WOOD VERSUS SUBSTITUTE MATERIALS
IN RESIDENTIAL CONSTRUCTION

by

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THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF FORESTRY

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Forestry

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA
June, 1971
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Date June 25, 1971
ABSTRACT

Residential construction has been a focus of attention in North America in recent years. Rising construction costs, and growing social pressures to meet housing needs, have resulted in a concentrated effort by government and industry to develop new and improved building methods.

Wood frame construction techniques, although traditional in Canada, are not guaranteed a dominant position in the future. With the high volume of wood products consumed in residential construction, the forest industries have a large stake in this market.

Two aspects of declining wood use in housing have been investigated in this thesis: (1) changing methods of construction; and (2) substitution of non-wood building materials for wood.

Although recent projections indicate a strong housing demand to 1980, the types of dwellings constructed are equally important, single-family units consuming the greatest volume of wood products, and high-rise apartments the least. A strong trend toward apartment construction has been evident since 1950, fostered by rapid urban population growth, mortgage investment preferences, the high cost of urban land, and the lower cost of rental accommodation. It is estimated that the loss of wood products markets from 1960 to 1969 due to this trend was 1,355 million bd. ft. of lumber, 245,075,000 sq. ft. of plywood and veneer, and 151,068,000 sq. ft. of building board.

Functional suitability is probably the most important determinant of materials choice. Tradition, a factor which has favoured wood frame
building, is losing its influence. Availability of materials and vertical integration are not significant factors in Canada. Upward trends in the price of wood products, price instability, and the much higher research and development expenditures in competing industries can be expected to result in an accelerated rate of substitution of other materials for wood. Although wood performs well in many applications, its combustibility has been a great disadvantage for construction uses. Building codes have significantly limited its use, but have also hindered the introduction of new building techniques, and products made of substitute materials.

Products made of aluminum, plastics, steel, and non-metallic minerals have had varying degrees of success in the housing market. Numerous developments such as aluminum and steel structural systems, plastic and metal sandwich panels, and precast concrete building systems, offer potential competition to wood frame methods.

Vertical integration with the building industry, and more active promotion of, and technical assistance in wood frame methods may help curb the trend to apartment construction. Greater efforts to reduce costs, higher research and development expenditures, increased activity in market research, and greater efforts to reduce price fluctuations are necessary to prevent higher rates of substitution. More effort should be concentrated on the development of foreign markets, both to help reduce price fluctuations, and to provide alternate markets for those lost through substitution.
### TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>vii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>viii</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>TRENDS IN HOUSING</td>
<td>5</td>
</tr>
<tr>
<td>1. Historical Developments in Housing</td>
<td>5</td>
</tr>
<tr>
<td>2. Sources of Housing Demand</td>
<td>5</td>
</tr>
<tr>
<td>(i) Net family household formation</td>
<td>6</td>
</tr>
<tr>
<td>(ii) Net non-family household formation</td>
<td>6</td>
</tr>
<tr>
<td>(iii) Undoubling</td>
<td>7</td>
</tr>
<tr>
<td>(iv) Net replacements</td>
<td>7</td>
</tr>
<tr>
<td>(v) Vacancies</td>
<td>8</td>
</tr>
<tr>
<td>3. Projections of Housing Demand</td>
<td>8</td>
</tr>
<tr>
<td>4. Trends in Dwelling Types</td>
<td>12</td>
</tr>
<tr>
<td>5. Factors Influencing Types of Dwellings Constructed</td>
<td>18</td>
</tr>
<tr>
<td>(i) Urban population growth</td>
<td>18</td>
</tr>
<tr>
<td>(ii) Consumer preferences</td>
<td>20</td>
</tr>
<tr>
<td>(iii) Investor preferences</td>
<td>21</td>
</tr>
<tr>
<td>(iv) Land costs</td>
<td>26</td>
</tr>
<tr>
<td>(v) Incomes and housing costs</td>
<td>26</td>
</tr>
<tr>
<td>CONSUMPTION OF WOOD PRODUCTS IN HOUSING</td>
<td>32</td>
</tr>
<tr>
<td>FACTORS INFLUENCING CHOICE OF MATERIALS IN RESIDENTIAL CONSTRUCTION</td>
<td>41</td>
</tr>
<tr>
<td>Tradition</td>
<td>41</td>
</tr>
<tr>
<td>Availability</td>
<td>43</td>
</tr>
<tr>
<td>Price of Materials</td>
<td>43</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Estimated housing construction requirements, 1956 - 1980.</td>
<td>9</td>
</tr>
<tr>
<td>2. Actual volume of housing constructed to 1969.</td>
<td>10</td>
</tr>
<tr>
<td>3. Components of housing demand based on demographic trends.</td>
<td>11</td>
</tr>
<tr>
<td>4. Starts by type of dwelling, all areas.</td>
<td>14</td>
</tr>
<tr>
<td>5. Completions by type of dwelling, all areas.</td>
<td>15</td>
</tr>
<tr>
<td>6. NHA - Approved loans by CMHC for new housing.</td>
<td>23</td>
</tr>
<tr>
<td>7. Mortgage loans approved by lending institutions, by type of dwelling</td>
<td>24</td>
</tr>
<tr>
<td>8. Wood used per unit in single-family houses inspected by the Federal Housing Administration, 1962 &amp; 1968</td>
<td>36</td>
</tr>
<tr>
<td>9. Wood used per unit by construction characteristics, 1962.</td>
<td>37</td>
</tr>
<tr>
<td>10. Wood products consumed per dwelling unit.</td>
<td>38</td>
</tr>
<tr>
<td>11. Intra-mural R &amp; D expenditures in Canada, by industry.</td>
<td>63</td>
</tr>
<tr>
<td>12. Extra-mural R &amp; D expenditures in Canada, by industry.</td>
<td>64</td>
</tr>
<tr>
<td>13. Funds for R &amp; D performance in the U.S.A., by industry.</td>
<td>66</td>
</tr>
<tr>
<td>14. Thermal conductivity of building materials.</td>
<td>74</td>
</tr>
<tr>
<td>15. Impact noise ratings using various floor constructions on concrete</td>
<td>78</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1.</td>
<td>Housing starts by dwelling type as percent of total.</td>
</tr>
<tr>
<td>2.</td>
<td>Housing completions by dwelling type as percent of total.</td>
</tr>
<tr>
<td>3.</td>
<td>Indexes of shelter cost and personal disposable income per capita</td>
</tr>
<tr>
<td>4.</td>
<td>Consumer price indexes of shelter cost: rental versus home-ownership</td>
</tr>
<tr>
<td>5.</td>
<td>Wholesale price indexes in Canada.</td>
</tr>
<tr>
<td>6.</td>
<td>Price index numbers of residential building materials in Canada.</td>
</tr>
<tr>
<td>7.</td>
<td>Industry selling price indexes.</td>
</tr>
<tr>
<td>8.</td>
<td>Industry selling price indexes.</td>
</tr>
<tr>
<td>9.</td>
<td>Industry selling price indexes.</td>
</tr>
</tbody>
</table>
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INTRODUCTION

During the past few years, housing has been a focus of attention in North America. As a subject which touches the lives of everyone in one form or another, residential construction remains of great concern to the general public, all levels of government, and private enterprise.

The problem of housing the old and the poor has always been present, but recently, arising from rapidly increasing house prices, claims have been made that many middle-class people can no longer anticipate owning a conventionally-styled single-family house. Contributing significantly to these rising prices have been the rising cost of serviced land and mortgage interest rates, coupled with a lack of mortgage investment funds, which have, in turn, resulted in a shortage of housing at prices which many people can afford. Anti-inflationary measures, such as increasing the prime lending rate, have also hindered the house building effort and added to the supply problem. These rates are now ameliorating, but whether this situation is temporary or permanent is uncertain.

In the United States, where the "housing crisis" has been listed as the number one problem, with top priority for legislative action, the situation is more severe than in Canada, and is coupled with a major social upheaval. However, it is recognized that a housing problem does exist in Canada, as exemplified by the Task Force on Housing and Urban Development (Hellyer, 1969). Resulting from this concern over housing, the various levels of government, the residential construction industry, and major construction materials suppliers, are all actively searching for new and better solutions to the question of how to provide acceptable forms of shelter at a reasonable cost.
Although the wood frame house has long been the conventional style of housing in this country, there is no guarantee that new construction techniques will continue to provide a substantial market for forest products. It has been said that no one knows with precision where wood products are used. However, a number of estimates are available, primarily for U.S. markets, which do not differ drastically from Canadian markets. 

Muench (1969) reported that residential construction in the U.S.A. accounted for about 35 per cent of softwood lumber consumption. In Canada, a slightly higher percentage of lumber is probably consumed by the housing industry. A little over half of the softwood plywood used in the U.S.A. enters residential construction, whereas in Canada, an estimated 23 per cent is employed in housing, with an additional 25 per cent going into non-contract homes and second home use (Bowland et al., 1968). According to FAO (1966), most insulation board and about half of the hardboard produced in the U.S.A. is used in construction (both residential and non-residential). Also about 22 per cent of the U.S. particle board production went into residential construction in 1965 (Lewis, 1969). A similar situation exists in Canada, although actual figures are not available. The above statistics should be sufficient to indicate the large stake which the forest industries have in residential construction.

The gradual trend away from the use of lumber in residential construction in North America and elsewhere has been documented in several studies. Tromp and Campredon (1966) have attributed the declining wood consumption to five different sources: (1) more rational utilization of wood; (2) greater durability of wood due to the use of preservatives; (3) substitution for
solid wood by wood-based panel products; (4) changing methods of construction; and (5) substitution of other (non-wood) building materials for wood. The first three aspects of declining wood use entail technological advances developed in an effort to overcome problems relating to wood use, and to lower costs. Such advances are essential if the forest industries are to remain competitive. The last two aspects of decreasing wood consumption involve either direct or indirect replacement of wood by substitute materials. In light of the trends toward apartment construction, and the renewed interest and activity of competing building materials manufacturers in the residential construction industry, these two sources of declining wood consumption are of particular interest at the present time.

The purpose of this study is to assess the current situation with respect to the use of wood and substitute materials in the housing industry in Canada, to identify recent trends in materials use, and to isolate and discuss those factors which have an influence on this question. Both changing methods of construction as reflected by trends in dwelling types, and direct replacement of wood by competing materials, will be investigated. The first question, relating to dwelling types and factors underlying recent trends, should be of interest to the forest industries, but their ability to influence such trends is negligible. The second question, relating to the substitution of other materials for wood, is of more immediate interest to materials suppliers since it is in this area that they have direct influence through their research, product development, and marketing programs.

It is intended that this study be based primarily on the Canadian residential construction market. However, due to similarities with the
U.S.A., much of the content of this thesis will apply to all of North America; and where Canadian data are lacking, U.S. data may be used as indicative of the overall situation in North America, or as a basis of evaluating the Canadian position.

Due to the importance of export markets to the Canadian forest industries, the significance of the domestic market is sometimes overlooked. Accordingly, it is noted here that, of the estimated 2,020,391 M sq. ft. (3/8 in.) of softwood plywood produced in Canada in 1969, 75 per cent was shipped to domestic markets, and the remainder exported, primarily to the United Kingdom and Europe, and Japan. For the same year, approximately 39 per cent of the total Canadian lumber production of 11,419 MM fbm was consumed by the domestic market, while 82 per cent of the exports went to the U.S.A. Combined, Canada and the U.S.A. consumed 88 per cent of Canadian lumber production in 1969.

The market will be further restricted to include "primary" housing only (residential construction intended for year-round occupancy), and will exclude such structures as summer cottages, cabins, shacks, trailers and boathouses. Mobile homes will also be considered a separate market and will be excluded from this study.
TRENDS IN HOUSING

Although the main discussion in this section focuses on trends in types of dwellings erected, the actual volume of residential construction is also significant in determining the demand for wood products by the housing industry. It is therefore appropriate to begin with a brief outline of the chief sources of housing demand, and some recent projections of this demand in Canada.

Historical Developments in Housing

Since World War II, Canada's performance in providing shelter has been good in relation to its growing needs and demands for housing. Nevertheless, a slight lag in production relative to requirements during the 1961-66 period developed into a severe housing shortage in many parts of the country by 1967 (Economic Council of Canada, 1967 and 1969). A major factor in this shortage was a severe curtailment of housing starts in 1966 (due largely to a deficiency of mortgage funds) at a time when family formations were growing at a high rate. The result is that Canada is entering a period of increasing housing demand (from several sources) while still faced with a shortage which has developed during the past decade.

Sources of Housing Demand

The demand for housing consists of several components:

(i) net family household formation;
(ii) net non-family household formation;
(iii) undoubling;
(iv) net replacements (accidental loss, farm abandonments, non-farm removals);
(v) vacancies.

Each of these factors will be briefly discussed in the context of Canada's present housing situation.

(i) Net family household formation

This is the most important source of new demand for housing (Dubé et al., 1957). The post-war "baby boom" has led to a substantial increase in marriages and family formation in the latter half of the 1960's, and the trend is expected to continue to 1980 (Illing, 1967). The proportion of net family formation made up from net immigration is quite variable but is expected to average 13 per cent of net family formation to 1980 (Illing, 1967). Although not all families form households, it was estimated that 94.3 per cent did so in 1961, and this figure was forecast to increase to 97.5 per cent in 1967 (Illing, 1964).

(ii) Net non-family household formation

This category of household formation is largely affected by the extent to which young single people and elderly individuals establish their own households (Economic Council of Canada, 1967). Since the early 1950's, there has been a great upsurge in non-family households, having risen from about 450,000 in the early 1950's to over 800,000 by the mid-1960's (Economic Council of Canada, 1967). In the 1960-65 period, when family formation was relatively low, the average annual increase in non-family households was 4.9 per cent, compared to 1.9 per cent for family households. It is predicted that these rates of increase will change to 2.9 per cent for non-family
households and 2.6 per cent for family households in the 1970-75 period (Illing, 1967). In the period to 1980, the age groups providing the bulk of people likely to establish non-family households will be growing strongly.

(iii) Undoubling

The increasing ability of families living in shared accommodations to set up their own households is an important factor contributing to housing demand. In the early 1950's, an estimated 10 per cent of all Canadian families lived in shared accommodation, but by 1965, probably less than five per cent remained in this category. A similar rate of undoubling is anticipated to 1980 (Illing, 1967).

The relationship between housing completions and the above three sources of demand is greatly influenced by general economic conditions and family incomes.

(iv) Net replacements

This source of demand can result from three causes: (1) accidental losses due to fire, flood, and other natural destructive forces; (2) abandonments of farm dwellings associated with rural-urban population shifts; (3) withdrawal of dilapidated non-farm dwellings, or removals for either private or public construction purposes (Illing, 1964). Losses in housing stock due to the first and third causes above were reported to average 8,000 units per year in the years just prior to 1957, equally shared by farm and non-farm dwellings (Dubé et al., 1957). These replacements are closely related to the age structure of the housing stock and the
Life expectancy of dwellings, and are expected to be at least as high in the future as they have been in the past (Dubé et al., 1957). Farm abandonments have undoubtedly been substantial in recent years, increasing housing demands elsewhere. Although such movements will continue, their relative importance is likely to decrease (Illing, 1964).

(v) Vacancies

A certain percentage of vacancies in the total housing stock is required to facilitate population mobility and allow for smooth adjustment between demand and supply (Economic Council of Canada, 1967). This vacancy rate was 3.3 per cent in 1951, 2.6 per cent in 1955, and for projection purposes Dubé et al. (1957) assumed a rate of 3.3 per cent. More recently, Illing (1964) reported vacancy rates of 3.5 and 3.9 per cent in 1961 and 1963, respectively; and assumed a rate of 4.0 per cent for his projections. A small but consistent demand will originate from this source as the total housing stock increases.

Projections of Housing Demand

Recent housing demand projections for Canada have incorporated various assumptions with respect to the sources of demand outlined above in order to determine future housing requirements. For the Royal Commission on Canada's Economic Prospects, Dubé et al. (1957) incorporated an estimate of housing requirements to 1980 in their report on "Housing and Social Capital." Their projections are shown in Table 1. Actual housing production to the end of 1969 has proven the above figures to be conservative.
### TABLE I

**ESTIMATED HOUSING CONSTRUCTION REQUIREMENTS 1956 - 80**

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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Net Family Formation</strong></td>
<td>348</td>
<td>414</td>
<td>500</td>
<td>605</td>
<td>683</td>
<td>2,550</td>
</tr>
<tr>
<td><strong>Non-Family Household Formation</strong></td>
<td>66</td>
<td>67</td>
<td>70</td>
<td>78</td>
<td>89</td>
<td>370</td>
</tr>
<tr>
<td><strong>Reduction of Crowding</strong></td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>250</td>
</tr>
<tr>
<td><strong>Replacements Rural-Urban Pop. Shifts</strong></td>
<td>25</td>
<td>20</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>50</td>
</tr>
<tr>
<td><strong>Other Replacements</strong></td>
<td>50</td>
<td>58</td>
<td>66</td>
<td>74</td>
<td>82</td>
<td>330</td>
</tr>
<tr>
<td><strong>Vacancies</strong></td>
<td>20</td>
<td>24</td>
<td>29</td>
<td>33</td>
<td>38</td>
<td>144</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>559</td>
<td>633</td>
<td>720</td>
<td>840</td>
<td>942</td>
<td>3,694</td>
</tr>
<tr>
<td><em>(Avg. Annual Requirements)</em></td>
<td>(112)</td>
<td>(127)</td>
<td>(140)</td>
<td>(168)</td>
<td>(188)</td>
<td></td>
</tr>
</tbody>
</table>

*Source: Dubé et al., 1957. Housing and Social Capital.*

In Table 2 is indicated the actual performance of the residential construction industry.

Comparing appropriate figures in Tables 1 and 2, it is apparent that the actual performance of the residential building industry has exceeded the requirements projected by Dubé et al. (1957). The largest single
TABLE 2
ACTUAL VOLUME OF HOUSING CONSTRUCTED TO 1969

<table>
<thead>
<tr>
<th></th>
<th>1956-60</th>
<th>1961-65</th>
<th>1966-69</th>
</tr>
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<tbody>
<tr>
<td>Starts</td>
<td>664,486</td>
<td>736,519</td>
<td>705,890</td>
</tr>
<tr>
<td>(Annual Average)</td>
<td>(132,897)</td>
<td>(147,304)</td>
<td>(176,472)</td>
</tr>
<tr>
<td>Completions</td>
<td>669,097</td>
<td>674,481</td>
<td>678,253</td>
</tr>
<tr>
<td>(Annual Average)</td>
<td>(133,819)</td>
<td>(134,896)</td>
<td>(169,563)</td>
</tr>
</tbody>
</table>

* A start is recorded when the footing of the structure has been installed.

† A completion is recorded when all proposed construction work on a dwelling unit has been performed.


