❑	❑	❑

2. PLEASE RANK THE EFFICIENCY OF STEEL, CONCRETE, WOOD, AND MASONRY ON THE FOLLOWING ENVIRONMENTAL DIMENSIONS.

   In each case, rank from 1 to 4, with one being the most effiicient material and 4 being the least efficient.

Recycling of Material:

steel ______ concrete ______ wood _____ masonry ______

Energy Use of Buildings Made from Material:

steel ______ concrete ______ wood _____ masonry ______

3. PLEASE RANK THE FOLLOWING STRUCTURAL MATERIALS ACCORDING TO HOW "GREEN" OR "ENVIRONMENTALLY FRIENDLY" YOU BELIEVE THEY ARE.

Rank from 1 to 4, with 1 being the greenest material and 4 being the least environmentally friendly material.

steel _____ concrete _____ wood _____ masonry _____

4. ON AVERAGE, WHAT WOULD YOU EXPECT THE ACTIVE SERVICE LIVES (*IN YEARS*) OF BUILDINGS FOUR STOREYS OR LESS MADE OF THE FOLLOWING STRUCTURAL MATERIALS TO BE?

steel _____ years concrete _____ years wood _____ years masonry _____ years

5. DO YOU HAVE ANY ADDITIONAL COMMENTS WITH REGARDS TO MATERIAL USAGE AND THE ENVIRONMENT?

____

____

____

Section VII

Please tell us a little about yourself and the place in which you work.
Remember, all information is **strictly confidential**.

1. WHAT IS YOUR GENDER? ☐ female ☐ male 2. WHAT IS YOUR AGE? _______ years

3a. WHERE DO YOU LIVE? City/Town: ____________

State/Province: ____________

3b. WHERE DID YOU RECEIVE YOUR FORMAL DESIGN EDUCATION?

City/Town: ____________

State/Province: ____________

Country: ____________

4. WHAT IS YOUR ETHNIC BACKGROUND? ☐ Caucasian ☐ Native American ☐ Hispanic ☐ African-American ☐ Asian ☐ Other (*please specify*) ____________

5. HOW MANY YEARS HAVE YOU BEEN A PRACTICING ARCHITECT? _______ years

6. HAVE YOU EVER BEEN SUED IN YOUR PROFESSIONAL CAREER AS AN ARCHITECT? ☐ Yes ☐ No

7. ARE YOU SELF-EMPLOYED? ☐ Yes ☐ No

8. HOW MANY YEARS HAVE YOU BEEN EMPLOYED AT YOUR PLACE OF WORK? _______ years

9. HOW MANY FULL-TIME ARCHITECTS DOES YOUR PLACE OF WORK EMPLOY? _______

10. HOW MANY FULL-TIME STRUCTURAL ENGINEERS DOES YOUR PLACE OF WORK EMPLOY? _______

11. HOW MANY EMPLOYEES ARE THERE AT YOUR PLACE OF WORK? _______

12. WHAT PERCENT OF YOUR DESIGN WORKLOAD, IF ANY, IS DEVOTED TO DESIGNING BUILDINGS 4 STOREYS OR LESS? _______%

13. HOW MANY ARCHITECTS AT YOUR PLACE OF WORK, IF ANY,...

...DESIGN BUILDINGS 4 STOREYS OR LESS? _______

...DESIGN BUILDINGS 4 STOREYS OR LESS USING WOOD AS THE MAJOR STRUCTURAL COMPONENT? _______

...SPECIALIZE IN DESIGNING WOOD BUILDINGS 4 STOREYS OR LESS ? _______

14. HOW MUCH BUSINESS DOES YOUR PLACE OF WORK DO IN TERMS OF BILLINGS PER YEAR?

Billings Per Year	Total	Buildings 4 Storeys Or Less	Wood Buildings 4 Storeys Or Less
under $100,000	❑	❑	❑
$100,000 to $500,000	❑	❑	❑
$500,001 to $1,000,000	❑	❑	❑
$1,000,001 to $2,000,000	❑	❑	❑
$2,000,001 to $5,000,000	❑	❑	❑
$5,000,001 to $10,000,000	❑	❑	❑
over $10,000,000	❑	❑	❑
do not know	❑	❑	❑

15. PLEASE LIST **UP TO THREE** TYPES OF BUILDINGS THAT YOU AND YOUR PLACE OF WORK ARE WELL KNOWN FOR:

You:	**Your Place of Work:**
1. ____________	1. ____________
2. ____________	2. ____________
3. ____________	3. ____________

16. PLEASE LIST ANY ARCHITECTS, ENGINEERS, SCHOOLS OF THOUGHT, MOVEMENTS, ETC., THAT HAVE BEEN AN INFLUENCE TO YOU IN YOUR CAREER:

1. ____________
2. ____________
3. ____________

17. WAS THIS SURVEY... ❑ ...sent to you? ❑ ...passed on to you?

18. DO YOU HAVE ANY ADDITIONAL COMMENTS?

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Thank you for your time and cooperation in completing this survey. Your participation is greatly appreciated. If you would like a summary of the research results of this survey, please leave your name and address below and it will be sent to you upon completion.