The error in these projections has been in the category of non-family household formations. During the 1961-65 period, non-family households were formed at a rate of 37,000 per year, a rate considerably higher than the estimated 13,400 per year (for a total of 67,000 for the five-year period) given in Table 1. It should also be noted that actual production in the years 1961-66 was not sufficient, resulting in a severe shortage of housing by 1967 (Economic Council of Canada, 1967 and 1969). More recently, the Canadian Government has voiced its commitment to the construction of one million new dwelling units in the 1969-74 period, an average of 200,000 units per year (Canadian Building, 1971). Considering the 210,415 starts
in 1969 and 190,528 starts in 1970, the housing industry has thus far kept pace with this prediction. With over 200,000 starts predicted for 1971 (Canadian Building, 1971), it is probable that the commitment to the construction of one million dwelling units over the five-year period to 1974 will be met.

The most recent projections of housing demand by the Economic Council of Canada are contained in the Sixth Annual Review (Economic Council of Canada; 1969), which have been summarized in Table 3. These estimates are dependent upon the expected rapid growth in new household formation as well as needs generated from the other sources previously outlined, and represent a high rate of growth in demand. The rate of growth of expenditures for new housing is expected to average 6.1 per cent in the 1967-75 period (Economic Council of Canada, 1969). By 1975, total housing expenditures in Canada would thus be approximately 4.4 per cent of Gross National Product, compared with 3.8 per cent in 1966 (Economic Council of Canada, 1967 and 1969).

TABLE 3

COMPONENTS OF HOUSING DEMAND BASED ON DEMOGRAPHIC TRENDS

(Annual Averages)

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<tbody>
<tr>
<td>Net Family Formation</td>
<td>76</td>
<td>111</td>
<td>135</td>
<td>155</td>
</tr>
<tr>
<td>Undoubling</td>
<td>11</td>
<td>11</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Net Non-Family Household Formation</td>
<td>37</td>
<td>50</td>
<td>56</td>
<td>60</td>
</tr>
<tr>
<td>Net Replacements</td>
<td>10</td>
<td>13</td>
<td>21</td>
<td>26</td>
</tr>
<tr>
<td>Vacancies</td>
<td>6</td>
<td>5</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Total (Annual Average)</td>
<td>140</td>
<td>190</td>
<td>230</td>
<td>257</td>
</tr>
<tr>
<td>(Five Year Totals)</td>
<td>(700)</td>
<td>(950)</td>
<td>(1150)</td>
<td>(1285)</td>
</tr>
</tbody>
</table>

Trends in Dwelling Types

A rapid expansion of house construction will not necessarily alone ensure an increasing market for wood products. An equally important question is the form this new construction will take. As a result of differing building techniques, structural requirements, and building codes, various types of dwellings have different materials requirements. Generally speaking, single-detached houses (using conventional wood frame construction) have the highest, and high-rise apartments the lowest consumption of wood products per dwelling unit constructed. Two-family structures are similar to single-detached houses in their use of materials, while row housing falls between these and apartments. Consumption data indicating the significant differences which exist between these dwelling types will be presented in the following section. Trends in dwelling types are thus an important factor in determining the volume of wood products employed as well as the form in which they will be needed.

Whether the factors which underlie these trends are beyond the control of the forest industries or not, a close examination of them is essential to a clear understanding of the housing market and its future potential for the wood products industries.

The Dominion Bureau of Statistics (DBS) and Central Mortgage and Housing Corporation (CMHC) report identical statistics for the volume of housing starts and completions by dwelling types. These data, for all areas of Canada, are presented in Tables 4 and 5, and illustrated in Figures 1 and 2. The single-family dwelling has been declining in relative importance over the period for which statistics are available. In 1950, starts of
single-detached units accounted for 74.1 per cent of all housing starts, but had declined to 61.7 per cent by 1960, and to 37.3 per cent by 1969. On the other hand, starts of apartment units rose from 15.8 per cent in 1950 to 27.3 per cent in 1960, and had reached 52.7 per cent of all starts by 1969. These data indicate that the trend toward apartment construction, which originated in the 1950's, began to accelerate in the 1960's. This increase in apartments and corresponding decrease in single-family units is quite evident in both Figures 1 and 2. Starts of semi-detached and duplex units remained relatively stable over most of the period since 1950, with a slight decrease evident since 1961. Row housing, which was almost non-existent in 1950, has gradually increased to represent 5.1 per cent of starts in 1969.

By comparing Figures 1 and 2, it is apparent that starts and completions follow a similar pattern, the main difference being that completions lag behind starts because many units begun in a given year are completed in the following year. Between 1950 and 1969, completions of single-family units (as a per cent of total completions) declined from 68.2 to 40.1 per cent, while over the same period, the proportion of apartment units completed rose from 14.4 to 50.5 per cent.
### TABLE 4

STARTS BY TYPE OF DWELLING, ALL AREAS

<table>
<thead>
<tr>
<th>YEAR</th>
<th>SINGLE DETACHED</th>
<th>SEMI-DETACHED AND DUPLEX</th>
<th>ROW*</th>
<th>APARTMENT †</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1949</td>
<td>71,425</td>
<td></td>
<td></td>
<td></td>
<td>90,509</td>
</tr>
<tr>
<td>1950</td>
<td>68,675</td>
<td>8,664</td>
<td>631</td>
<td>14,561</td>
<td>92,531</td>
</tr>
<tr>
<td>1951</td>
<td>53,002</td>
<td>5,658</td>
<td>54</td>
<td>9,865</td>
<td>68,579</td>
</tr>
<tr>
<td>1952</td>
<td>60,696</td>
<td>5,360</td>
<td>299</td>
<td>16,891</td>
<td>83,246</td>
</tr>
<tr>
<td>1953</td>
<td>70,782</td>
<td>7,202</td>
<td>553</td>
<td>23,872</td>
<td>102,409</td>
</tr>
<tr>
<td>1954</td>
<td>78,574</td>
<td>6,498</td>
<td>1,000</td>
<td>27,455</td>
<td>113,527</td>
</tr>
<tr>
<td>1955</td>
<td>99,003</td>
<td>10,606</td>
<td>1,909</td>
<td>26,758</td>
<td>138,276</td>
</tr>
<tr>
<td>1956</td>
<td>90,620</td>
<td>9,441</td>
<td>2,263</td>
<td>24,987</td>
<td>127,311</td>
</tr>
<tr>
<td>1957</td>
<td>82,955</td>
<td>9,272</td>
<td>2,214</td>
<td>27,899</td>
<td>122,340</td>
</tr>
<tr>
<td>1958</td>
<td>104,508</td>
<td>10,713</td>
<td>2,457</td>
<td>46,954</td>
<td>164,362</td>
</tr>
<tr>
<td>1959</td>
<td>92,178</td>
<td>10,468</td>
<td>1,908</td>
<td>36,791</td>
<td>141,345</td>
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<tr>
<td>1960</td>
<td>67,171</td>
<td>9,699</td>
<td>2,301</td>
<td>29,687</td>
<td>108,858</td>
</tr>
<tr>
<td>1961</td>
<td>76,430</td>
<td>11,650</td>
<td>1,864</td>
<td>35,633</td>
<td>125,577</td>
</tr>
<tr>
<td>1962</td>
<td>74,443</td>
<td>10,975</td>
<td>3,742</td>
<td>40,935</td>
<td>130,095</td>
</tr>
<tr>
<td>1963</td>
<td>77,158</td>
<td>7,891</td>
<td>3,895</td>
<td>59,680</td>
<td>148,624</td>
</tr>
<tr>
<td>1964</td>
<td>77,079</td>
<td>8,706</td>
<td>4,755</td>
<td>75,118</td>
<td>165,658</td>
</tr>
<tr>
<td>1965</td>
<td>75,441</td>
<td>7,924</td>
<td>5,306</td>
<td>77,894</td>
<td>166,565</td>
</tr>
<tr>
<td>1966</td>
<td>70,642</td>
<td>7,281</td>
<td>5,000</td>
<td>51,551</td>
<td>134,474</td>
</tr>
<tr>
<td>1967</td>
<td>72,534</td>
<td>9,939</td>
<td>7,392</td>
<td>74,258</td>
<td>164,123</td>
</tr>
<tr>
<td>1968</td>
<td>75,339</td>
<td>10,114</td>
<td>8,042</td>
<td>103,383</td>
<td>196,878</td>
</tr>
<tr>
<td>1969</td>
<td>78,404</td>
<td>10,773</td>
<td>10,721</td>
<td>110,917</td>
<td>210,415</td>
</tr>
</tbody>
</table>

*Includes only single attached houses in a row of three or more dwelling units.

†Includes the following: (i) double-duplex; (ii) triplex; (iii) row-duplexes; (iv) apartments as commonly known; and (v) dwellings over, or at the back of a store, or other non-residential structure.

A dwelling unit is defined as a structurally separate set of living quarters with private entrance from exterior or common hall, lobby, vestibule, or stairway inside the building.

### TABLE 5

**COMPLETIONS BY TYPE OF DWELLING, ALL AREAS**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>SEMI-DETACHED</th>
<th>SINGLE DETACHED AND DUPLEX</th>
<th>ROW*</th>
<th>APARTMENT†</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Number of Dwelling Units++)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1949</td>
<td>68,966</td>
<td>7,309</td>
<td>485</td>
<td>11,473</td>
<td>88,233</td>
</tr>
<tr>
<td>1950</td>
<td>68,685</td>
<td>7,376</td>
<td>145</td>
<td>12,809</td>
<td>89,015</td>
</tr>
<tr>
<td>1951</td>
<td>60,366</td>
<td>7,568</td>
<td>585</td>
<td>12,791</td>
<td>88,441</td>
</tr>
<tr>
<td>1952</td>
<td>55,967</td>
<td>5,314</td>
<td>99</td>
<td>11,707</td>
<td>73,087</td>
</tr>
<tr>
<td>1953</td>
<td>68,916</td>
<td>7,714</td>
<td>372</td>
<td>19,837</td>
<td>96,839</td>
</tr>
<tr>
<td>1954</td>
<td>71,760</td>
<td>6,098</td>
<td>1,065</td>
<td>23,042</td>
<td>101,965</td>
</tr>
<tr>
<td>1955</td>
<td>90,553</td>
<td>8,278</td>
<td>1,547</td>
<td>27,551</td>
<td>127,929</td>
</tr>
<tr>
<td>1956</td>
<td>95,656</td>
<td>11,872</td>
<td>2,137</td>
<td>26,035</td>
<td>135,700</td>
</tr>
<tr>
<td>1957</td>
<td>81,096</td>
<td>8,464</td>
<td>2,350</td>
<td>25,373</td>
<td>117,283</td>
</tr>
<tr>
<td>1958</td>
<td>96,830</td>
<td>10,004</td>
<td>2,226</td>
<td>37,626</td>
<td>146,686</td>
</tr>
<tr>
<td>1959</td>
<td>95,455</td>
<td>10,923</td>
<td>2,308</td>
<td>36,985</td>
<td>145,671</td>
</tr>
<tr>
<td>1960</td>
<td>78,113</td>
<td>9,911</td>
<td>1,616</td>
<td>34,117</td>
<td>127,575</td>
</tr>
<tr>
<td>1961</td>
<td>76,171</td>
<td>10,593</td>
<td>2,019</td>
<td>26,825</td>
<td>115,608</td>
</tr>
<tr>
<td>1962</td>
<td>75,593</td>
<td>11,922</td>
<td>2,451</td>
<td>36,716</td>
<td>126,682</td>
</tr>
<tr>
<td>1963</td>
<td>71,585</td>
<td>7,150</td>
<td>3,487</td>
<td>45,969</td>
<td>128,191</td>
</tr>
<tr>
<td>1964</td>
<td>76,225</td>
<td>8,091</td>
<td>3,861</td>
<td>62,786</td>
<td>150,963</td>
</tr>
<tr>
<td>1965</td>
<td>75,104</td>
<td>8,730</td>
<td>4,097</td>
<td>65,106</td>
<td>153,037</td>
</tr>
<tr>
<td>1966</td>
<td>73,858</td>
<td>7,707</td>
<td>6,412</td>
<td>74,215</td>
<td>162,212</td>
</tr>
<tr>
<td>1967</td>
<td>73,631</td>
<td>9,089</td>
<td>5,431</td>
<td>61,091</td>
<td>149,242</td>
</tr>
<tr>
<td>1968</td>
<td>74,640</td>
<td>10,098</td>
<td>7,896</td>
<td>78,359</td>
<td>170,093</td>
</tr>
<tr>
<td>1969</td>
<td>78,584</td>
<td>10,483</td>
<td>7,827</td>
<td>98,932</td>
<td>195,826</td>
</tr>
</tbody>
</table>

* Includes only single attached houses in a row of three or more dwelling units.

† Includes the following: (i) double-duplex; (ii) triplex; (iii) row-duplexes; (iv) apartments as commonly known; and (v) dwellings over, or at the back of a store, or other non-residential structure.

+++ A dwelling unit is defined as a structurally separate set of living quarters with private entrance from exterior or common hall, lobby, vestibule, or stairway inside the building.

Source: Central Mortgage and Housing Corporation, 1969a.

Canadian Housing Statistics 1968.
Figure 1. Housing starts by dwelling type as percent of total

Figure 2. Housing completions by dwelling type as percent of total

The trend to apartment construction will continue, and level off at some upper limit which can only be speculated upon at the present time. In both Europe and the U.S.A., a recent trend toward low-rise multi-family dwellings, rather than high-rise, has been noted. This may indicate that an increase in low-rise apartments and row houses will also occur in Canada.

Factors Influencing Types of Dwellings Constructed

To understand the evolving emphasis on apartments and decreasing single-family units, it is necessary to isolate the factors influencing the types of dwellings constructed and weigh their relative importance. Although a few others may exist, the following are probably the most significant elements interacting to produce the trends noted above: urban population growth, availability of mortgage money, land costs, rental costs versus house prices, personal disposable and family incomes, consumer preferences, and zoning by-laws.

(i) Urban population growth

This is the greatest single element influencing the trend toward apartment construction, and is closely linked with some of the other factors listed above. Urban growth in Canada has been both extensive and swift. About 40 years ago, urban population became larger than rural population, and today approximately three-quarters of the population is urban (Smith, A.J.R., 1969). In fact, over the past 10 or 15 years, the rural population has declined. It is anticipated that by 1980, 80 per cent of the population will be living in urban areas (Economic Council of
Canada, 1969). There is possibly some upper limit to the concentration of urban population but, judging from the experience of other highly urbanized countries, there is no evidence that this level is likely to be under 80 per cent (Economic Council of Canada, 1967). The fastest growing areas are the large urban centres, particularly Montreal, Toronto, and Vancouver, which collectively accounted for one-quarter of the population in the mid-1960's and are forecast to contain one out of three Canadians by 1980 (Smith, A.J.R., 1969). These trends have important implications for housing, and will influence the demand for wood products to the extent that location of housing (urban versus rural) influences the type of dwelling constructed.

Apartments account for a greater proportion of new housing in urban areas than shown in Figures 1 and 2 for all regions and, consequently, single-family dwellings account for a smaller proportion of new urban housing than in the country as a whole. Based on CMHC data, in 1969 starts of detached houses accounted for 37.3 per cent of all starts in Canada, but only 27.6 per cent of starts in urban areas. In the same year, apartments composed 52.7 per cent of all starts in Canada, and 61.6 per cent of starts in urban areas. It may also be noted that in 1969, 94.3 per cent of all apartment starts were in urban areas, while only 60.0 per cent of starts of detached houses are in these areas. These latter proportions have been relatively constant over the past seven years. Between 1962 and 1969, according to the same source, total starts in urban

*Centres of 10,000 population or more.*
areas has increased from 78.4 per cent to 80.7 per cent of total starts in Canada. The Economic Council of Canada indicated in its 1967 annual review that possibly 98 per cent of residential construction will be urban by the late 1970's. This would suggest a considerably higher relative construction of apartments than at the present time.

(ii) Consumer preferences

Closely associated with the increasing urban population are the housing preferences of the various groups of which it is composed. It has been indicated above that a high rate of new family formation is expected to continue to 1980. Young family household heads (who will be predominant among new family household heads) will accentuate the demand for rental accommodation for income and other reasons (Illing, 1964). Non-family households, which are composed primarily of females (and to some extent males) in older age groups, and by young adults, will also be providing considerable demand for housing to 1980 (Economic Council of Canada, 1967). The preference of these groups, particularly the younger non-family household heads, is largely for rentals (Illing, 1964). High mobility of the population (which is frequently associated with higher educational levels) will also tend to increase the demand for rentals (Davis, 1967). Although difficult to quantify, Illing (1964) has suggested that the trend to apartment living may also reflect a disenchantment with life in the suburbs, greater availability of attractive apartment space, and troublesome commuting problems.

On the other hand, no one dwelling type would likely suit every household at every stage of life and, accordingly, there should be a variety of
dwelling types to correspond to the variety in households (Royal Architectural Institute of Canada, 1960). In Canada, it has been traditional for families to own their own home and the social value of land ownership is high (Rashleigh, 1962). Adamson (1967) and Mansur (1967) feel that the trend to apartment living does not spell the doom of the single-family dwelling and that, in the long term, there will be a need for a larger proportion of the housing stock in the form of detached houses.

Most new rentals have been designed for small family or non-family groups (Rose, 1967) and do not meet the needs of family living other than well-serviced physical shelter (Erickson, 1967). It was found by the recent Task Force on Housing and Urban Development that the overall preference is for single-family houses. Using informal (and non-scientific) sampling techniques, it was found that at least 80 per cent of those present at their public meetings wanted to own their own home, a figure which is reported to correspond with the findings of a Toronto professor using more scientific sampling procedures (Hellyer, 1969).

(iii) Investor preferences

The residential construction industry, being composed largely of numerous small companies, depends heavily on borrowed funds for its construction activities (Porter, 1964); approximately 82 per cent of the financing was from external sources from 1954 to 1964. The potential influence of external investors on types of dwellings constructed is thus worth considering.

The majority of mortgage loans made in Canada fall under one of three categories: (i) NHA insured loans by lending institutions (life
insurance companies, trust companies, mortgage loan companies, chartered banks, etc.); (ii) conventional loans by lending institutions; (iii) NHA insured loans by CMHC. In 1968, the number of dwelling units approved under each of these was:

(i) NHA-insured loans (by institutions)  61,601  
(ii) conventional loans  86,036  
(iii) CMHC loans  27,487  

The types of loans made by CMHC are summarized in Table 6. It is evident that the majority of direct loans made under Section 40 of the National Housing Act have been to individuals for the purchases of new houses. The "other" category, which has been increasing rapidly in the past few years, consists largely of low-rise multi-unit dwellings. Although CMHC mortgages have been largely for single-family dwellings in the 1960's, in 1968 they were divided fairly evenly between single and multiple units.