[OPTIONAL]:

Company Name: ____________

Contact: ____________

Address: ____________

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APPENDIX E:

COVER LETTERS
(3-POINT CONTACT WITH ARCHITECTS)

APPENDIX F:

ROTATED FACTOR LOADINGS
(3 FACTOR ANALYSES)

Factor Analysis #1 - **Importance of Various Considerations When Selecting Materials (by professional group):**
(high loading variables in ***bold italic***, moderate loading variables in *italic*)

Structural Engineers:	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**
preference of architect	.00210	.10630	.14522	-.06759	***.73340***
preference of structural engineer	*.36832*	.14751	.04950	-.11282	.35959
preference of owner / developer	.24359	.03867	-.01844	*.35325*	.25394
preference of contractor	-.00836	-.21837	.07961	.26249	***.71302***
availability of tradespeople	-.23247	.01581	*.45020*	.02626	.12725
appearance of material	.18602	*.57593*	.02161	-.29060	.42133
design considerations	.40401	*.42263*	-.19968	-.39375	-.01061
architectural considerations	.03836	.07206	-.00346	.02937	*.41197*
environmental considerations	-.00014	***.72240***	-.09299	.00879	-.02749
material strength	***.81924***	.11871	.09703	-.05412	-.05576
material longevity	***.78144***	.22955	.09014	.20768	-.00316
material consistency / quality	***.79474***	.23125	.06745	.20950	-.01531
material adaptability	***.66130***	.10345	.10748	.36231	.09443
ease of installation	***.64900***	.00084	.29486	.19661	.20911
cost of installation	***.60035***	.06877	.41293	.03166	.19762
building occupancy	.29970	.20553	.00304	***.70588***	.08659
proximity to other buildings	.14572	.41415	.19048	***.67510***	-.14559
building resale value	.05343	*.59887*	.35496	.26692	.11862
material costs	.33263	.03669	***.81578***	-.01342	.09888
material value	.25647	.29665	***.77947***	.03484	-.03589
material supply	.34549	.06382	***.75857***	.13424	.01245
fire performance of material	.21895	***.66921***	.10034	.21796	.08441
product guarantees / warranties	.12525	***.78351***	.22625	.17744	-.03685
proven record for product	.41735	*.59699*	.15381	.14144	.13176

Architects:	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**
preference of architect	.06058	.04297	-.02139	.32801	***.65492***
preference of structural engineer	.02523	.17444	.09570	.06529	***.67261***
preference of owner / developer	.00443	-.03089	.31452	.22916	*.31841*
preference of contractor	.00221	-.05122	***.72971***	.06682	.11481
availability of tradespeople	.04459	-.06677	***.66177***	.32830	.01622
appearance of material	.04533	.05307	.18539	***.64269***	.26903
design considerations	.09094	.06650	.05678	*.35911*	.00539
architectural considerations	.03997	.00648	-.17925	*.27141*	.17128
environmental considerations	.31374	.21420	.06319	*.56109*	.04938
material strength	-.03364	***.61733***	.12768	-.13393	.14615
material longevity	.23766	***.82838***	-.01240	.17154	.06391
material consistency / quality	.17532	***.82571***	-.04435	.24791	-.00108
material adaptability	.36865	***.64855***	.14495	.17326	.13173
ease of installation	.07437	.15640	*.44318*	-.08254	.02821
cost of installation	.36089	.27054	*.58519*	-.00572	-.04340
building occupancy	*.54379*	.18072	-.03823	-.35589	.48881
proximity to other buildings	***.65052***	.05850	.00468	-.15316	.38100
building resale value	***.65912***	-.03428	.10128	.24342	.08037
material costs	*.27016*	-.20673	.25910	-.09617	-.02145
material value	***.68631***	.10714	.31743	.13434	-.08671
material supply	***.61264***	.11568	.45913	.14422	-.12740
fire performance of material	***.66891***	.19452	-.08154	.10274	.19699
product guarantees / warranties	***.64327***	.23670	-.03519	.41281	-.05280
proven record for product	***.61297***	.26212	.10354	.19987	-.07386

<u>Factor Analysis #2</u> - Fulfillment of Quality Described (by structural material):
(high loading variables in ***bold italic***, moderate loading variables in *italic*)

Wood:	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Factor 6**	**Factor 7**
material is attractive in appearance	.16110	.22020	-.02602	.19321	-.02346	.11867	***.71179***
material is warm and inviting	-.01352	-.04951	.01931	-.01844	.07562	-.03555	***.80980***
material is simple to design with	.01339	.16713	.07406	***.60357***	.07590	.28957	.22304
material is strong	*.53023*	.30347	.15591	.35144	-.05611	-.03105	.16572
material is durable	***.68404***	.22304	.20810	.27555	-.14704	-.04880	.06299
material is adaptable	.09391	.10234	.10498	***.67788***	.00455	.01534	.02134
material is uniform	.17629	.03978	***.79761***	.07892	-.06821	.03324	-.07447
material is of consistent quality	.20532	-.09472	***.75569***	.09523	.07367	.09032	-.01469
material is long-lasting	***.63694***	.18184	.31174	.24451	-.16820	.06362	.05729
material is simple to install	-.06915	.03404	-.15080	***.66039***	.42320	.08891	-.06288
material is inexpensive to install	.00594	.07847	.01132	.39602	***.69049***	-.03663	-.05702
material is easy to maintain	***.60490***	-.01696	.12686	.10590	.09763	.11270	.14604
material is fire resistant	***.72629***	-.03099	-.00784	-.23941	.15850	.00372	-.02627
material is non-combustible	***.67539***	-.09270	.11803	-.18330	.07336	.13672	-.13442
material is safe	*.43721*	.35589	.06345	.37119	-.13377	.11200	.16623
material is inexpensive	.03965	.21476	.16548	-.03490	***.76763***	.07810	.05655
material is competitively priced	.14966	*.45322*	.21539	.26709	.30285	.06961	.13012
material is priced consistently	.15588	.15044	*.59922*	-.06704	.17834	-.04691	.04343
material is easy to obtain	.04222	***.82490***	.09404	.12678	.21915	.03584	-.02488
material is readily available	-.02922	***.83348***	.17937	.09446	.12761	.02480	-.05625
supply of material is consistent	-.04155	.44024	***.60479***	.00381	.06976	.11443	.10763
material has good value for price	.21781	*.53881*	.12457	.33687	.19531	.09494	.30207
tradespeople are readily available	-.11147	*.44991*	-.12401	.29791	.14852	.13130	.15926
building costs are low	.02319	.26342	.04512	.01014	***.73633***	.10765	.08112
building codes are easy to understand	-.00033	.07329	.06426	.14200	.06986	***.88754***	.05521
fire codes are easy to understand	.25102	.14772	.05968	.09069	.07909	***.79977***	.00432
material is environmentally friendly	.29155	*.45092*	-.03981	-.10891	.06473	.09028	.04388

Steel:	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Factor 6**	**Factor 7**	**Factor 8**
material is attractive in appearance	.08327	.18088	-.06321	.11452	.00921	.00323	***.79051***	.05205
material is warm and inviting	.04101	-.24145	.08602	-.00337	.06107	.01982	***.79448***	.04324
material is simple to design with	.16350	-.00632	.12288	.45806	*.47361*	.15700	-.00520	-.16113
material is strong	.16841	*.45312*	.00947	.04180	.16958	.34333	.09368	-.17865
material is durable	.04651	***.79434***	.05826	.10164	.13815	.12714	.00404	-.01408
material is adaptable	.04799	.29952	-.03165	***.63817***	.15328	-.01056	.16771	-.08385
material is uniform	.05155	.19465	-.03643	.07996	.10759	***.73988***	-.00718	.08590
material is of consistent quality	.09017	.16927	.02229	-.05318	.03223	***.83053***	.01507	-.00988
material is long-lasting	.16887	***.76870***	-.01886	.05475	-.00729	.22823	-.00901	.01576
material is simple to install	.19635	-.04736	.18506	***.75188***	.03047	-.01366	-.00134	.23276
material is inexpensive to install	.16529	-.09951	.51480	*.59868*	-.08317	.07018	-.02650	.13044
material is easy to maintain	-.00556	.35694	.26245	.16037	-.14538	.07668	.17355	*.41674*
material is fire resistant	.10054	-.08522	-.14403	-.05066	.11001	.03006	-.01700	***.74737***
material is non-combustible	.18190	***.63084***	.05207	-.07447	.10081	-.02481	-.11570	.24357
material is safe	.39274	*.56785*	-.03225	.10992	.16962	.20123	-.01697	-.03326
material is inexpensive	.18019	-.07101	***.83049***	.08897	.00479	-.06040	-.06888	.00040
material is competitively priced	.39839	.20366	*.54917*	.12990	.04606	-.03773	.04655	-.01988
material is priced consistently	***.67141***	-.06160	.22905	-.01872	.18563	.16994	.05196	.07479
material is easy to obtain	***.72373***	.33407	.25029	.17729	.13599	-.09312	.12174	.02896
material is readily available	***.76328***	.34359	.11709	.18298	.05313	-.06931	.08634	.05153
supply of material is consistent	***.78064***	.10159	.03597	.06944	.09447	.23220	-.04004	.02511
material has good value for price	*.39068*	.37611	.28475	.31001	.16370	.08025	.08616	.04452
tradespeople are readily available	*.47462*	.26257	.11137	.37177	.29071	-.06756	.01469	.03291
building costs are low	.08103	.08588	***.77679***	.09737	.24025	.04589	.06742	-.03524
building codes are easy to understand	.17842	.14695	.16856	.15514	***.80204***	.11684	.03560	.10345
fire codes are easy to understand	.19822	.19005	.01929	-.00614	***.80122***	.04418	.04724	.16179
material is environmentally friendly	.00543	.19010	.12912	.33466	.16747	-.01110	.13001	*.52395*