Institutional lenders account for by far the largest portion of mortgages approved, and are thus in the best position to influence the type of dwelling units constructed. In Table 7 is indicated the relative disposition of institutional mortgage funds between new single-detached houses and multiple unit housing for conventional and NHA-insured loans. In the 1950's, the National Housing Act stimulated the construction of detached dwellings not exceeding a specific size and value (Illing, 1964). At least since 1957, there has been a definite trend toward the financing of multiple-unit dwellings under NHA-insured loans. It is also apparent from Table 7 that the majority of conventional mortgage funds provided by institutional lenders have been for multiple-unit residences, although no major trend is apparent.
### TABLE 6
NHA-APPROVED LOANS BY CMHC FOR NEW HOUSING

<table>
<thead>
<tr>
<th>YEAR</th>
<th>HOME-OWNERSHIP (Dwelling Units)</th>
<th>RENTAL</th>
<th>OTHER*</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1962</td>
<td>13,223</td>
<td>--</td>
<td>1,328</td>
<td>14,551</td>
</tr>
<tr>
<td>1963</td>
<td>21,953</td>
<td>562</td>
<td>2,094</td>
<td>24,609</td>
</tr>
<tr>
<td>1964</td>
<td>25,254</td>
<td>1,566</td>
<td>1,861</td>
<td>28,681</td>
</tr>
<tr>
<td>1965</td>
<td>27,465</td>
<td>2,328</td>
<td>2,521</td>
<td>32,314</td>
</tr>
<tr>
<td>1966</td>
<td>27,844</td>
<td>2,828</td>
<td>5,403</td>
<td>36,075</td>
</tr>
<tr>
<td>1967</td>
<td>28,185</td>
<td>4,947</td>
<td>9,912</td>
<td>43,044</td>
</tr>
<tr>
<td>1968</td>
<td>12,992</td>
<td>1,352</td>
<td>13,143</td>
<td>27,487</td>
</tr>
</tbody>
</table>

*Includes activity under the following sections of the National Housing Act: Limited Dividend (Sec. 16), Non-Profit (Sec. 16A), Primary Industry (Sec. 17), Public Housing (Sec. 35D), Student Housing (Sec. 36B).

<table>
<thead>
<tr>
<th>YEAR</th>
<th>NHA-Insured</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SINGLE DETACHED DWELLINGS</td>
<td>MULTIPLE DWELLINGS</td>
</tr>
<tr>
<td>1957</td>
<td>92.5</td>
<td>7.5</td>
</tr>
<tr>
<td>1958</td>
<td>82.6</td>
<td>17.4</td>
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<tr>
<td>1959</td>
<td>85.7</td>
<td>14.3</td>
</tr>
<tr>
<td>1960</td>
<td>67.0</td>
<td>33.0</td>
</tr>
<tr>
<td>1961</td>
<td>62.2</td>
<td>37.8</td>
</tr>
<tr>
<td>1962</td>
<td>69.4</td>
<td>30.6</td>
</tr>
<tr>
<td>1963</td>
<td>65.4</td>
<td>34.6</td>
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<tr>
<td>1964</td>
<td>43.4</td>
<td>56.6</td>
</tr>
<tr>
<td>1965</td>
<td>33.5</td>
<td>66.5</td>
</tr>
<tr>
<td>1966</td>
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</tr>
<tr>
<td>1967</td>
<td>22.0</td>
<td>78.0</td>
</tr>
<tr>
<td>1968</td>
<td>32.8</td>
<td>67.2</td>
</tr>
</tbody>
</table>

The chartered banks, which virtually withdrew from NHA lending in 1959, resumed mortgage lending in May, 1967. The banks favour single-family units as recipients of their mortgage funds, partly because it enables them to spread funds more effectively across the whole country through extensive bank networks (CMHC, 1969a), and partly because of the short-term turn-over of these mortgages versus mortgages on apartments (Mathias, 1968). The chartered banks (which accounted for 18.5 per cent of mortgage loans approved by lending institutions in 1968) can be expected to increase their mortgage participation (Smith, L.B., 1969) and thus ensure the availability of funds for detached houses.

On the other hand, life insurance companies (the largest group of institutional lenders) are showing an increasing preference for mortgages on rental projects (Mathias, 1968). One reason for this is that in a rental project, they can lock a borrower into the mortgage for a relatively long period (which is negotiable, and often 25 years or more) compared to five years for conventional and NHA-insured loans to home owners. Thus, when interest rates are high, rental projects are favoured (Mathias, 1968). A second reason for preferring mortgages on rental projects is the possibility of equity participation which provides a hedge against inflation. Such participation cannot be obtained in the case of individual homes (Boyd, 1968). Another reason for more money going into apartments is the lower cost of servicing the mortgage, a cost which is reportedly three times higher for single-family units than for apartments (Gibson, 1969). Other NHA-approved lenders (trust companies, loan companies, etc.) also favour rental projects for their funds for the reasons indicated above. Pension funds, which are now beginning to increase their commitment to mortgages,
appear to be following the lead of life insurance companies in demanding equity participation (Gibson, 1969). At present, with the highest proportion of institutional mortgage funds coming from life insurance, trust, loan, and other such companies (approximately 80 per cent) institutional investor preferences are definitely balanced in favour of multiple unit structures.

(iv) Land costs

The cost of land, as it influences the building of apartments, only operates in urban areas. If land prices become too high, it becomes uneconomical to build detached houses, the land requiring more intensive use such as for apartments. With the high degree of urbanization expected, as previously outlined, increasing pressures on urban land can be anticipated. This will logically lead to more intensive use and higher costs of land in urban areas, with the result that multiple unit dwellings will be favoured. It should be recognized that the allocation of land to apartment construction is largely a zoning matter, hence high land costs alone are not a sufficient basis on which to forecast increases in multi-family dwellings.

(v) Incomes and housing costs

The relative cost of various types of accommodation, combined with ability to pay, together influence a family's choice of residence. Increases in housing costs can be attributed to a number of factors. Hellyer (1969) indicated that the three major causes are: (i) the cost
of money; (ii) the cost of land; and (iii) sales tax on building materials. The increase in land costs is largely due to demands from municipalities that developers install a variety of fully-paid services in new subdivisions (Andras, 1969). Municipal zoning laws have been cited by the Royal Architectural Institute of Canada (1960) to be responsible for the waste of substantial portions of suburban land, thus raising the cost per individual lot. In recent years, interest rates on mortgages have climbed steeply. According to Hellyer (1969), a rise of one percentage point in interest rates on a $15,000 25-year mortgage increases the monthly payment by over $9, raising its total amortization cost by more than $2,800. In addition to these reasons, price increases can be traced to larger floor areas, and mounting quotas of mechanical gear and conveniences built in during construction.

In spite of rapid increases in shelter costs, incomes have been rising even faster (Adamson, 1967). Evidence of this is shown in Figure 3, where it is apparent that personal disposable income per capita has been rising faster than housing costs. Although family incomes may be a better measure to use than personal disposable income per capita, such data are somewhat incomplete. Figures presented by CMHC (1969a) for available years indicate that family incomes are rising at an even higher rate than personal disposable income per capita. Assuming that the distribution of incomes is not becoming less equitable throughout Canada, the ability of Canadians to purchase housing is thus increasing. At the same time, the increasing volume of goods and services available to the consumer may be decreasing the proportion of his income which is willing to allocate to housing. In support
Figure 3. Indexes of shelter cost and personal disposable income per capita
of this, Rich (1970) indicated that, in recent years, a greater portion of the consumer's discretionary purchases has been for travel, sport, recreation, education, and a variety of other services.

Since 1960, the cost of home-ownership has been increasing at a faster rate than the cost of rental accommodation. This is illustrated in Figure 4. Although the extent to which this has been influencing the trend to apartment living would be difficult to determine, it has undoubtedly been an underlying factor.

Associated with this relatively higher cost of detached houses (and the trend toward apartment living) is the increasing down payment requirement which often acts as a deterrent to home-ownership (Mansur, 1967). Under the National Housing Act it is possible to obtain a mortgage with a five per cent down payment. Conventional lenders are theoretically limited to a 75 per cent loan, but in practice it is possible to increase this to 90 per cent (Hellyer, 1969). The NHA loan ceiling (which was $18,000 and just recently raised to $25,000), coupled with increasing market prices, have often resulted in an even higher down payment. The average down payment for houses under NHA terms increased from $2,475 in 1961 to $4,547 in 1968 (CMHC, 1969a), an increase of 84 per cent as compared to a 70 per cent increase in family incomes over the same period. The down payment probably has the greatest effect in deterring new (young) families from purchasing a house.

It is almost impossible to indicate the relative influence the factors discussed above have had on the trend towards apartment construction. The growth of urban centres has been singled out as the most important, yet some of the other factors are closely related to this phenomenon;
Figure 4. Consumer price indexes of shelter cost: rental versus home ownership.

and all the aspects outlined undoubtedly had a significant effect.

Looking over the list of items involved in the increasing proportion of apartment construction, it is evident that they are all virtually beyond the influence of the forest industries, with the possible exception of house prices. House prices can only be influenced by the forest industries through decreases in their product costs to the builder or through increased industrialization of wood frame construction methods. Viewing the historical upward trends in lumber prices, there must be some doubt that significant economies can be effected. Even given such cost reductions, it is unlikely that the demand would be sufficiently elastic to result in increased profits, due to the influence of the other factors which have affected the trends to multi-family dwellings. It can be concluded that the trends noted must be accepted as given. Efforts by the forest industries to improve their position in the housing markets must be superimposed upon this framework of dwellings types.
CONSUMPTION OF WOOD PRODUCTS IN HOUSING

In the previous section, trends in dwellings types were outlined. Their significance lies in the effect that type of dwelling has on wood consumption. There is little statistical information on this for Canadian housing, but some general observations and American statistics are somewhat enlightening.

In the past, the bulk of Canadian housing was of the single-family variety, and has traditionally been of wood frame construction, with resultant high demands for softwood lumber and other wood products (McCance, 1969a). According to the Canadian Department of Trade and Commerce (ca. 1965), about 90 per cent of Canadian houses use wood frame construction. More recently, other forms of low housing have developed, including semi-detached, duplex, and row or townhouse dwellings. The use of wood is also high in these dwelling types since they largely follow wood frame construction methods, with the exception of fire-resisting party walls where required in building codes (McCance, 1969a).

It may be noted that the absolute volume of wood per unit used in wood frame row housing would be less than in a wood frame single-family house due to the elimination of some walls. Similarly, there are significant reductions in roofing materials required in low-rise dwelling forms which have one dwelling unit above another. These observations apply to low-rise apartments of wood frame construction which are constructed up to three storeys high. Prestemon (1970b) indicated that low-rise...
"garden apartments" of one to three storeys have traditionally been of the wood frame type in the U.S.A. It is reasonable to assume that this is also the case in Canada. High-rise apartments use substantially less wood than low housing forms (including low-rise apartments), both because of the threat of fire spread and for structural reasons (McCance, 1969a).

There is no distinction made in CMHC data between low-rise and high-rise apartments. The U.S. Department of Agriculture (1965) has indicated that low-rise apartments of less than four storeys have accounted for over 75 per cent of all multi-family dwelling units built in the U.S.A. in recent years, and Prestemon (1970b) stated that about 80 per cent of apartments built in 1968 were in this category.

If this latter figure is applied to the 1968 starts and completions of apartments in Canada (from Tables 4 and 5), an estimated 20,677 starts and 15,672 completions were in high-rise apartments, corresponding to 11 and nine per cent of total starts and completions, respectively. If 90 per cent of all other forms of housing are assumed to be of wood frame construction (as is the case for single-family houses), then approximately 158,580 starts, and 139,790 completions in 1968, corresponding to 81 and 82 per cent of all starts and completions, respectively, were in dwellings utilizing wood frame construction methods. This is a gross (and perhaps liberal) estimate based on two assumptions, the validity of which can neither be proven nor disproven on the basis of available information. Nevertheless, this estimate does indicate that the situation is not as depressing for the forest industries as might be assumed from Figures 1 and 2.

Actual volumes of wood consumed by type of dwelling are not
available for Canada. Some American studies do provide insight into this question, but their application to the Canadian situation is not entirely valid. The most thorough study to date, carried out by the U.S. Forest Service, reports wood consumption in single-family dwellings inspected by the Federal Housing Administration in 1959, 1962 and 1968 (Phelps, 1970). Some of the findings of this study, covering the whole of the U.S.A., are shown in Table 8. In the houses sampled, it was found that, between 1962 and 1968, average lumber consumption decreased from 10,701 bd. ft. to 10,271 bd. ft. This was largely attributed to the replacement of lumber by plywood for roof sheathing, by carpeting in finish flooring, and by plywood and non-wood materials in siding.

The use of plywood per house, as indicated by this study, increased from 2,382 sq. ft. in 1962 to 4,158 sq. ft. in 1968. This was attributed largely to increased plywood consumption for subflooring and underlayment, millwork and trim, and in roof sheathing. The increased consumption of hardboard per house, from 507 sq. ft. in 1962 to 1,062 sq. ft. in 1968, was due to the increased use of this material in siding and in millwork and trim. The use of insulation board per house remained relatively constant throughout the period, decreasing slightly from 750 sq. ft. in 1962 to 742 sq. ft. in 1968. Most of the increased use of particle board per house, from 70 sq. ft. to 180 sq. ft. over the same period, was due to the greater use of this material as underlayment. Increased shingle consumption per house, from 3.0 to 3.7 squares, reflected a higher percentage of houses using wood shingle roofs (18 per cent in 1968 compared to 10 per cent in 1962).
A number of construction characteristics, notably floor area, type of foundation, number of storeys, and type of exterior wall construction, influence the wood consumption per house. The number of storeys influenced wood consumption primarily through differences in floor area. One-storey houses (79 per cent of the 1968 sample), had an average area of 1,318 sq. ft., split levels (nine per cent of the 1968 sample) had an average area of 1,490 sq. ft., and 1-1/2 to two-storey houses averaged 1,812 sq. ft. of floor area. The overall average floor area was 1,392 sq. ft. This compares to an average floor area of 1,112 sq. ft. for houses financed under the National Housing Act in Canada in 1968. Hence, one might expect that less wood was consumed in Canadian houses than shown in Table 8. On the other hand, 43 per cent of the houses sampled had concrete slab foundations which decreases considerably the volume of wood required. Few houses are constructed in Canada with such foundations, which would tend to increase Canadian consumption per unit above that shown in Table 8. Approximately 91 per cent of the sampled houses had wood frame exterior walls, which is probably close to the Canadian situation. How these factors influence wood consumption per unit is shown in Table 9 using data for 1962. With the probable differences which exist between houses built in the U.S.A. and Canada, it would not be entirely acceptable to assume that figures presented in Tables 8 and 9 are applicable to Canada.
TABLE 8
WOOD USED PER UNIT IN SINGLE-FAMILY HOUSES INSPECTED BY THE FEDERAL HOUSING ADMINISTRATION, 1962 and 1968

<table>
<thead>
<tr>
<th>YEAR</th>
<th>LUMBER (bd.ft.)</th>
<th>PLYWOOD (sq.ft. - 3/8 in.)</th>
<th>HARDBOARD (sq.ft. - 1/4 in.)</th>
<th>INSULATION BOARD (sq.ft. - 1/2 in.)</th>
<th>PARTICLE BOARD (sq.ft. - 3/4 in.)</th>
<th>SHINGLES &amp; SHAKES (Squares)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1962 2,633.</td>
<td>488</td>
<td>9</td>
<td>---</td>
<td>31</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>1968 2,126</td>
<td>1,386</td>
<td>22</td>
<td>---</td>
<td>131</td>
<td>---</td>
</tr>
<tr>
<td>Floor and foundations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1962 3,387</td>
<td>347</td>
<td>333</td>
<td>720</td>
<td>---</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>1968 3,387</td>
<td>277</td>
<td>571</td>
<td>677</td>
<td>---</td>
<td>0.1</td>
</tr>
<tr>
<td>Walls and partitions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1962 3,070</td>
<td>1,080</td>
<td>1</td>
<td>30</td>
<td>---</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>1968 2,927</td>
<td>1,578</td>
<td>*</td>
<td>65</td>
<td>---</td>
<td>3.6</td>
</tr>
<tr>
<td>Roof and ceiling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1962 1,611</td>
<td>467</td>
<td>164</td>
<td>*</td>
<td>39</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>1968 1,831</td>
<td>917</td>
<td>469</td>
<td>*</td>
<td>49</td>
<td>---</td>
</tr>
<tr>
<td>Millwork and trim</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>1962 10,701</td>
<td>2,382</td>
<td>507</td>
<td>750</td>
<td>70</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>1968 10,271</td>
<td>4,158</td>
<td>1,062</td>
<td>742</td>
<td>180</td>
<td>3.7</td>
</tr>
</tbody>
</table>

*Less than 0.5 sq. ft.

### TABLE 9
WOOD USED PER UNIT* BY CONSTRUCTION CHARACTERISTICS, 1962

<table>
<thead>
<tr>
<th></th>
<th>LUMBER (bd. ft.)</th>
<th>PLYWOOD (sq. ft. 3/8 in.)</th>
<th>INSULATION BOARD (sq. ft. 1/2 in.)</th>
<th>PARTICLE BOARD (sq. ft. 3/4 in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Storeys:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One-storey</td>
<td>9,394</td>
<td>1,947</td>
<td>750</td>
<td>68</td>
</tr>
<tr>
<td>1 1/2 - two</td>
<td>12,080</td>
<td>2,970</td>
<td>558</td>
<td>97</td>
</tr>
<tr>
<td>Split level</td>
<td>13(\frac{1}{2})007</td>
<td>3,234</td>
<td>850</td>
<td>66</td>
</tr>
<tr>
<td><strong>Foundation:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-slab</td>
<td>11,823</td>
<td>2,508</td>
<td>766</td>
<td>92</td>
</tr>
<tr>
<td>Slab</td>
<td>7,387</td>
<td>1,673</td>
<td>730</td>
<td>41</td>
</tr>
<tr>
<td><strong>Exterior wall:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood/ frame</td>
<td>10,400</td>
<td>2,205</td>
<td>840</td>
<td>74</td>
</tr>
<tr>
<td>Masonry</td>
<td>6,820</td>
<td>1,829</td>
<td>84</td>
<td>48</td>
</tr>
</tbody>
</table>

*Excluding wood used for exterior wall siding.


Figures showing wood use per dwelling unit were also presented by the U.S. Forest Service in "Timber Trends in the United States" (U.S. D.A., 1965). Their data for 1962, and projections for 1970 and 1980 are presented in Table 10. A substantial difference in wood consumption between dwelling types is evident. In 1962, one and two family dwellings...
TABLE 10
WOOD PRODUCTS CONSUMED PER DWELLING UNIT+

<table>
<thead>
<tr>
<th>YEAR</th>
<th>LUMBER (bd. ft.)</th>
<th>PLYWOOD AND VENEER (sq.ft. - 3/8 in.)</th>
<th>BUILDING BOARD* (sq.ft. - 1/2 in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ONE AND TWO FAMILY</td>
<td>MULTI- FAMILY</td>
<td>ONE AND TWO FAMILY</td>
</tr>
<tr>
<td>1962</td>
<td>11,190</td>
<td>4,500</td>
<td>3,010</td>
</tr>
<tr>
<td>1970</td>
<td>10,740</td>
<td>4,280</td>
<td>3,610</td>
</tr>
<tr>
<td>1980</td>
<td>10,290</td>
<td>4,050</td>
<td>4,010</td>
</tr>
</tbody>
</table>

+ Estimates include allowance for manufacturing and on-site waste.

* Includes insulation board, hardboard, and particle board.


Consumed approximately 2-1/2 times more lumber, 66 per cent more plywood and veneer, and almost four times more building board than did multi-family dwellings on a per unit basis. It should be noted that the figures for multi-family dwellings include both high-rise and low-rise apartments. The volume of lumber employed in these units ranged from about 1,200 bd. ft. per unit in high-rise apartments to 5,600 bd. ft. per unit in the low-rise variety. No comparable figures appear to be available for plywood, hardboard, particle board, or insulation board. The projections indicate that lumber consumption per unit is expected to continue its decline in the future, while plywood and building board increase in per unit consumption.
More recently, Hair and Ulrich (1967) have indicated that multi-family units require only 2/5 as much lumber and 3/5 as much plywood as single-family dwellings. The close correspondence between these ratios and ratios which could be calculated from figures presented in Table 10 would suggest that they were derived from "Timber Trends in the United States."

Several other figures on wood consumption in residential construction are worth noting. According to the American Plywood Association, plywood use per single-family dwelling was 5,500 sq. ft. in 1968 and was expected to rise to 5,700 sq. ft. by 1970 and 6,000 sq. ft. by 1972 (Lambert, 1969). There is evidence that Canadian houses are on the average considerably smaller than in the U.S.A., and hence the consumption of plywood (and other wood products) per unit may be considerably lower. According to the same author, the average floor area of FHA-insured houses in the U.S.A. was 1,365 sq. ft. in 1963 and 1,570 sq. ft. in 1967. The comparable Canadian figures for NHA-insured houses are 1,136 sq. ft. and 1,153 sq. ft. for 1963 and 1967, respectively (CMHC, 1969a).

Lewis (1969) recently indicated that U.S. particle board consumption in 1965 was 65 sq. ft. per one and two family units, and 35 sq. ft. per apartment unit. Hardboard consumption was reportedly 640 sq. ft. and 180 sq. ft. per unit for one and two family dwellings and apartments, respectively.

With such little data available on the consumption of wood products by type of dwelling, the impact of current trends toward relatively more apartments and fewer single-family houses is difficult to estimate quantitatively, although it is undoubtedly large.
Some of the problems of applying American data to Canada have already been pointed out. Another problem is that there is no evidence that the proportion of low-rise to high-rise apartments is the same in both countries. A further complication is that the proportions of prefabricated dwellings in the two countries may diverge considerably. Platts (1964b) estimated that about 35 per cent or more of U.S. single-family dwellings were prefabricated in 1962, compared to 15 per cent for Canada at the time of his report. The U.S.D.A. (1965) reported that the consumption of lumber per unit in prefabricated single-family units is substantially below that used in conventionally constructed units. These two considerations, coupled with the previously mentioned problems appear to invalidate the use of American data, such as contained in Tables 8 and 10, for application in Canada.

It can only be concluded that in Canada, apartments probably use from one-third to one-half the volume of wood products that conventional houses use on a per unit basis, and that the current trend in dwelling types is having a heavy impact on the demand for wood in residential construction.
FACTORS INFLUENCING CHOICE OF MATERIALS IN RESIDENTIAL CONSTRUCTION

Competing with wood in the residential construction market are a host of products falling in the categories of non-metallic minerals, metals, and plastics. How these products fare in the housing market is dependent upon numerous factors, any one of which may prohibit the use of a product regardless of how well it meets other requirements. In some instances there is little tangible evidence indicating how certain factors do influence the choice of materials, and often statistical data are lacking. Nevertheless, an examination of these factors, to the extent permitted by available information, is essential to this study.

Tradition

Wood frame construction, developed over the past two centuries, is traditional in Canada, and has typically called for large volumes of softwood lumber and other wood products (McCance, 1969a). Wood frame construction has proved to be adaptable to temperature extremes from \(-40^\circ F\) to \(100^\circ F\) and has been used economically in both single- and multi-family dwellings, with height limitations of three storeys (Orr, 1966). Since 1940, prefabrication in wood frame construction has been adopted on an increasing scale, with components manufactured off-site and shipped to the building site for assembly. Although house construction is often cited by critics as being very backward and inefficient, Dickens (1969) maintains that house builders have a good record for holding down construction.
costs. He indicated that in spite of a cost increase of 51 per cent for materials and 136 per cent for labor in the 1949-65 period, house construction costs rose by only 44 per cent over the same period. In comparison to price movements of other consumer durables, house prices have not performed as well as Dickens implied. The consumer price index for new houses in 1970 (1961 = 100) was 161.4, compared to 96.6 for appliances, 126.2 for furniture, and 98.8 for new passenger cars. Seen in this perspective, house builders have not kept prices (and presumably costs) down to the levels attained by producers of other consumer durables. Yet it is maintained that wood frame construction is still difficult to surpass for versatility, structural adequacy, and low cost production (Orr, 1966).

Traditional ways of performing tasks embody the assurance of the test of time. Proven methods such as wood frame construction provide reliability and entail less risk for entrepreneurs in the house building industry. This applies both to builders and to suppliers of mortgage money, who are reported to be extremely conservative in their approach to new building designs, methods, and materials. It would thus appear that wood suppliers have the weight of tradition in their favour.

Too much emphasis should not be placed on the influence of traditional factors in the future. Over time, as the building industry develops more sophisticated management techniques, and more highly educated individuals enter the field, the bonds of tradition will lose their hold and allow for innovations in building techniques and materials which provide economies in production. In the short term, tradition will probably have a stronger effect than over the long run.
Availability

Closely associated with the development of wood as the traditional building material in Canada was its availability in large volumes. The early settlers, in clearing land for buildings and farms, had sufficient wood at their disposal for all of their building needs. At that time the technology for making suitable metals and plastics available for building had not been developed. Indeed, at that time the vast mineral deposits in Canada were virtually unknown. The situation has now changed with the discovery of substantial volumes of both ferrous and non-ferrous mineral ore bodies as well as vast petroleum resources. The availability of these materials is, therefore, no longer a limiting factor. Unlike the forest resource, mineral resources are non-renewable, thus implying increasing cost industries due to external diseconomies (Mead, 1966). But, it can also be argued that similar external diseconomies exist in the forest industries in that increasing expenditures will be required to manage the forests at a level sufficient to ensure sustained or increasing yields. In addition, it may be noted that decreasing quality and size of the timber resource, and increasing distances to merchantable stands, have been significant factors contributing to higher costs and the loss of markets for wood. For the foreseeable future, relative availability of resources, except perhaps for regional disparities, should not significantly influence the use of materials in construction.

Price of Materials

Relative prices of competing materials are one of the most important factors influencing materials choice. Real prices are often elusive because of additional price factors not included in price quotations.
These include discounts, assembly or erection costs, and frequency of maintenance inherent with a given material. Because of the multiplicity of firms, products and pricing policies, it is impossible to evaluate the influence of most of these additional price variables in anything but a product-by-product comparison. Such a detailed analysis will not be entered into here. Instead, a comparison of relative prices of materials will be made in order to help evaluate the price position of wood and wood products with respect to competitive materials.

Wood products have maintained a favourable price position relative to competing products, a situation which largely accounts for their widespread use for residential construction. There is, however, substantial evidence that the price advantage held by wood products has been gradually diminishing over most of this century. Zaremba (1958) indicated that the wholesale price index of all commodities in the U.S.A. remained relatively stable over the period 1860 to 1955, while lumber prices steadily rose above the all-commodities index, following roughly a three per cent trend line. Potter and Christy (1962) also indicated that, over the 1870-1957 period, only the forest products sector showed an important uptrend in prices, which was accompanied by a decline in per capita consumption. Since the U.S. market has always been an overriding factor in the determination of lumber prices in Canada (Widman, 1969), their observations are probably equally applicable to the Canadian situation.

In Figure 5 the movement of the Canadian general wholesale price index is illustrated along with some of its major components over the period 1940 to 1968. The increase in the price of wood products is shown to have greatly exceeded the increases in other product groups. As of 1968,
Figure 5. Wholesale price indexes in Canada

the wholesale price index of wood products stood at 367.9 as compared to 276.8 for iron products, 250.8 for non-ferrous metals products, and 206.0 for non-metallic minerals products. Zaremba (1958) explained the divergence of lumber prices above all-commodity prices as being related to the divergence of the cost structure of the lumber industry from that of the whole economy. In the long run, prices must cover average costs of production, hence lumber prices will parallel the trend in average costs of production. Thus, the high lumber prices noted represent the divergence of the cost structure of the lumber industry from the cost structure of the economy. He further related the rising cost structure of the lumber industry to the failure of that industry to increase the productivity of labour as wages and productivity increased throughout the economy.

More specific to the housing market are the price index numbers of residential building materials shown in Figure 6. The overall form of these curves is similar to the wholesale price indexes in Figure 5; but prices of residential building materials have risen at a faster rate. In the period from 1940 to 1951, the prices of lumber and lumber products increased at a much higher rate than other building materials. Calculated from the 1935-39 base years, prices of lumber products had increased 325 per cent by 1951, compared to 41 per cent for concrete products, 81 per cent for bricks, and 113 per cent for metal products. Relatively stable prices prevailed during the remainder of the 1950's, but, since 1962, the prices of lumber products used in housing have again accelerated rapidly, while increases in the prices of other building materials have been minor in comparison. It should be noted that the total price index of residential building materials has closely followed the pattern of lumber prices.
Figure 6. Price index numbers of residential building materials in Canada

throughout the period shown, evidence of the strong influence of lumber products in the total index. In 1968, the building materials index for lumber products stood at 577 compared to 189 for concrete products, $263 for bricks, and 262 for metal products. This represents a substantial decrease in the price advantage of lumber products.

Economists have distinguished two types of building cycles: a short cycle about the same length as the general business cycle, and a long cycle of approximately 15 to 20 years.

Zivnuska (1952) has shown that the consumption of lumber in construction is closely related to short building cycles (which in turn had corresponded closely to general business cycles over the period he investigated). There was less evidence of a relationship existing between lumber consumption and the long cycle, largely due to a lack of lumber consumption data over a sufficiently long period.

Residential construction, the most important single source of lumber demand, is subject to particularly violent cyclical fluctuations. Both White (1967) in Canada, and Mead (1961) in the United States, have indicated that, since World War II, there has been a tendency for cycles in residential construction to move contracyclically (as opposed to procyclical movements between the two World Wars). This contracyclical movement in residential construction has been related to the action of government sponsored mortgage aid programs: (FHA-VA mortgages in the United States, and NHA mortgages in Canada). It is explained by both of the above authors that during periods of strength in the whole economy, interest rates are high and rising, with the result that limited funds are available for low-
interest government-insured mortgages. Conversely, when the economy is slowing down and interest rates falling, government-insured mortgages become more attractive, hence the contracyclical activity in residential construction.

The significance of these cycles to the lumber industry lies in the fact that the demand for lumber is a derived demand. Thus, cyclical fluctuations in building activity result in similar fluctuations in the demand for lumber. Although building cycles have been stressed above, the demand for lumber in industrial uses is similarly related to business cycles. The development of cycles in lumber production thus depends on the combined influence of building and business cycles, their relative importance in determining lumber demand depending on the general level of activity in each, and the amplitude of their respective cyclical movements.

In addition to cyclical fluctuations, lumber prices have typically followed a clear pattern of seasonal behavior, as demonstrated by Mead (1964) for ponderosa pine and Douglas-fir. This seasonal pattern has been attributed to the seasonal nature of construction activity which picks up in the spring and is maintained at a high level throughout the summer. Normally, lumber prices have peaked during five different months from April to September and are at a low between November and January (Mead, 1964).

Fluctuations in lumber demand, as effected through cyclical movements in business and building, are primarily responsible for lumber price fluctuations. Given a change in demand, the lumber industry (approaching
the economist's model of pure competition) is more apt to adjust through a price change rather than a change in output. The result is that substantial fluctuations in lumber prices tend to occur frequently in response to changes in demand.

In addition to demand cycles, the seasonality of log supply also influences price levels. Severe winter weather, spring break-up, and high forest-fire danger, can all terminate logging operations, which, in turn, affects log and lumber supply (Rich, 1970). Other factors, such as labour strikes and box-car shortages have also been cited as reasons for lumber supply shortages. The problem of fluctuating prices, as caused by the above influences of supply and demand, and possible solutions will be discussed subsequently.

Having observed price trends of wood products in relation to competing materials, it is apparent that the price elasticity of demand for wood products requires some discussion here. The question to be answered is: how does an increase in the price of lumber (or other wood products) influence the demand for that product? This question involves both price elasticity of demand and cross elasticity, which is included in the former.

Mead (1966) has presented a theoretical discussion of qualitative factors influencing the price elasticity of demand for lumber. Elasticity of demand increase with time after a price change. He indicated that time is required to change firmly entrenched buying habits, to alter regulatory factors (such as amendments to building codes to permit the use of new materials), and to allow recently purchased goods to wear out. Zaremba (1963) added that time was required after a price increase for the training of labour in the use of new materials, and for new product research to find substitutes.
According to Mead (1966), probably the most important determinants of demand elasticity are the availability and suitability of substitutes. Given that close substitutes are available, an increase in the price of lumber will result in a decrease in the demand for lumber and a corresponding increase in the demand for the substitute, reflecting a high cross elasticity of demand. On the question of availability, he concluded that the supply of substitutes of various materials groups (metals and non-metallic minerals) was not a limiting factor. Although lumber (primarily boards) has been largely replaced in a number of uses by plywood and other panel products, there has been a lack of satisfactory substitutes for structural lumber. From this viewpoint, the cross elasticity of demand for lumber is relatively inelastic. However, it has probably tended to increase in recent years as a result of new product developments which have occurred. Zaremba (1963) has stressed that even given a possible substitute, consumer preference could prevent its use.

Mead (1966) further stated that the relatively small importance of lumber in total construction costs, together with the probable inelastic demand for residential construction, would support the theory of an inelastic demand condition for lumber. On the other hand, Zaremba (1963) cautioned against such a conclusion, since even a small cost reduction may be significant in a highly competitive construction industry. Zaremba (1963) introduced in-place cost as a further consideration, indicating that the final purchaser of a house is not interested in the cost of individual materials but the purchase price of the completed dwelling. Taken together, Mead (1966) concluded that the evidence indicated that the demand for lumber
was in the inelastic range but was becoming more elastic over time.

The historically high softwood lumber prices reached in the spring of 1969 have, perhaps, brought with them some evidence that the demand for lumber is becoming more elastic. The course of these recent price trends are plotted in Figure 7 for Douglas-fir lumber and plywood. Other softwood species experienced similar price trends over the 1967-69 period. In the same illustration, the relatively stable price patterns for clay products, steel sheets and strips, and aluminum sheets and strips are shown for comparison.

The shortage in softwood lumber supplies, which contributed to these sharp lumber price increases, created a serious problem for Canada's entire building industry (Widman, 1969). Growing world demand for Canada's softwood lumber has been cited by him as the cause of this development.

According to Canadian Forest Industries (1969) and McCance (1969a), these rapidly increasing lumber prices have accelerated the demand for alternative products. McCance indicated that lumber had ceased to be competitive with many substitute products when lumber prices were nearing their peak early in 1969. Frequent press reports of builders trying out steel studs would appear to bear this out. Given such price trends as shown in Figure 7, McCance (1969a) stated that builders will make strong efforts to reduce the lumber content of their buildings to the lowest possible level. Such reports as these appear to support the statement that lumber demand is becoming more elastic. On the other hand, the substantial price increases which attended the recent shortage in supply indicate that lumber demand is still quite inelastic, at least in the short run.
Figure 7: Industry selling price indexes

It should be noted that as the price differential between wood products and alternative materials decreases, the probability of competitive products being developed using these substitute materials increases. This would suggest a growing importance of research and development, a topic which will be discussed in subsequent pages.

Producers of metal and plastic products are particularly eager to enter the housing market on a large scale. An indication of how their prices have been moving is shown in Figure 8. Plastics and synthetic resins have been decreasing in price since 1961. Aluminum sheets and strips increased in price between 1961 and 1965, but by 1968 were down to one per cent above the 1961 level. In 1968, cold rolled steel sheets and strips were only 3.3 per cent above the 1961 level. These specific materials were chosen for comparative purposes here because they are either being employed or most likely to be employed in products for the housing market. In comparison, Douglas-fir lumber averaged a 51.5 per cent price increase between 1961 and 1968 while Douglas-fir plywood averaged a 39.2 per cent increase. However, it should also be noted that plywood had been decreasing in price for many years prior to 1961.

Figure 9 illustrates how prices of some specific wood products have behaved since 1961 in comparison with plastics and steel. Mouldings and flooring are areas in which plastics manufacturers are attempting to make further inroads. The 53 per cent increase in wood moulding prices over the 1961-68 period compare unfavourably with the nine per cent decrease in plastic and synthetic resin prices. This has certainly improved the prospects for plastic manufacturers attempting to compete in this field.
Figure 8. Industry selling price indexes

Figure 9. Industry selling price indexes

The competitive position of hardwood flooring is also rapidly deteriorating with respect to price, marking a 33 per cent price advance over the same period. With steel doors presently entering the housing market, the increasing prices of wood slab and flush doors shown in Figure 9 will only tend to accelerate the acceptance of this new product.

Although further price comparisons could be made, the above should be sufficient to illustrate that wood products are quickly losing their price advantage, a most critical parameter of competition.

Building cycles, as the source of price fluctuations of wood products, have been discussed previously. The problem of fluctuating prices will be discussed below, with particular reference to possible stabilizing measures.

Rapid price fluctuations preclude a stable market and will also influence builders to seek alternative construction methods (Canadian Forest Industries, 1969). Cyclical or other price fluctuations create problems for the builder by making planning and estimating costs of construction difficult. Unexpected large price increases may result in a projected selling price which exceeds the purchasing ability of the target market (Rich, 1969). Rapid fluctuation of prices, as well as high prices, is thus another problem which the lumber industry is faced with.

Considerable interest has been aroused recently with respect to futures markets for lumber and plywood, a tool with which it is hoped to at least partially alleviate the above problem. Since October 1969, three commodity exchanges have begun to sell futures contracts for wood products. The Chicago Mercantile Exchange is dealing in lumber futures, while the
Chicago Board of Trade and the New York Mercantile Exchange are handling plywood futures contracts (White and Conway, 1970). As of January 1970, the prices of these commodities were relatively stable, particularly in the case of plywood. It is still too early to determine whether this marketing tool will be successful. The amount of trading in these contracts has been small, as is the usual case for a new commodity being traded. The extent of trade participation will probably determine its ultimate success (White and Conway, 1970). One builder, commenting on futures markets, stated that "anything that puts stability into our markets is a good thing." (Rich, 1969).