Factor Analysis #2 (continued):
(high loading variables in ***bold italic***, moderate loading variables in *italic*)

Concrete:	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Factor 6**
material is attractive in appearance	.27800	.11660	-.02986	***.66570***	.03692	.02373
material is warm and inviting	-.19463	-.06460	.21102	***.61530***	.08157	.11480
material is simple to design with	.25634	.00575	.16343	*.58384*	.31353	.03907
material is strong	*.55568*	.43436	-.11890	.08754	.13282	.09064
material is durable	.45309	*.46381*	-.10236	.19786	.12716	.13761
material is adaptable	.19183	.22039	.10036	*.46846*	-.05985	.15767
material is uniform	.17875	.04283	.04453	.15220	-.00093	***.80217***
material is of consistent quality	.04822	.05956	.03717	.09673	.00435	***.83630***
material is long-lasting	.44982	*.51009*	-.11366	.18501	.15441	.13106
material is simple to install	.05175	-.00804	*.55164*	.32533	.09002	.24377
material is inexpensive to install	-.03442	-.05950	***.78289***	.12763	.00716	.08255
material is easy to maintain	.31641	.25569	-.08144	*.37554*	.22070	.06502
material is fire resistant	.00505	***.80771***	-.01151	.09051	.00599	-.01287
material is non-combustible	.03193	***.81195***	-.04316	-.00818	.13619	-.04226
material is safe	.32697	*.59491*	-.02043	.04374	.10183	.13009
material is inexpensive	.14705	-.04134	***.75427***	-.02533	-.03544	-.15451
material is competitively priced	*.59202*	.04051	.42343	.16314	-.07717	-.07698
material is priced consistently	*.41482*	.12948	.23812	.29100	-.16141	.01673
material is easy to obtain	***.81788***	.15113	.07790	.04985	.12905	.01192
material is readily available	***.83801***	.09101	.06239	.00883	.11113	.04420
supply of material is consistent	***.68465***	.13185	.03912	-.00019	.12945	.26844
material has good value for price	***.61949***	.01692	.18477	.21010	.25502	.11204
tradespeople are readily available	***.61355***	.04941	.14208	.34844	.18371	-.01096
building costs are low	.16747	-.08630	***.77463***	.03278	.11994	.06885
building codes are easy to understand	.20677	.02560	.01978	.26281	***.80545***	-.10138
fire codes are easy to understand	.12324	.19286	-.02435	.05160	***.74778***	-.06664
material is environmentally friendly	.12953	.13579	.14289	-.02981	*.50692*	.26163