Although the trading of futures contracts should theoretically tend to flatten out price fluctuations, the degree of success in doing so will probably be minimal. It has been argued that the reason for having a commodity market and for the speculator entering it is the fact that price fluctuation does exist, and that the effect of futures trading on price situations as in 1968-69 (which were determined through supply and demand) will be limited (Josephson, 1969). The primary purpose of having a futures market for lumber and plywood is so that buyers and sellers of these commodities will have a means of hedging against increases and decreases in price. By using the futures market to hedge against price changes, both buyers and sellers will be able to estimate future costs and revenues much more accurately and thus eliminate much of the uncertainty inherent in fluctuating prices.

Although lumber and plywood futures markets have drawn much attention recently, there are several other ways in which the severity of price
fluctuations can be reduced. The first of these is through greater diversification of markets served by the forest industries. This includes both increasing the number of specific end uses for wood products and expanding export markets to include a larger number of off-shore buyers. By so doing, the demand cycles for wood products are more apt to be compensating in their cyclical movements, thus reducing the probability of large price fluctuations.

The second suggested method of reducing lumber price fluctuations is to increase government spending on public housing when private expenditures in residential construction are low. Coupled with this is the need for more stable mortgage financing methods which are not subject to the vagaries of fluctuating market interest rates, and not adversely affected by government monetary and fiscal policies. With the overriding influence which present financing methods have on the development of building cycles, this area holds considerable opportunity for the development of stabilizing measures.

A third method which would add stability to wood products prices is to allow for greater flexibility in annual allowable cuts (Zivnuska, 1952). Relatively fixed allowable cuts create an inelastic timber supply condition, thus restricting the degree to which lumber producers can respond to increased demand. The result is that further pressures are put on prices than if timber supply was not so regulated. The adoption of a more flexible formula for determining allowable cut than provided by presently administered sustained yield policies would allow timber producers to align their timber harvests more closely with demand conditions and hence reduce or eliminate the pressures exerted on lumber prices by an inelastic timber supply.
Another aid to price stabilization, akin to the question of timber supply, is that of improved inventory management. The existence of lumber inventories either too large or too small relative to demand results in fluctuating prices (Holemo, 1971). Through good inventory management by individual firms, lumber supply can be more closely co-ordinated with demand, and should accordingly smooth out lumber price fluctuations.

Closely related to improved inventory management is the need for more accurate predictions of future market requirements. Since sophisticated market forecasting techniques require considerable expertise, improved market analysis could probably best be approached on an industry-wide basis.

The measures suggested above for approaching the problem of fluctuating prices would probably not eliminate cyclical price movements, but could possibly reduce them to a more acceptable level.

Research and Development

Research and development (R & D) is the source of new products, whether of wood or competing materials and, as such, plays a significant role in any industry facing competition in the market. As previously stated, wood products have historically been priced at levels lower than their possible substitutes; but with a diminishing price differential, manufacturers of competing products will find it easier to compete for traditional wood markets. Their ability to do so will largely depend on their success in developing functionally suitable products with reasonable in-place costs. The amount of R & D carried out by competing industries
may thus be some indication of their success in this area, and of the probability of their developing new products that would be competitive with wood.

In the construction field, the manufacturers are the primary innovators, devoting much energy to the development of new products (Handegord, 1969). An important motivation is to improve performance in relation to competitor's products. Closely associated with this is research carried out by specialty trade and product associations. Other housing research activity in Canada (related to building materials and methods) is largely carried out by the National Research Council's Division of Building Research and the National House Builder's Association. The Division of Building Research, the main agency involved in technical research related to construction, initiates its projects in response to requests made by members of industry or public agencies (Canadian Construction Association, 1969). On the basis of available information, it is not possible to accurately assess the proportion of their research devoted to wood products versus substitute materials.

The Technical Research Committee of the National House Builders Association has built seven experimental houses with the aim of investigating new building materials and techniques (McCance, 1969a). The latest of these should be of particular interest to the forest industries due to its use of steel floor joists, steel studs, and vinyl siding, soffits and fascia (McCance, 1969b). Financial assistance for this research program has been largely provided by CMHC which can support a variety of housing research programs under the terms of Part V of the National Housing Act of 1954 (CMHC, 1969b). In 1968, this agency provided $212,550 for research in construction,
and an estimated $308,485 in 1969.

No information is available concerning R&D expenditures made by manufacturers and suppliers of building materials specifically for, or contributing to, innovations for the housing market. But statistics are available showing expenditures on R&D by industry in Canada. Although such data do not throw light on the effectiveness or success of the research activity, they generally indicate the level of effort directed towards reducing costs and introducing new products. Table 11 contains total intra-mural R&D expenditures for selected industries in Canada. These data include grants received under various research incentives programs sponsored by federal government agencies.

The performance of the wood industries compared to other industries is not impressive judging from the figures in Table 11. In 1968, these industries spent only $667,000 on intra-mural R&D compared to $6,299,000 for primary ferrous metals industries, $5,845,000 for metal fabricating industries, $3,333,000 for non-metallic mineral products, and $32,926,000 for the "other" chemical products industries (which presumably includes plastics, synthetic resins, and industrial chemicals). Overall, the wood industries, in 1968, contributed approximately 0.2 percent of the total R&D outlay by manufacturing industries in Canada. Whether the above figures are accurate is open to question, but are accepted here on the basis of there being no alternative source. The preliminary nature of the 1968 figures, coupled with upward revisions of preliminary data in the past, indicate that the 1968 data in Table 11 are probably conservative, particularly the figure for the wood industry. Although federal
INTRA-MURAL R & D EXPENDITURES IN CANADA, BY INDUSTRY

<table>
<thead>
<tr>
<th>Industry</th>
<th>1965 (thousands of dollars)</th>
<th>1966 (thousands of dollars)</th>
<th>1967 (thousands of dollars)</th>
<th>1968 (thousands of dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>417</td>
<td>449</td>
<td>1,341</td>
<td>667</td>
</tr>
<tr>
<td>Primary metals (ferrous)</td>
<td>7,621</td>
<td>8,696</td>
<td>6,225</td>
<td>6,299</td>
</tr>
<tr>
<td>Primary metals (non-ferrous)</td>
<td>13,834</td>
<td>16,632</td>
<td>20,066</td>
<td>16,199</td>
</tr>
<tr>
<td>Metal fabricating</td>
<td>2,456</td>
<td>3,113</td>
<td>4,856</td>
<td>5,845</td>
</tr>
<tr>
<td>Non-metallic mineral products</td>
<td>1,844</td>
<td>2,795</td>
<td>3,346</td>
<td>3,333</td>
</tr>
<tr>
<td>Other chemical products</td>
<td>30,592</td>
<td>35,970</td>
<td>36,542</td>
<td>32,926</td>
</tr>
<tr>
<td>Total: Other manufacturing</td>
<td>214,784</td>
<td>228,619</td>
<td>240,323</td>
<td>252,393</td>
</tr>
<tr>
<td>industries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total: Manufacturing industries</td>
<td>271,548</td>
<td>296,274</td>
<td>312,699</td>
<td>317,662</td>
</tr>
</tbody>
</table>

r = Revised
p = Preliminary


government in-house research is not being presented here, it might be noted that in the 1966-67 fiscal year, operating and capital funds expended by the Forest Products Laboratories in Ottawa and Vancouver totalled $2,240,000 (Department of Fisheries and Forestry, 1968).
In Table 12, industry expenditures on extra-mural R & D are presented for selected industries, i.e., industry funds spent in support of R & D by contract research organizations and universities. Again, the wood industries, in supporting $0.2 million of extra-mural research in 1968, exhibited the lowest degree of participation in comparison with its competitors. Metal fabricating industries were not far ahead, supporting $0.3 million of such research, while the primary non-ferrous metals industry supported the largest amount of extra-mural research with $7.7 million.

### TABLE 12

**EXTRA-MURAL R & D EXPENDITURES IN CANADA, BY INDUSTRY**

<table>
<thead>
<tr>
<th>Industry</th>
<th>1965(^r)</th>
<th>1966(^r)</th>
<th>1967</th>
<th>1968(^p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Primary metals (ferrous)</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Primary metals (non-ferrous)</td>
<td>7.3</td>
<td>7.3(^\frac{3}{4})</td>
<td>7.2</td>
<td>7.7</td>
</tr>
<tr>
<td>Metal fabricating</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Non-metallic mineral products</td>
<td>0.9</td>
<td>1.0</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Other chemical products</td>
<td>1.3</td>
<td>1.4</td>
<td>1.8</td>
<td>1.7</td>
</tr>
<tr>
<td>Total: Other manufacturing industries</td>
<td>24.1</td>
<td>26.7</td>
<td>27.4</td>
<td>27.7</td>
</tr>
<tr>
<td>Total: Manufacturing industries</td>
<td>34.3</td>
<td>37.2</td>
<td>38.3</td>
<td>38.9</td>
</tr>
</tbody>
</table>

\(^r\) = Revised  
\(^p\) = Preliminary  

Judging from the relative expenditures on R & D by the industry groups outlined above, it would appear that substitutes have a good chance of making further inroads into traditional wood markets.

It may be noted that many Canadian firms are foreign owned, and that much of the research is performed by the parent company and then adapted to the Canadian situation (Financial Post, 1969a). Since the United States is by far the largest source of foreign ownership in Canada, and information flows readily across our border, American expenditures on R & D are also relevant to some extent in Canada. In Table 13, total industrial research expenditures are shown by selected manufacturing industries in the United States. The industrial groups listed closely correspond to those in Table 11 for Canada.

Similar to the Canadian case, wood products industries in the U.S.A. only accounted for 0.1 per cent of the total expenditure on R & D by manufacturing industries in 1967. The $14 million expenditure on wood products research in 1967 was small compared to $144 million on ferrous metals and products, $165 million on fabricated metal products, $152 million on stone, clay and glass products, and $206 million on the "other" chemicals group. Figures such as these help explain why substitute materials are beginning to compete more favourably with wood products. In the U.S.A., forest products industries as a whole (including pulp and paper) spent approximately 0.6 per cent of sales on R & D in 1964 compared to the all industry average of 4.4 per cent (McKean, 1966). The conclusions arrived at by McKean were that R & D funds were especially small for lumber and wood products, that the employment of scientists by the wood industries was falling behind, and that the forest industries have lost important markets due to
research in competing industries. All these would appear to be undeniably true. Unless the R & D effort of the forest industries is substantially increased, and is successful, one may anticipate a continuing loss of markets to substitute materials.

TABLE 13
Funds for R & D Performance in the U.S.A., By Industry

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumber, wood products and furniture</td>
<td>11</td>
<td>12</td>
<td>12</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Primary metals:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferrous metals and products</td>
<td>106</td>
<td>116</td>
<td>128</td>
<td>139</td>
<td>144</td>
</tr>
<tr>
<td>Non-ferrous metals and products</td>
<td>77</td>
<td>79</td>
<td>85</td>
<td>93</td>
<td>102</td>
</tr>
<tr>
<td>Fabricated metal products</td>
<td>153</td>
<td>148</td>
<td>145</td>
<td>154</td>
<td>165</td>
</tr>
<tr>
<td>Stone, clay and glass products</td>
<td>100</td>
<td>110</td>
<td>117</td>
<td>128</td>
<td>152</td>
</tr>
<tr>
<td>Other chemicals</td>
<td>214</td>
<td>186</td>
<td>184</td>
<td>188</td>
<td>206</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>661</td>
<td>651</td>
<td>671</td>
<td>715</td>
<td>783</td>
</tr>
<tr>
<td>Other manufacturing industries</td>
<td>11,693</td>
<td>12,543</td>
<td>13,132</td>
<td>14,343</td>
<td>15,097</td>
</tr>
<tr>
<td><strong>Total: Manufacturing industries</strong></td>
<td>12,354</td>
<td>13,194</td>
<td>13,803</td>
<td>15,058</td>
<td>15,880</td>
</tr>
</tbody>
</table>

Functional Suitability

Before a product can be employed for any purpose, it must meet the functional requirements of the specified end use. Such requirements are varied in nature, ranging from structural performance and durability to sound absorption properties and aesthetic appeal. Inherent in all products are the properties of the basic material(s) of which it is composed. It would be appropriate therefore to examine the properties of materials competing in the housing market, pointing out their strengths and limitations. Although there are large variations in properties between individual products within given groups of materials, an attempt will be made to build this discussion around large groupings and general characteristics.

One of the primary requirements in construction is for a building material capable of supporting the structure and the loads it may be expected to bear. Materials commonly recognized as capable of performing structural functions are concrete, steel, and wood. It is recognized that the major advantage of steel lies in its strength, yet in high-rise apartment construction, concrete is used almost exclusively, with steel rods employed for reinforcing purposes (Moreau and Van der Ryn, 1967). The lack of steel supporting members in apartment buildings has been attributed by these authors to its relatively high cost, and the fact that steel alone cannot perform functions other than structural support, thus requiring additional materials to provide other needs. Steel fails to provide adequate sound insulation, thermal insulation, will corrode if not adequately coated, and is not sufficiently fire-resistant, losing strength rapidly at temperatures over 1000°F (Moreau and Van der Ryn, 1967).
Concrete possesses high compressive strength, but its strength in tension is often as little as one-tenth its strength in compression; it is therefore not efficient by itself in resisting tensile and bending stresses (Hutcheon, 1961). Combined with steel reinforcement, both compressive and tensile strength requirements can be met. Steel and concrete are also compatible with respect to thermal expansions and both exhibit similar strains when loaded to their normal working stresses (Hutcheon, 1961). At the same time, concrete is capable of providing other functions, particularly fire resistance and insulation.

Wood does not possess the high compressive strength of steel and concrete (on a mass basis), nor the tensile strength of steel and is accordingly limited in structural uses. (In Canada, the height restriction for structural wood frame construction in housing has been set at three storeys by the National Building Code). Yet wood does have good strength in both tension and compression along the grain, which, combined with its light weight, gives it a very high strength-to-weight ratio (Hutcheon and Jenkins, 1967a), higher, in fact, than both steel and concrete. Its ability to withstand bending loads has always contributed greatly to its value as a building material. However, the relatively low shear strength along the grain necessitates careful design when utilizing wood in tension members (Hutcheon and Jenkins, 1967b).

Unlike steel and concrete, which are homogeneous materials with uniform properties that can be calculated in advance, solid wood is a heterogeneous material of great variability (Tromp and Campredon, 1966). This wide range of quality has made necessary the establishment of lumber
grades to facilitate proper use of the material. Softwood lumber may be either graded as "Yard Lumber" or "Structural Lumber." Structurally graded material is intended to meet engineering requirements and must be categorized by intended use as well as species and grade (Dickens, 1967). It is seldom economical to use this type of lumber in housing, with the result that tables have been prepared showing size and span relationships for yard grades of dimension lumber for use as joists and rafters in housing (Dickens, 1967). Due to the inherent variability of wood, most wood structures are grossly over-designed in the interests of safety, and hence cost more than they should (Milligan, 1965). It is hoped that this can be overcome with mechanical stress grading of lumber intended for structural use. One of the more immediate uses for mechanically stress rated lumber could be in factory-built structural components where performance and predictability could be ensured through the use of lumber known to meet specific strength requirements.

It has been pointed out by Tromp and Campredon (1966) that architects consider the risks greater when building with wood than with isotropic materials. Furthermore, a knowledge of wood is no longer considered a part of the education of architects and structural engineers, a factor which may be responsible for shrinking markets (Rich, 1969). These comments may not be particularly relevant to the housing market in which wood frame construction has been used traditionally, resulting in well known building methods which do not usually require engineering or architectural services in initial designs.
Plastics are not normally thought of as structural materials. They can be divided into two major groups: thermoplastics and thermosets; the former can be melted to liquid form by heat and reformed to solids by cooling, while the latter can be formed only once, by heat-curing, and rather than liquify, will either soften and char or burn when reheated (Platts, 1964a). Thermosetting plastics offer the best possibilities for structural purposes, particularly the glass reinforced plastics (GRP) in which polyester resins are most commonly used (Makowski, 1966). Problems involved in using plastics structurally are that they creep under sustained load, have an inherent lack of stiffness (Makowski, 1966), have a high coefficient of expansion, and their heat distortion temperature is generally low, making them unsuitable for structural use in buildings (Benjamin, 1968). Proper structural design can overcome the lack of stiffness to a large extent, but the shape and appearance of such structures differ appreciably from conventionally accepted designs (Makowski, 1966).

Plastic sandwich panels offer an additional application of plastics for structural purposes. Various expanded plastics foams are finding applications as the core for sandwich construction, expanded polystyrene, rigid polyurethane, expanded polyvinylchloride (PVC) and phenolics being frequently used types (Makowski, 1966). With skins of aluminum, steel, plywood, or asbestos cement, they provide structural strength, thermal insulation, and act as a water vapour barrier. Although Makowski indicated that one and two storey buildings have been constructed using plastic sandwich panels as external load-carrying walls, Platts (1964a) suggested that the costs of such components would not permit serious competition with wood frame housing for some time.
Strength is only one requirement of building materials and is not critical in some applications. Another major consideration is the fire-resistance of the material. The rate and extent of fire spread through buildings is of prime importance in fire protection. The flammability of materials will determine the ease of ignition and rate of development of a fire (Shorter, 1963).

Wood has been known as a natural fuel for centuries, and as a rule will burn until destroyed. It is now recognized that large timber sections are slow to ignite and, although they support combustion initially, they soon char and the flames are extinguished (Milligan, 1965). The wood will continue to char at a rate of approximately 1/40 inch per minute (Galbreath, 1965), but will only lose strength due to the reduction in its cross-sectional area (Milligan, 1965). The slow charring rate enables such heavy structural timbers to support their load for a considerable time after the fire has begun, thus allowing sufficient time for the building to be evacuated and the flames extinguished. This is only true with heavy timber construction which is not usually employed in residences. In common light frame construction, wood framing members have a relatively short fire endurance (often less than 10 minutes) if exposed directly to fire (Shorter, 1964). Wood thus has two disadvantages with respect to fire resistance: it adds to the fuel load, and can be completely destroyed. Although fire retardants are now available for treating wood, there are a number of problems limiting their use. These include leachability (which restricts most retardant treated wood to interior applications), a decrease in most strength properties of treated material, a decrease in the
and most of all, the cost of treated wood is high.

As previously indicated, steel is also severely affected by fire. At temperatures above 1000°F, steel loses strength significantly and it is thus essential that steel be protected with an insulating layer when used in structural applications in buildings (Moreau and Van der Ryn, 1967). As in the case of light wood construction, light steel framing members, if exposed directly to fire, have short fire endurance, often less than 10 minutes (Shorter, 1964).

Brick and other burned clay products are relatively stable materials in fire, losing little strength (Galbreath, 1965). Concrete will lose strength when exposed to fire, retaining about one-half its original strength at 950°F and one-third at 1300°F; the strength loss is irreversible. However, the good thermal insulation properties of concrete, as with wood, prevent sufficient heating up of the interior of concrete members to cause significant strength reduction (Galbreath, 1965).