Masonry:	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Factor 6**
material is attractive in appearance	.35806	.09474	-.03726	***.71486***	.05614	.10064
material is warm and inviting	.21068	.10816	.06075	***.76821***	.02845	.06565
material is simple to design with	.42359	.19041	*.43448*	.23473	.14658	.25920
material is strong	***.69926***	.20612	.10005	.07104	.06519	.17877
material is durable	***.76155***	.07655	.03917	.17392	.06656	.11073
material is adaptable	*.41139*	.10075	.26260	.27084	.04371	.10490
material is uniform	.20322	.22144	-.02771	.10615	.05746	***.77677***
material is of consistent quality	.22874	.11277	.05620	.11212	.03774	***.81356***
material is long-lasting	***.72026***	.19240	-.05269	.24337	.12284	.19977
material is simple to install	.32608	.28493	*.55287*	.06278	.05925	.05126
material is inexpensive to install	.14638	.13581	***.78530***	.00806	-.05124	-.12711
material is easy to maintain	***.61615***	.11857	.14474	-.07773	.21754	.08938
material is fire resistant	*.53913*	.39315	-.08698	.39676	.21059	-.01756
material is non-combustible	***.61404***	.41612	-.03162	.33631	.21290	-.01734
material is safe	*.52349*	.37939	.02917	.37837	.23606	.10850
material is inexpensive	-.08229	.04106	***.77163***	-.02838	.13561	-.01168
material is competitively priced	.10635	***.65861***	.28384	.09192	-.00023	.07348
material is priced consistently	.05152	*.52548*	.31413	.08325	.05520	.21634
material is easy to obtain	.30412	***.78588***	.11383	.13632	.13273	-.01248
material is readily available	.27870	***.79513***	.12667	.16762	.14414	-.00134
supply of material is consistent	.10587	***.71229***	.09734	-.08840	.16966	.28252
material has good value for price	.25343	*.50083*	.14441	.14929	.40828	.14157
tradespeople are readily available	.24992	*.48861*	.13361	.20273	.33271	.16810
building costs are low	-.05106	.29375	***.70970***	.00063	.18057	.14141
building codes are easy to understand	.22778	.18431	.16446	.07015	***.75469***	.00081
fire codes are easy to understand	.24242	.16178	.07254	.05243	***.79427***	.02660
material is environmentally friendly	-.06043	.10851	.05959	*.48096*	.44755	.14262

Factor Analysis #3 - Building Types (by structural material):
(high loading variables in ***bold italic***, moderate loading variables in *italic*)

	Wood			Steel		
Building Type:	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 1**	**Factor 2**	**Factor 3**
offices	.38502	.41269	*.54993*	***.81261***	.00407	.15316
commercial buildings	-.03361	.57685	*.59984*	*.68616*	.32787	.30111
industrial buildings	.13452	***.84924***	.18409	*.66482*	-.04795	-.08178
hospitals	.24149	***.88161***	-.11959	.50935	.22611	*.61918*
schools	.19696	***.88361***	.13946	-.06756	***.85460***	.27338
hotels / motels	***.74501***	.27865	.15653	.20854	.08558	***.78320***
restaurants	***.77165***	.20366	.08773	.47785	*.53706*	.30492
public buildings	.29014	***.87676***	.06087	.42872	.02214	***.75850***
indoor recreational buildings	.37118	*.58321*	.29272	.40517	*.51593*	.49176
entertainment facilities	.35513	*.54729*	.47410	***.75035***	.30603	.25549
religious buildings	***.88433***	.06668	.18963	*.62587*	.24997	.38137
farm structures	.17387	-.06837	***.87749***	-.14642	.35431	***.71656***
seniors' residences	***.89181***	.18965	.00883	.18656	***.78478***	.15637
multifamily dwelling units	***.81507***	.13828	.35317	.04707	***.70128***	.28335
commercial / residential combinations	***.75045***	.38802	.03437	.21898	***.70613***	-.19664

	Concrete			Masonry		
Building Type:	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 1**	**Factor 2**	**Factor 3**
offices	.13914	.29552	***.76077***	*.68706*	.44489	.26495
commercial buildings	.31477	.15319	***.84755***	.58387	*.63260*	.02794
industrial buildings	.45941	.36988	*.52902*	.18436	***.87675***	.31474
hospitals	.11256	***.90928***	.12588	.61295	*.64685*	-.00416
schools	.57650	*.62413*	.35421	***.88276***	.25378	.23040
hotels / motels	*.55730*	.45826	.37859	*.65781*	.63373	.09155
restaurants	***.89257***	.14501	.24979	***.79382***	.46229	.06305
public buildings	.10515	***.86695***	.32175	***.81258***	.40937	.28754
indoor recreational buildings	***.87403***	-.07562	.40518	***.78490***	.44004	.27548
entertainment facilities	***.79017***	.31336	.12244	***.76530***	.44625	.24385
religious buildings	***.71637***	.05516	.54570	***.90834***	.30757	.16414
farm structures	***.86365***	.23336	.09205	.19720	.15685	*.95106*
seniors' residences	.27178	.50016	*.60398*	***.83069***	.45887	.18788
multifamily dwelling units	*.60824*	.48312	.29400	***.87262***	.14203	.07628
commercial / residential combinations	.29182	.54288	*.58299*	***.84889***	.41133	.10459