Fire, along with smoke and toxic fumes, is a major problem with plastics. In structural applications, plastics would lose strength and collapse at temperatures much below those reached in any well developed fire (Platts, 1964a), and in such a situation, the "self-extinguishing" characteristics of some plastics have little bearing on the fire resistance of the structure since the critical question is how much time passes before the supporting members collapse. There is a considerable variation in the flammability of different plastics, but generally it is felt that where used as non-structural finishes, trims and coverings, they represent a small fire load (Platts, 1964a).
Four groups of plastics are particularly troubled by flammability problems because of their general and widespread markets: vinyls and polyolefins, styrenics (mostly ABS*), polyesters, and foams (mostly urethanes and expanded polystyrene) (Wood, 1968). A major problem with retardants developed to increase the flame resistance of such plastics is that most of the retardant materials either tend to degrade the plastic or increase its production of smoke and toxic fumes when burned (Wood, 1968). This only adds to the problem of smoke emission which can be high, thereby raising the question of practicality in multi-storey buildings where egress is difficult (Platts, 1964a).

Good thermal insulation is desirable for materials used in exterior walls and roofs where an important function is to isolate the interior from inclement exterior conditions. Very few residential construction materials provide sufficient insulating value of themselves, and with both wood frame and solid masonry construction, it is common practice to place insulation within the exterior walls (Ball, 1961). The insulation provided by the basic wall system will, however, affect the amount and cost of additional insulation required to meet accepted standards.

Metals are the poorest thermal insulators, hence they are highly dependent upon other materials where thermal insulation is required. By comparison, the insulating properties of most other building materials are quite good. Table 14 shows thermal conductivity values for several common

* A type of plastic-composed of acrylonitrile, butadiene, and styrene.
building materials. It may be noted that wood is a better insulator than brick and concrete. The foamed plastics offer excellent insulating properties, the urethanes in particular offering K values about one-half those of conventional insulation materials. It would thus appear that plastic foams have considerable potential as insulation in residential buildings and may offer stiff competition to glass wool, mineral wool, and insulation boards presently in common use.

**TABLE 14**

**THERMAL CONDUCTIVITY OF BUILDING MATERIALS**

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>THERMAL CONDUCTIVITY (K) [(Btu)(in.)/(sq.ft.)(°F)(hr.)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>1400</td>
</tr>
<tr>
<td>Steel</td>
<td>315</td>
</tr>
<tr>
<td>Concrete, sand, and stone aggregates</td>
<td>11 - 16</td>
</tr>
<tr>
<td>Brick, common building</td>
<td>4.8</td>
</tr>
<tr>
<td>Wood, parallel to grain (sp. gr. 0.35 - 0.70)</td>
<td>1.6 - 2.9</td>
</tr>
<tr>
<td>Gypsum board, between layers of paper</td>
<td>1.4</td>
</tr>
<tr>
<td>Wood, across the grain (sp. gr. 0.35 - 0.70)</td>
<td>0.65 - 1.15</td>
</tr>
<tr>
<td>Insulating boards (sp. gr. 0.15 - 0.30)</td>
<td>0.27 - 0.32</td>
</tr>
<tr>
<td>Glass wool</td>
<td>0.27</td>
</tr>
<tr>
<td>Urethane foam</td>
<td>0.16</td>
</tr>
</tbody>
</table>


Sound insulation is another desirable property of building materials: in wall systems to exclude noise disturbances from outside, and in floors and ceilings to reduce noise transmission between dwelling units in multi-storey structures. Lightweight construction in modern building methods has required that sound absorption be explicitly dealt with in the basic design of walls and floors (Northwood, 1960). Available building materials as used in standard wood frame and masonry construction do not provide sufficient sound insulation without additional design considerations.

In detached houses, sound problems are at a minimum. In multi-family dwellings, however, noise can be a significant problem. In any discussion concerning sound transmission, it is necessary to distinguish between airborne sound transmission (through walls and floors) and impact sound transmission (through floors). Impact noises are more difficult to control. In the case of airborne and impact noises, the factors governing sound transmission are the mass of the wall, its stiffness, the continuity of the transmission path, and sound absorption in the space inside the wall or floor (Northwood et al., 1967).

For sound transmission through walls between occupancies, the Residential Standards of the National Building Code (NBC), require a transmission loss of Sound Transmission Class (STC) 45 or higher. The most common (and probably simplest) stud wall meeting this requirement is an arrangement of staggered studs with 1/2-inch plaster on 3/8-inch lath, or with 5/8-inch gypsum board, with mineral wool between the studs. In comparison, the simplest masonry wall satisfying this requirement is
a wall of 8-inch dense aggregate block or an 8-inch light weight block painted on both sides (Northwood et al., 1967). The masonry wall would appear to have the simplest construction, but under normal circumstances would be faced with plaster or gypsum board, providing an even higher STC rating. Plastics sandwich panels, due to their light weight and hard surface, provide poor acoustic insulation, but continuing research using multi-layered cores of high and low density foams arranged alternately may produce an adequate solution to the problem (Makowski, 1966).

Impact noise is often rated by the Impact Noise Rating (INR) developed by the U.S. Federal Housing Administration. Although there are no residential standards relating to impact noise in Canada, it is generally agreed that for satisfactory performance, the INR should be zero or positive (Olynyk, 1967). The reduction of impact noise depends largely upon the design of the floor system since no commonly used structural building materials possess sufficient insulating properties on their own. For example, common wood frame floors (as used in detached houses) have an INR of -8 to -18, and a STC of 47 to 32 (Northwood et al., 1967). A 4-inch bare reinforced concrete slab floor tested by Olynyk (1967) had an INR of -21. Although concrete is relatively effective in reducing airborne sound, impact noise transmission through concrete slab is a problem in apartments (Moreau and Van der Ryn, 1967). The use of a soft floor covering such as a carpet is the most effective method of reducing impact noises. Resilient coverings such as vinyl, linoleum or rubber tile are of little value in controlling impact noise (Northwood et al., 1967). These authors describe other methods of controlling impact noise which
include providing a floating floor (using a resilient layer such as fibreboard), providing a suspended ceiling, and placing mineral wool insulation between the floor and ceiling.

Steel presents poor acoustical characteristics both for airborne and impact noises and would require elaborate systems of sound-proofing before becoming acceptable (Moreau and Van der Ryn, 1967).

It would appear that the acoustic properties of structural materials, although important, do not play a significant part in the choice of such materials, since structural performance and fire resistance are given prime consideration. However, acoustic properties are important in choosing finished flooring materials and materials used in floating floors and hanging ceilings. Some impact noise ratings obtained by Olynyk for various floor constructions used on a 4-inch reinforced concrete slab are shown in Table 15. Several materials including fibreboards, corkboard, various expanded plastic foams, and carpeting all possess good acoustical properties in floor constructions, and their ability to compete will largely depend on their relative prices and the total in-place cost of the floor system in which they are used. It may be noted in Table 15 that the viscose carpet provides the highest INR and is also the simplest surface construction.

Another consideration in choosing appropriate materials is their durability under the conditions of use. Materials requiring frequent maintenance are in a poorer competitive position than those which are virtually maintenance free. In exterior applications, climatic factors and natural phenomena are responsible for most of the deterioration that occurs in building materials.
TABLE 15

IMPACT NOISE RATINGS USING VARIOUS FLOOR CONSTRUCTIONS ON CONCRETE

<table>
<thead>
<tr>
<th>FLOOR CONSTRUCTION</th>
<th>IMPACT NOISE RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8-in. vinyl-asbestos tile bonded to 1/4-in. plywood on 1/2-in. fibreboard</td>
<td>+ 5</td>
</tr>
<tr>
<td>(density = 16.9 lb./cu.ft.) on b.c.*</td>
<td></td>
</tr>
<tr>
<td>1/8-in. vinyl-asbestos tile bonded to 1/4-in. plywood on 5/8-in. plywood bonded to 1/4-in. regular flexible polyurethane foam (density = 1.4 lb./cu.ft.) on b.c.</td>
<td>+ 2</td>
</tr>
<tr>
<td>1-3/8-in. precast concrete on 1/4-in. fibreboard (density = 19 lb./cu.ft.) on b.c.</td>
<td>0</td>
</tr>
<tr>
<td>1-3/8-in. precast concrete on 1-in. corkboard (density = 7.9 lb./cu.ft.) on b.c.</td>
<td>+ 5</td>
</tr>
<tr>
<td>1-3/8-in. precast concrete on 5/8-in. gypsum wallboard (density = .49 lb./cu. ft.) on b.c.</td>
<td>- 1</td>
</tr>
<tr>
<td>1-3/8-in. precast concrete on 1-in. semi-rigid expanded polyurethane (density = 1.9 lb./cu.ft.) on b.c.</td>
<td>+ 6</td>
</tr>
<tr>
<td>Viscose carpet with 1/4-in. loop pile, coated back (surface density = 0.35 lb./cu.ft.) on b.c.</td>
<td>+13</td>
</tr>
</tbody>
</table>

* 4-in. bare concrete slab


Most materials are subject to some type of weathering or corrosion, for which the presence of water is often a requirement. With metals there is a problem of corrosion (for which water is necessary), a major reason why there has been limited use of metal curtain walls in
apartment construction (Moreau and Van der Ryn, 1967). Iron and steel have no monopoly on corrosion problems. Water running over copper and aluminum can also result in disfiguring marks and streaks on exterior surfaces, such as below aluminum window frames (Latta, 1962). Recent advances in plastic coatings, baked enamel finishes, and other protective coatings have contributed much to the solution of these problems.

Materials such as concrete and porous stones can suffer damage from a number of causes. Salts may be dissolved by free water in the pores of the material, carried to the surface and deposited there leaving a stain called efflorescence (Sereda, 1969). If water is present in the voids of such materials such that the material is nearly saturated, freezing of the water can result in sufficiently high forces to rupture it (Latta, 1962). Sulphate attack on concrete and the weathering of stone and mortar by rainwater acidified by sulphur gases in the air are additional examples of degradation (Sereda, 1969). Basically, however, such materials are regarded as being almost maintenance-free (Benson, 1968a).

Wood is a durable material and will remain intact over long periods without the use of coatings; but weathering effects do result in a change of appearance of the exposed surface (Ashton, 1967). Rapid moisture content changes due to wetting and drying of exposed surfaces can result in serious checking as well. Exterior wood surfaces are thus normally coated in order to improve the appearance. Concentrations of moisture at the interface between the wood and paint often cause blisters and failure of the paint surface. Bleed through of knots has also been a common problem (Ashton, 1967). Depending on the type of coating used, wood surfaces normally
require repainting at regular intervals of about one to four or five years. The need for frequent maintenance of wood surfaces in exterior conditions is a significant factor in not choosing such material for siding (Benson, 1968a) and also for soffits, fascia, and trim.

Although many plastics suffer from crazing (cracking on a small scale) and fading due to exposure to ultraviolet light (Ashton, 1969), some plastic films have been developed which can retain their resilience and appearance indefinitely (Platts, 1964a). Chlorosulphonated polyethylene ("Hypalon") and polyvinyl fluoride ("Tedlar") are two of the most important such coatings yet developed, and can be used on a variety of surfaces including metals and wood (Platts, 1964a). These will undoubtedly influence a movement toward maintenance-free surfaces provided that the costs are reasonable.

Rotting is another problem faced by wood but not by its competitors. Dry rot, caused by *Poria incrassata*, is the main decay fungus active in dwellings in North America, although a few other brown rots are also found (Boyce, 1938). Decay in houses is largely preventable and results in the first place from faulty design, faulty construction, the use of wet timber, or lack of sanitary conditions after construction. With the knowledge of these fungi which now exists, and the availability of a number of preservatives, there is no reason why decay should continue to be a problem with wood.

The above discussion has touched on aesthetic considerations of materials in connection with weathering. It may also be noted that natural materials, particularly wood, have an aesthetic appeal not present in synthesized materials. According to Tromp and Campredon (1966), several
studies have indicated that wood in the home environment increases the feeling of well being. In support of this, Blomgren (1965) stated that wood has a number of basic appeals and is associated with security, peacefulness, and relaxation. A unique advantage of the aesthetic qualities of wood is the wide range of distinctive individuality that wood products can assume. The advantage of wood from an aesthetic viewpoint in interior decorating is supported by attempts made to emulate it using other materials, notably plastic laminates (Tromp and Campredon, 1966). A variety of products are now available which do a remarkably good job of simulating wood grain pattern and colour.

Building Codes

The manner and extent to which building codes influence materials use, although sometimes clear, is not always evident. Direct code restrictions which prevent the use of specific materials are the easiest to appreciate. Code regulations basically rest on the criterion of public safety which requires structural sufficiency, proper fire prevention measures, and provisions for public health. Wood, being combustible, has been widely restricted by building codes and, according to the National Forest Products Association (ca. 1965), has been more closely controlled than any other material. Manufacturers of other materials have also claimed undue restrictions due to building regulations. Doering (1967) indicated that steel still faces ancient restrictions and aesthetic inhibitions. Similarly, the proposed revisions to the National Building Code outlined by Solomon (1969), which call for the use of building materials having fewer smoke-producing qualities, will have the greatest effect on the plastics industry.
Requirements which call for noncombustible construction exclude wood and less obvious rules may also result in limitations on its use. As long as such regulations are justified, they cannot be rationally opposed. In such cases, the only alternative is to pursue further research on fire retardants to lower their cost and eliminate other problems related to their use, or combine other materials with wood to meet fire code approval. According to McCance (1969a), discrimination against wood is practiced in many of our largest cities in an effort to increase fire safety. Where such practices are excessive, the only result is to increase building costs without the benefits of added safety. Opposition by national or regional forest products associations should be made in such instances.

A major problem facing the residential construction industry in Canada is the multiplicity of building codes which are often contradictory and unnecessarily restrictive (Fowke, 1969a). This has resulted from the delegation of authority for building regulations to municipalities which often lack the capability of producing and administering a realistic code. The lack of uniformity in codes has been cited as the greatest hindrance to the utilization of new building materials and techniques.

A degree of uniformity has been attained through the National Building Code (NBC), an advisory document published under the authority of the Associate Committee on the National Building Code of the National Research Council (Legget, 1967). According to Legget, at the end of 1966 over 70 per cent of the Canadian urban population lived in municipalities using the NBC in whole or in part, while over 90 per cent of the incorporated cities had adopted it. However, it is thought that in the majority
of cases where the NBC has been altered for use by municipalities, the altered version bears little resemblance to the original (Plywood World, 1968). The idea of a truly uniform building code throughout Canada is supported by every professional and trade association directly or indirectly connected with construction, including architects, engineers, contractors; homebuilders, and manufacturers (Plywood World, 1968). Support of this objective is also forthcoming from such organizations as the National Research Council, the Association of Canadian Fire Marshalls, and the Canadian Underwriters Association, to name a few. With increasing pressure for a uniform code, it is anticipated that the 1970 NBC will receive greater acceptance by municipalities (Fin. Post, 1969b).

The relevant question for the forest industries is: how will a uniform building code influence wood consumption in dwellings? It may act to eliminate excessive fire restrictions on combustible materials which would be of definite advantage to wood products manufacturers. If uniformity promotes the acceptance of suitable new materials and techniques as is claimed, then it will favour the innovators in this traditional industry. If industrial R & D expenditures as previously outlined are an indication of innovative prowess, then substitutes for wood could be expected to enter the housing market at a faster rate. Another implication of uniform building codes is that it will facilitate industrialized building by making the products of any given factory acceptable in all municipalities. The question of the influence of industrialized building on the forest products industries will be dealt with in a subsequent section.
Preferences

Preferences of customers, builders, architects and engineers play a part in materials choice. These preferences are normally based on the characteristics of the alternative materials and a desire for specific qualities to be built into the structure. The characteristics of materials which in large part determine preferences have been discussed, but the weight given them is much less clear. According to Rich (1966), very little has been done by the forest industries in consumer research, most of the studies having been carried out by trade associations and one or two large companies. The interest of the wood industries in such market research has been growing in the past few years as evidenced by the increasing volume of literature, but information concerning consumer preferences is still scarce. As one builder summed it up, the lumber industry doesn't appreciate how its products are used, doesn't know the basic motivations of the builder or his problems, doesn't talk the same terms as the builder, and has poor contact with the building industry (Rich, 1965). Properly directed market research is capable of revealing consumer needs and motivations, thus providing valuable information for the design of products and for promotional appeals.

Another relevant question is the degree of influence which various groups exert on final materials choice. In single-family house building, the control of the architect is relatively small, being largely confined to custom-built houses (Fowke, 1969b). In a recent survey made by "Canadian Builder", builders were asked what proportion of their projects were carried out without architectural services. It was found that 83 per
cent of house construction and 41 per cent of apartment construction was
done without the services of an architect (Fowke, 1969b). In high-rise
apartments, structural engineers are also a major part of the design
team. Because the study of wood is insignificant in the education of
architects and engineers (Rich, 1969), there would appear to be a need
to provide them with educational, factual, and promotional literature
relating to wood products as well as to make a greater effort in deter-
mining their needs.

Another professional that should be mentioned is the specification
writer, an individual who evolved out of the need for specialists
who study and become familiar with materials and construction techniques
(Canadian Builder, 1969a). Since their duties are primarily to determine
products and materials to comply with any given performance criteria,
the importance of providing this group with factual information on new
wood products is obvious.

Whereas the architect, engineer, and specification writer are
highly important in apartment construction, builders and consumers are
most important in choosing materials in house construction. A recent
survey indicated that a high percentage of building contractors have a
moderate to high degree of influence on the final choice of products
(Fowke, 1969b), particularly for structural materials, flooring, and doors
and windows. However, it may also be noted that builders reflect to a
large extent the preferences of their customers. Evidence supporting
this has been found by Prestemon (1970a) in an exploratory study in Iowa.
Zaremba (1963) also found that, with respect to materials used on house
exteriors, there was a high correlation between consumer preference and actual ownership. This appears to emphasize the fact that in the purchase of a house, which represents an occasional purchase (sometimes only once in a person's lifetime), the buyer is more determined to fulfill his desires for particular materials.

Corporate Links

The existence of close ties between manufacturers and builders is a source of influence which has been growing strongly in the United States in recent years, but is not yet of great significance in Canada.

In the United States many large builders have been acquired by corporations looking for a guaranteed market for their building materials, and/or as a means of diversification and expansion. Vertical integration, however, accounts for only a small amount of the total flow of materials and products since any one firm only produces a limited share of building materials needs (Building Materials Merchandiser, 1967a). Other manufacturers have chosen to provide financial assistance for selected builders or building operations.

In the past, a number of large corporations have failed in their attempts to enter the building industry, including Allied Chemical Corporation, Monsanto Company, U.S. Steel Corporation, Aluminum Company of America (Alcoa), Union Carbide Corporation, and Reynolds Metals Company (Business Week, 1967). Many of their problems stemmed from attempting to become builders themselves, with the result that most companies now entering the field are utilizing the expertise of established builders, either through acquisition or joint ventures.
A number of American forest products companies have been active in this area. U.S. Plywood-Champion Papers Incorporated has participated with the Jim Walter Corporation in a joint venture, and through its wholly owned subsidiary Lewers & Cooke Development Corporation, has participated in joint projects in Hawaii and on the mainland (Business Week, 1967). The company has also acquired manufacturers of wooden doors, kitchen cabinets, and Drexel Enterprises, a large furniture manufacturer (B.C. Research, 1968).

Boise Cascade Corporation is active in the area of light construction and land development. This company produces manufactured houses through its subsidiary Kingsberry Homes, and mobile homes through Divco-Wayne Corporation, another of its acquisitions (B.C. Research, 1968). Joint housebuilding ventures have also been carried out with R. A. Watt Company, and Perma-Bilt Enterprises; R. A. Watt is now a subsidiary of Boise Cascade (Taylor, 1969).

Evans Products Company is participating in house construction through its Capp-Homes Division which precuts and sells houses throughout most of the United States (B.C. Research, 1968). According to the same authority, Potlatch Forests Incorporated supplies custom-made components to house builders through its Component Fabricating Centre.

The Weyerhaeuser Company, by working closely with selected franchised dealer-builders through its Registered Home Program, has also moved into the housing field (Rich, 1966).

Many non-forest product companies are also becoming active in house building. Alcoa has participated in a number of projects since its
initial failures, and Westinghouse Electric Corporation has been developing a community in Florida (Business Week, 1967). The General Electric Company has long range plans for a town development, and Goodyear Rubber Company announced the development of a new city in Arizona (Building Materials Merchandiser, 1967a). Several other major U.S. corporations are either operating, building, or planning to build plants to produce sectional housing, including: Occidental Petroleum Corporation, International Telephone & Telegraph Corporation, American Standard Incorporated, and Penn Central Company (Financial Post, 1970a).

With few exceptions, this movement into residential construction by major manufacturers has not been paralleled in Canada. Fairchild Aircraft attempted to build manufactured homes in Montreal for a short period but discontinued production in 1947 (Financial Post, 1970a). General Motors Corporation has investigated factory-built housing periodically over the past 40 years and has up to now decided against entry. The Aluminum Company of Canada (Alcan) was the first large manufacturer in Canada to move directly into the housing industry and remain in it. Alcan now operates a factory in Woodstock, Ontario, producing complete houses in two sections, through its wholly owned subsidiary Alcan Design Homes Limited.

The Steel Company of Canada (Stelco) has now formed a marketing group to work exclusively in the housing field. It will work closely with customers in developing new housing designs, assist in field development work, and co-operate in solving fabrication and erection problems (Dack, 1967). Polymer Corporation has taken its first step out of petrochemicals into industrialized building, having recently purchased the exclusive
Canadian license to use the Uniment system of Stressed Structures Incorporated (Denver) (Financial Post, 1970c).

The forest products industries in Canada have not yet made attempts to follow the lead of their counterparts in the U.S.A. or the above Canadian corporations. If more competing manufacturers become involved directly in housing, it would be reasonable to assume that major forest products companies would follow suit. Not to do so would surely lead to a further deterioration in their housing markets should competing companies enter residential construction with non-wood frame building methods for single-family dwellings and low-rise multiple dwellings.

Due to the lack of participation of major corporations in residential construction in Canada, vertical integration of materials suppliers and builders has virtually no effect on materials use in building at the present time.

Although it may be argued that changing labour costs in the construction industry influence the competitive ability of wood, it is felt that the main effect of increasing labour costs is the substitution of capital for labour in the construction process. How this actually affects the position of wood as a building material will be dealt with in the discussion of industrialized building.
PENETRATION OF SUBSTITUTES FOR WOOD INTO THE HOUSING MARKET

An attempt will be made to draw together the scattered, incomplete, and sometimes conflicting information pertaining to the nature and extent of penetration of wood substitutes into the housing market. Recent and important potential developments will be discussed for the main materials groups involved.

Aluminum

Some of the advantages of aluminum for construction uses cited by Bower (1966) are its lightness, high strength-to-weight ratio, good resistance to corrosion and good reflecting properties. However, because of its relatively high cost, aluminum has largely been confined to architectural and semi-structural applications.

Aluminum has been successful in penetrating the housing market in a few applications in which wood has been used traditionally. It is used primarily in windows, siding, fascia, and soffits (Phillips, 1967). Alcan Design Homes is reportedly using aluminum for door hardware, louvres, vents, foil vapour barrier, exterior door thresholds and the electric wiring system in its factory-built homes (Holroyd, 1969), most of which do not replace wood.

According to Phillips (1967), 50 per cent of windows entering new houses in the United States are aluminum. A study by Benson (1968b)
appears to support this figure. His study indicated that 45 per cent of the new houses built in the U.S. use aluminum windows primarily, and an additional 15 per cent use both wood and aluminum. The study revealed that a chief factor favouring aluminum windows is the maintenance-free characteristic as opposed to wood windows which require frequent painting. Furthermore, aluminum units are less expensive with respect to both purchase price and installed costs, and are thus used more extensively in lower priced homes. The main advantages of wood windows cited were better insulation and appearance. As aluminum window manufacturers improve the appearance of their products through the use of baked-on finishes, the price differential may result in further substitution of wood in favour of aluminum.

As siding, aluminum holds a smaller share of the market, estimated by Benson (1968a) to be about nine per cent of the U.S. siding market. This was corroborated by a survey of builders by the American Plywood Association (Crow's Forest Products Digest, 1970). For the same year, Phelps (1970) indicated that non-wood materials were employed on 70 per cent of the FHA-inspected single-family houses in his survey. It may be noted that about 80 per cent of aluminum siding in the U.S. goes into remodelling and the remainder into new construction (Building Materials Merchandiser, 1967b). These aluminum products are available in a variety of colours, textures, and styles. One of the major advantages of aluminum siding (as well as most other non-wood sidings) is that it is generally considered maintenance-free. The introduction of polyvinyl fluoride finishes on aluminum siding virtually eliminated painting, and some man-
ufacturers are offering 30-year guarantees on these products. However, such maintenance-free finishes can be used on a variety of substrates, including wood. (It may be noted that U.S. Plywood-Champion Papers began production of wood siding coated with Tedlar (a polyvinyl fluoride finish developed by Dupont) in 1963). Benson also found that the cost of aluminum siding was equal to that for fibreboard and plywood, and slightly lower than for lumber. However, architectural style and the home-buyer's preferences are also important in determining the siding employed. In fact, Zaremba (1963) found that consumer preference had a very strong influence on the siding material used. Often a number of materials can be used satisfactorily for a given house style; hence styles, although they may influence the choice of materials, do not necessarily determine the siding materials used. With respect to preferences, lumber appears to be favoured for siding, at least in high-priced houses.

The total usage of aluminum per new house in the U.S. was reported as 300 pounds by Phillips (1967). In comparison, Alcan Design Homes is reported to be using approximately 1200 pounds of aluminum per house (total house weight is 18 tons) constructed at its Woodstock, Ontario plant. No average statistics comparable to those cited above for the U.S.A. are available for Canada.

A promising development is that of structural sandwich panels in which aluminum is used as a facing material bonded to a thick lightweight core (Bower, 1966). In such panels, the aluminum provides the strength while the core separates the faces to provide rigidity, and also acts as bulk insulation. As previously indicated, the cost of such systems using
foamed plastic cores has prevented widespread commercial production up to the present time.

More recently, Alcoa has developed two types of aluminum systems for house construction known as the "Alumiframe System" and the "Rib Wall Building System" (Tibbot, 1970). Both of these building systems are in an advanced state of development, but neither is commercially available yet.

The "Alumiframe System" is composed of a number of extruded aluminum components, including window and door frames, 2 x 3 studs and plates for use in interior partitions, and other structural components including floor beams and roof trusses. Studs and plates are perforated to allow for wiring and plumbing, and no special tools or hole drilling are required. A development house using this system was built jointly by Ryan Homes and Alcoa. Aluminum 2 x 6 floor joists were used over the conventional basement, and plywood decking was screwed onto the joists. The pre-assembled wall panels used 2 x 4 aluminum studs and the roof trusses were fabricated of aluminum. Some lumber was incorporated into the frame, but most of it was of aluminum. Although the cost analysis of this system is not yet complete, it is felt that it will be competitive within a few years, and that the wall system may be competitive today.

The "Rib Wall Building System" has been used to build both a ranch style house and a two storey, four family townhouse. In the ranch style house, three main components were used: the rib wall panel, window panel, and door panel, all of which had a baked enamel factory finish. This system used steel floor joists to which the plywood deck was fastened.
Individual panels (of all three types) were first joined together on the site and then the whole wall erected. An inexperienced five man crew was able to erect the walls in 9-1/2 hours. Rigid polystyrene insulation was glued directly to the inside of the wall panels. In this particular house, wood roof trusses were used, and the remainder of the interior finishing was done by conventional techniques. The townhouse used techniques similar to those in the ranch house, with some variations, including the use of a crane to place the much larger wall panels into position. Rather than three basic components there were only two: a rib wall panel, and a window-door panel, the panels being 16-feet high rather than 8 feet as in the case of the ranch house. The claim has been made that this system will be more competitive than conventional wood frame building methods.

Steel

The interest which steel manufacturers have in the housing market has already been indicated. This interest extends into both multi-family and single-family dwellings. According to Dack (1967), the typical house recently used about one ton of steel, a figure which steel authorities felt could be raised to three tons through the development of suitable products and building techniques. Since then, steel makers have begun marketing several products for use in single-family dwellings.

In 1967, the "Mod" house, built of steel, brick, and concrete, was shown at the National Home Show in Toronto (Financial Post, 1967). It used steel wherever practicable, and, although not a commercial product, stimulated considerable interest, and is symbolic of efforts being made by steel producers to enter the housing field.
Light gauge steel, the most logical and promising contender for the housing market, has been used in commercial and industrial buildings in such applications as roofing, decking, flooring, cladding, ceiling fixtures, door frames and other forms of trim (Hill, H.V., 1966). The nature of steel, as previously outlined, requires that it be used in combination with other materials. One of the chief objections to light gauge steel has been the possibility of corrosion, but with the recent developments in baked enamel and plastic coatings, this problem has been virtually eliminated. According to Hill, H. V. (1966), there are two light-weight steel frame housing systems in use in England which are reportedly being sold at competitive prices. Whether these would meet Canadian building codes or be competitive in Canada are unanswered questions.

In Canada, Anthes Products Limited has been developing a steel joist which obtained provisional acceptance by CMHC in 1967 (Financial Post, 1967). This product (of light gauge cold rolled steel) was given its first field trial in a venture by Consolidated Building Corporation in 1967, in co-operation with Anthes (Canadian Builder, 1967). Advantages cited for this type of joist are easy installation by unskilled labour, no warping, and clear span basements. Although there were still minor problems to be worked out, it was felt that there was a market for such joists if they could be provided in sufficient lengths to prevent site work, and become as easily available as lumber.

More recently, the National House Builders Association employed both steel joists and steel studs in its experimental house built in Kitchener, Ontario (McCance, 1969b). These floor joists were employed
on both the first and second floors, while the 1-5/8 in. steel studs were used for all non-loadbearing interior partitions. It was claimed that steel studs require less labour to install and that predrilled holes at one foot intervals to accommodate wiring speed up this job. Hoyle (1970) has stated that pre-drilled holes in wood studs have been offered to builders in the past but were not successful because of reduced versatility and usefulness of such studs at the building site. This objection does not apply to pre-drilling of steel studs since the holes are drilled in all such studs.

During 1968 and the spring of 1969, the record high lumber prices brought with it many claims that the price of steel studs was competitive with wood studs for non-loadbearing interior partitions. In commercial buildings, steel studs for interior partitions have found a fair degree of acceptance over the past few years (Canadian Forest Industries, 1969). Although non-loadbearing steel studs were claimed to have a competitive edge over lumber (at least in some areas), the substantial drop in lumber prices in the latter half of 1969 has reversed this situation in most cases.

In Hoyle's (1970) analysis of steel versus wood studs, the non-combustible nature of the former is pointed out as a definite advantage in multi-family dwellings. He indicates that wood stud walls are, on the average, stiffer than steel stud walls, have higher bending strength, and are about 2-1/2 times stronger in compression. This latter property is of little importance in non-loadbearing walls and, given that the bending strength of steel studs is sufficient for the intended purpose, the greater
bending strength of wood studs may be viewed as over-design rather than a real advantage. It would appear that, in non-loadbearing walls, steel studs will continue to threaten the position of wood studs, particularly if lumber prices rise relative to steel prices. However, in exterior load bearing walls, the required use of heavier gauge steel for studs would at least double their price. Thus, Hoyle concludes that there is no apparent reason for steel to replace wood in exterior walls.

Metal shelving is another area in which steel products are competing. A study by Benson and Host (1968) determined that the proportion of metal shelving used in single-family homes ranged from one percent in kitchens to 21 percent in garage and utility areas. The remaining shelving was composed of lumber, plywood, and particle board. Metal shelves were said to have the advantages of being warp free and easy to install since they are generally purchased ready to fasten in place. On the negative side, they are not readily accepted by home buyers, have a tinny appearance, rattle, and are more expensive. This last disadvantage cited was based on purchase price rather than in-place costs since the builders surveyed were unaware of the in-place costs of their shelving. The findings of this study suggest that steel will meet only limited success in the area of shelving.

Metal doors are a more recent entry in the housing market. U.S. Steel has developed a steel door in partnership with a millwork company (Rich, 1965). This door comes from the factory pre-hung, does not warp, chip, scratch, or peel and has good insulation properties. Metal clad doors are also being produced in Ontario for houses. These doors have metal cladding on both sides, wood stripping around the edges,
and a polyurethane foam core. Such doors are much higher priced than wood doors and are thus used primarily in houses in the high price range.

Steel siding is another recent development. The same coating techniques which are used for aluminum can also be applied to steel. As early as 1967, steel siding was reportedly used on hundreds of new houses in Southern Ontario (Financial Post, 1967). Steel siding with protective coatings does not crack, flake, chip, blister, or peel, and is economically cleaned and maintained. As with aluminum, steel siding is available in a variety of textures and colours. Stelco began marketing pre-painted steel house siding in 1970 (Globe and Mail, 1970a). Aside International Corporation, a wholly owned subsidiary of U.S. Steel, is also entering the Canadian market with steel siding that simulates a wood grain pattern and is finished with vinyl. A 30+year factory guarantee on these products places them among the maintenance-free sidings. Steel officials claim that steel siding is slightly lower priced than aluminum siding (Financial Post, 1967), but both are higher priced than wood siding. With installation and maintenance included in the total cost, aluminum and steel are claimed to be competitive with wood sidings.

Plastics

The plastics industry has for many years claimed to be on the verge of entering the construction market on a large scale. For a number of reasons, no such breakthrough has been achieved. A gradual increase in the use of plastics in construction has occurred, and this industry now has a number of promising developments. The high price of plastics has been a major impediment to more widespread use. Three other reasons cited
for the slow adoption of plastic in construction are: the fire hazard and smoke generation of plastics, antiquated specification-type building codes which discriminate against new products, and lack of information on plastics available to architects (Canadian Plastics, 1969).

In most of the applications in which plastics have met success, there has been no replacement of wood products. In a few instances, the use of plastics has been at the expense of wood products, although the extent of substitution is difficult to determine and probably quite small.

According to Salmond (1969), the construction industry has used 20 to 24 percent of the U.S. plastics production in each of the previous 10 years. In 1967, Modern Plastics (1968) reported that the total U.S. plastics consumption in building construction was close to 4 billion pounds. There are no data for the residential construction market. Salmond (1969) indicated that the per capita consumption of plastics in construction in the U.S.A. and Canada in 1965 was 12.6 and 5.8 pounds, respectively. There is reason to believe that the latter figure is somewhat high since he also reported that plastics consumption in Canada first exceeded one billion pounds in 1968. If the same proportions hold in Canada as in the U.S., the volume of plastics used in building construction in Canada would have been approximately 200,000 to 240,000 pounds in 1968.

Platts (1964a) found in his study that plastics now dominate the fields of coatings, claddings, and coverings in building. Modern Plastics (1968) indicated that paints, coatings, and adhesives represent over half of the plastics employed in the building market. These, as well as most other uses of plastics in housing, do not compete with wood products. For
example, polyethylene vapour barriers, reinforced plastics and acrylics in glazing and skylights, polystyrene and acrylics in lighting and fixtures, and polyvinyl chloride (PVC) extrusions of gutters and downspouts are complementary rather than substitute products. Also, the very promising developments of drain-waste-vent systems of ABS and PVC, and glass reinforced polyester plumbing and bath fixtures will have little or no effect on the consumption of wood products. It is also interesting to note that one of the largest single "construction" uses of plastics is considered to be urea, melamine, and phenolic resins used in the bonding of wood panel products (Modern Plastics, 1968).

In the area of flooring, vinyl and vinyl-asbestos tiles dominate such areas as kitchens and bathrooms, and have found wide use in recreation and play rooms. Foam-backed types of seamless vinyl flooring have more recently been introduced (Modern Plastics, 1968). These floor surfaces are being promoted for all areas of the house, not merely utility areas, and thus represent potential competition for finished wood flooring.

Synthetic carpeting of acrylic, nylon, and polypropylene is another contender in the finished flooring market, along with traditional carpeting materials. The use of wall-to-wall carpets (synthetic or otherwise) installed by the builder has already led to a significant loss of wood flooring markets, particularly in apartments where carpets can be used very effectively to reduce impact noise transmission.

Josephson (1969) indicated that, since 1955, the share of the residential flooring held by wood products has dropped from two-thirds to
one-quarter of the total market, while carpeting and other non-wood materials now cover the other .75 per cent of the total floor area of new dwelling units built. In Canada, the substitution of non-wood flooring materials has been less drastic, probably because of the much lower use of concrete slab foundations in single-family houses. Carpeting made of synthetic fibres, particularly nylon and acrylon, have had much success to date; and the potential remains high for wall-to-wall carpeting in general.

The very good insulating value of some of the foamed plastics has already been indicated. Although polyurethane foam has the best insulating properties, polystyrene is the lowest in cost of those available (Platts, 1964a), which accounts for its greater use up to the present time. As early as 1967, several high-rise apartment buildings were reported to be completely insulated with urethane foam (Modern Plastics, 1968); and it is now one of the major markets for plastics in construction. These foams have been relatively well accepted as insulation and appear destined to capture much of this market from the traditional mineral wool and insulation board.

Another significant development using foamed plastics is the load bearing sandwich panel with a foamed plastic core. Since a core material must be able to support the loadbearing skins, styrene foams (which begin to soften at 200°F and are subject to creep under sustained load) appear somewhat limited in their potential as such a core material (Platts, 1964a). The better heat resisting properties of urethane foams indicates a greater long-range potential as a core for sandwich panels than any other plastic foam.
Platts (1964a) indicated that the technology for producing metal faced panels with a urethane foam core at high production rates already exists, but that the cost of such components would not be competitive with wood frame systems for many years. Foams can be used in conjunction with a variety of skin materials, including aluminum, steel, plywood, asbestos cement, and glass reinforced plastics (Makowski, 1966). A description of several different panels of this general type, both commercial and in some stage of development, has been given by Makowski. He also indicated that phenolic resin foam core (used with glass reinforced plastics) and expanded PVC are finding use as core material in sandwich panels. Many one and two-storey buildings are reported to have been built in which large factory-built plastic sandwich panels were used as external load bearing walls. One set of townhouses employing glass fibre reinforced resin panels was even described as low cost (Makowski, 1966).

In citing the feasibility of fully load-bearing walls with expanded foam cores and stressed GRP skins, the Financial Post (1968a) has indicated that external walls offer the biggest potential for plastics. Modern Plastics (1968) indicated that reinforced polyester panels and sandwiches are enjoying reasonable sales. It is reported that the use of GRP panels with a backing of rigid urethane foam is growing rapidly, but housing was not cited as a market.

It would appear that economics is still holding back large-scale commercial production of sandwich panels with plastic foam cores. However, the potential of such panels is tremendous if the price structure can be made competitive with wood frame construction.
A recent entry into the housing market has been vinyl siding. Although introduced in the U.S.A. in 1963, it has more recently entered the Canadian market. High thermal expansion and contraction has in the past resulted in bowing of the panels, but new installation techniques have overcome this problem (Modern Plastics, 1968). It is considered a maintenance-free material and is being sold with a 30-year guarantee. Benson's (1968a) study on siding materials in the U.S. does not mention vinyl, and Modern Plastics (1968) indicated that no reliable estimates are available on the amount of PVC going into house siding. According to McCance (1969b), vinyl siding costs about five per cent more than aluminum. He also noted that the Mark VI experimental house of the National House Builders Association used vinyl siding, fascia, soffits, and eaves, reflecting the interest of the house building industry in this new material.

High-pressure decorative laminates using phenolic and melamine resins are commonly used in kitchen counter and vanity tops. The hard abrasion and chemical resistant surfaces have led to the virtual elimination of competitive products in the uses mentioned above.

Attempts to extend the application of high-pressure laminates to vertical wall surfaces have been relatively unsuccessful. Modern Plastics (1968) stated that low-pressure laminates of polyester-impregnated papers on various composition boards are now attempting to enter this market, offering potential competition to decorative wood veneers. The most successful plastic product type in this area to date has been wood-grained vinyl films over a variety of low-cost substrates including plywood, gypsum
board, and even corrugated cardboard (Modern Plastics, 1968). This has been referred to as one of the fastest growing markets for plastics. Modern grain printing techniques are capable of producing patterns on vinyl which are hardly distinguishable from natural wood, at the same time providing a water resistant, easily cleaned surface. Tane (1967) cited an increasing tendency towards the surfacing of gypsum board with vinyl film. He also noted that the average price of a vinyl covered 4 x 8 ft. plywood panel was about $7 compared to $11 and up for natural wood panels.

While the prospects for vinyl in decorative wall coverings appear good, this is becoming a highly competitive area, with hardwood plywood panels and direct grain-printed hardboards still supplying the vast majority of panels used. Hardwood plywood is still the favoured material. The market is a segmented one with a large variety of styles and prices to suit individual tastes, indicating that no single material will be able to supply the whole market.

Glass fibre reinforced polyester (GRP) is the most important and best known structural plastic material. GRP panels can be manufactured with a variety of properties depending on the resin-fibre ratio and the type of fibre employed (Benjamin, 1968). Until the present, GRP panels have been excluded from the housing market, largely on the basis of cost. Nevertheless, the high strength of these materials has sustained interest in them. The potential of sandwich panels with plastic foam cores and GRP faces has already been outlined. GRP plumbing and bath fixtures are now being sold, in some cases as complete factory-built bathroom core
units. Whether these will be successful or not still remains to be seen. Only the use of complete core units would result in a replacement of small volumes of wood. GRP plastics have been used in a variety of non-residential structures, often taking on exotic forms. Potential uses cited in housing are roofing, cladding, internal components such as partitions, doors, staircases, and ceilings (Interbuild, 1967).

The world's first high rise apartment building clad with reinforced plastics was started in London, England in 1965 (Buildings, 1968). Protective Plastics Limited, of Ontario, is reported to have successfully marketed a prefabricated building using GRP sandwich panels with a urethane foam core (Financial Post, 1968a). The same source reported that a British company has developed a FRP-panelled house which has been approved by local building authorities in Britain for low-rise housing. This panel system has also been approved for apartments and office buildings. Although GRP panel systems are not yet competitive in Canadian housing, active research in this area is continuing and new developments can be expected.

A few other minor developments are also worth noting. Runeberg (1969) indicated that doors entirely of plastic have been reported and that PVC doors are being produced in large quantities in both West Germany and Italy. Extruded profile products such as window and door frames are rapidly infiltrating this traditional wood market in Europe (Runeberg, 1969). Modern Plastics (1968) has indicated that production of PVC window frames began in the U.S. in 1966 and, although residential homes have provided the largest market so far, this product has been relatively unsuccessful to date.
A more recent Canadian development is a large polystyrene foam block designed to act as the forms for the concrete frame of the house and as the insulation (Canadian Builder, 1969b). The blocks are first assembled using adhesives, reinforcing rods are placed in position, and the concrete is poured. A variety of sidings and interior finishes may be used. Fennell (1969) reported that houses have been erected in Barrie and Oakville, Ontario using the "Foam Form" system, as well as a townhouse complex in Leamington. Universal Sections Limited, a large Ontario builder, has acquired 50 per cent ownership of Foam Form Canada Limited, which plans to build a plant to produce these plastic units in the Toronto area.

In October, 1969, a plastics house was exhibited at the Plastics Show of Canada in Toronto (Canadian Builder, 1969c). Unlike most previous plastics houses, it was of conventional design and used plastics to replace more conventional materials. This house, sponsored by the Department of Trade and Development of Ontario, and the Society of the Plastics Industry of Canada, was used to demonstrate only those plastic products which are in commercial production and readily available. (Materials other than plastics were employed where no plastic substitute was available). Many of these products should interest wood products manufacturers: PVC siding, vinyl fascia and soffits, plastic faced wallpaper, kitchen cabinets of vacuum formed impact styrene and polyester laminates, irradiated wood-plastic flooring, PVC ceiling panels, "Foam Form" wall system (described above) epoxy-aggregate wall panels, vinyl wall coverings, urethane foam filled front door, PVC faced bi-fold closet doors,
sliding PVC and aluminum rear doors, polyethylene moulding for door frames, PVC-faced gypsum board interior walls, a bathroom with FRP walls, floor and ceiling, and PVC window frames. That these products are commercially available in Canada is evidence that plastics manufacturers are becoming major contenders in the housing market, if not so much for structural components, at least for ancillary products related to interior and exterior finishes, and for a wide variety of accessories.

Non-metallic Minerals

This group includes several different materials including asbestos, gypsum, clay (brick and tile) and concrete products. Although grouped together here, each is unlike the others with respect to properties and area of application.

Although asbestos products are the least used of this group in residential construction, asbestos cement shingles have been employed in Canada as a siding material for many years. Benson's (1968a) study of siding in single-family dwellings in the U.S. indicated that asbestos shingles were used on four per cent of the houses surveyed, while the American Plywood Association did not report the use of asbestos siding at all in its study (Crow's Forest Products Digest, 1970). Although no Canadian figures are available, the use of asbestos siding in Canada is also relatively low. Perhaps this can be accounted for by a result of a survey of housing performance which found that asbestos cement shingles are frequently broken or chipped, resulting in unsatisfactory appearance (Build International, 1970). It would appear that this product is not a
major contender for the residential siding market and competition from it will be limited. The only other use of asbestos in housing is as an insulating material to provide adequate fire protection for steel members in multi-family dwellings. On the whole, asbestos doesn't compete significantly with wood materials in housing at the present time, and is not likely to in the future.

Stucco (composed of either Portland cement or hydrated lime) is another material which has been employed as an exterior cladding. Both Benson and the American Plywood Association reported that stucco was used in eight per cent of the houses built in the U.S. in 1968. The use of crushed glass or stone embedded in the surface often produces an attractive exterior finish. Considered a maintenance-free material, stucco will probably remain popular in some regions without altering its market share significantly.

Gypsum has been used in the interior finishing of dwellings for many years and must be regarded as the traditional material in this application. It was once used primarily as gypsum plaster and applied to interior walls over wood lath and, more recently, metal lath. Other plastering materials which have and still are being employed are quicklime, hydrated lime, and inorganic aggregates. These materials have now largely been replaced by gypsum wallboard panels consisting of a gypsum core with heavy paper faces, commonly referred to as "dry wall" construction. In 1955, this wallboard was used in less than 15 per cent of Canadian dwelling units, but increased to about 50 per cent by 1965 (Hansen, 1965). Using wallboard is more economical than applying plaster and has the im...
portant advantages of speed of erection and being little affected by winter weather as opposed to plaster which is slower and more difficult to apply when cold. Both the declining use of plaster in favour of wallboard, and the increasing use of metal lath, have almost eliminated the use of wood lath. It could be argued that this has been balanced by the high volumes of paper used as a facing material on wallboard. Thus, although the form of wood product employed changed drastically, the volume of wood-based material required has probably not changed significantly.

The use of decorative wall panels (which has been discussed with respect to grain printed vinyl overlays) in dwellings is generally limited to small areas such as in dens, living rooms and recreation rooms. Although the extent of use of such panels fluctuates periodically with style trends and personal taste, the general preference in large areas is for a smooth, paintable surface free from joints (Worth, 1957). Plaster and wallboard have traditionally provided such a surface economically. Attempts to provide suitable wood-based panel products as an alternative to wallboard have not yet been successful. On the other hand, a trend toward applying vinyl film to gypsum wallboard for decorative applications has already been noted (Tane, 1967).

It has previously been indicated that wood frame construction is the traditional method of building in Canada for both single-family and multi-family dwellings up to three storeys. If 90 per cent of Canadian houses use wood frame construction, as indicated by the Department of Trade and Commerce (ca. 1965), and if this figure also applies to low-rise apartments, then approximately 10 per cent of all dwellings built in Canada
up to three storeys are of masonry (primarily) or solid concrete construction.

Since dwellings over three storeys exclude wood in the basic structure, the question of the replacement of wood structural components in such dwellings has been largely covered in the discussion of trends toward high-rise apartments. Little was said about the materials used in the basic structures in place of wood. Reinforced concrete has been used almost exclusively in the construction of the load bearing walls of apartments over three storeys (Moreau and Van der Ryn, 1967). For reasons that will not be dealt with here, steel structural frames with curtain walls have been employed sparingly in high-rise apartments.

Due to building code regulations, unit masonry construction has (until recently) been excluded from load bearing walls in apartments over three storeys. A revision of the National Building Code in 1965, however, has resulted in the use of masonry in high-rise construction (Financial Post, 1968b). But such developments do not affect the markets for wood products in housing.

Masonry construction in low-rise housing forms includes those dwellings in which the load bearing walls are composed of relatively small units such as stone, clay bricks, and concrete blocks, cemented together by mortar. Masonry is used in both solid and cavity walls, the latter having the advantage of providing excellent protection against rain penetration (Ritchie, 1961).

The Canadian Brick Company and Dow Chemical of Canada Limited have together recently developed a complete masonry wall system which is reportedly more economical than conventional masonry construction. It
is comprised of a brick wall held in place with normal brick ties, to which sheet styrofoam insulation is glued, and gypsum wallboard is in turn glued to the insulation (Canadian Builder, 1968).

The use of brick veneer as an exterior cladding is more common in Canada than load bearing masonry walls. Although Canadian statistics are not available, Benson (1968a) found that 28 per cent of houses constructed in the U.S. in 1968 had brick exterior walls. The American Plywood Association obtained a corresponding figure of 43 per cent from its survey (Crow's Forest Products Digest, 1970). The reason for this discrepancy is not known, but it may be reasonably assumed that between 30 and 40 per cent of Canadian houses are built with a brick exterior. The use of brick is probably fostered by building codes and insurance rates in large metropolitan areas such as Toronto and Montreal where fire codes are quite severe. Benson has indicated that the cost of brickwork (installed) is higher than all other exterior claddings but also pointed out that this is not the deciding factor in most cases.

There is little evidence that masonry is making inroads against wood frame construction in housing. Most of the recent developments in masonry construction relate to the prefabrication of panels of brick. These will be discussed in reference to industrialized building.

The use of concrete has been briefly noted as a structural system for housing. Although it finds its major application in apartments above three storeys, it has found limited use in single-family houses and low-rise dwellings. Two recently developed concrete house systems will be briefly outlined to demonstrate the imaginative efforts being made with this material.
Kettle (1968) described a demonstration house built in Galt, Ontario in 1968. Curved metal forms, plastic insulation, and a metal mesh were erected in one day to form the basic structure. Concrete was then sprayed on the following day to complete the wall system.

A second system (previously outlined with respect to foamed plastics) utilizes large polystyrene foam blocks into which concrete is poured in situ after assembling the foam blocks (Canadian Builder, 1969b). A number of houses have already been built and the system is now being commercialized.

Although these are interesting building innovations, the major developments in housing using concrete is in the area of pre-stressed and precast concrete components for use in multi-family structures. Since these developments are closely linked with industrialized building, they will be discussed below in connection with this topic.

Combined Materials

Although there has been great interest in recent years in the concept of using combinations of materials, with the objective of exploiting the desirable properties of each in the final product, the idea is by no means a new one. A number of well accepted combinations have been in use for many years. Paints applied to various materials to reduce corrosion and improve appearance is probably one of the oldest combinations. Perhaps a more sophisticated one is reinforced concrete in which the steel rods provide high tensile strength to complement the high compressive strength of the concrete; at the same time these materials are compatible with respect to other properties.
The "combining of materials" in construction can be regarded in two ways: (1) the intimate mating of two or more materials in a single component product; and (2) the use of two or more single-product components; in both cases the materials are rationally chosen on performance and price criteria. The first of these two aspects will first be discussed with respect to combination products presently used in residential construction.

Throughout the discussions of steel, aluminum, plastics and non-metallic mineral products, frequent reference was made to products which are actually combinations of materials. Steel and aluminum siding with polyvinyl fluoride and other highly protective plastic coatings were mentioned. Plastic foam sandwich panels with metal faces, and aluminum-faced wood siding are further examples of metals in combination with other materials. Plaster on wood lath or metal lath, and paper facing on gypsum wallboard are examples from the non-metallic minerals group. A large number of wood-plastic composites are presently used in construction. These include urea and phenolic resins in plywood and particle board, high-pressure plastic laminates on wood, vinyl-faced wood composition boards, phenolic impregnated paper overlays, and irradiated wood-plastic parquet flooring. The extent to which these products are employed has already been indicated where this information is available.

One notable feature about the combination products mentioned above is the high incidence of plastics among them. This is not a coincidence but rather a reflection of the ability of various plastics to provide properties which are either lacking or deficient in the materials with
which they are combined, primarily metals and wood. Outstanding among these properties are corrosion and impact resistance, water resistance, durability, and aesthetic characteristics of various plastics which make them ideally suited for a wide variety of coatings and coverings on many materials. That wood can be combined successfully with plastics has already been demonstrated. It would appear, however, that the relatively high prices of plastics has been a limiting factor in some instances; a situation which will likely improve in the future.

Although plastics have been the most used material in combination with wood, a few products using combinations of metals with wood have been marketed. The relative infrequency of these combinations (as opposed to wood-plastic combinations) is probably due to a narrower range of possibilities of product improvement by so doing, and fewer possible ways of physically combining these materials. Non-metallic mineral products also appear to offer fewer possibilities for joint use with wood for the reasons noted above for metals.

In summary, it must be concluded that wood can be used successfully in combined products, and that wood-plastic combinations offer a particularly attractive avenue of product development for the forest industries. It is generally acknowledged that the era of combined materials is now here. As indicated, combinations can be realized in two different ways: (1) the joining of two materials in one product; and (2) the use of two or more single product components. The first of these two aspects has already been discussed.

The second aspect of combining materials implies that all materials manufacturers should be completely rational with respect to the pro-
ducts they manufacture, and not attempt to market and promote products which are not suitable for a specific use. This requires an acknowledgment of the shortcomings and advantages of each material, and the admission that a competing material may be more satisfactorily employed in a given application. There are many instances in which each product has certain disadvantages, and the choice is mainly subjective and based on consumer preference.

The promotion of products which obviously have poor performance characteristics relative to competing products, or which frequently result in complaints from consumers, probably does more harm in the long run through weakening the consumers' confidence in the material than the short-run sales revenues justify. How this line of reasoning will affect the forest industries is perhaps debatable. It may signify a recognition that wood products, which have been so widely employed in housing in the past, can no longer be expected to command such a large share of the residential construction market, given new materials and products which provide superior performance. It definitely implies that funds would be better spent on research to overcome the deficiencies of wood in specific uses rather than on promoting inferior products. The underlying tacit admission that wood products cannot provide all the required functions in specific end uses should point to a need for greater R & D effort to develop more suitable products, using other materials where their properties are required to complement those of wood. Although this approach will lead to a reduction in the consumption of wood in those products which have been produced entirely of wood in the past, it is easily appreciated that this is still a more rational proposal than attempting to compete with a less desirable product and risking the loss of an entire market.
INDUSTRIALIZED BUILDING

Much has been written over the past decade about industrialized building and its implications for the building industry. Many European countries are already actively engaged in factory production of housing units or their components which are shipped to the building site for assembly. The systems of factory-built houses developed in Europe have been primarily multi-family structures of concrete, some of which have been recently introduced to North America. However, developments in systems building indigenous to this continent have not been lacking, but have been gradually evolving over a number of years. It is the general consensus of opinion among authorities on this subject, that industrialized building will continue to evolve, and although it will not replace traditional construction methods entirely, it may become a major factor in the residential construction industry, particularly where high volume, repetitive structures are required. It would therefore be appropriate to assess its implications with respect to materials requirements in an effort to determine the effects it will likely have on wood products markets.

A brief outline of some important aspects of industrialized building is in order to place the subject in perspective. The rationale behind factory production of components (or whole housing units), which are then shipped to the site for final assembly or erection, lies in certain economies which can be realized. These include higher volume production with resultant economies of scale such as bulk purchasing, the sub-
stitution of less skilled factory-type labour for skilled on-site labour, improved working conditions which eliminate or reduce many difficulties implicit in conventional on-site construction, consistent high quality production, and faster building time which shortens the period in which capital is tied up (Webb and Legget, 1967).

McMeekin (1966) has indicated that much of the cost savings of industrialized building is due to indirect factors resulting from the imposition of certain disciplines on the whole building operation: pre-planning, standardized members, preferred dimensions, repetition, and more precise control and scheduling of operations. He suggests that these are aspects of building which could also be applied to conventional on-site construction with resulting economic gains; and that the growth of industrialized building will in fact induce such "rationalization" of normal on-site construction.

On the negative side, a high capital outlay is required for a factory and the necessary erection equipment, and in order to recover the investment, all equipment must be continuously productive, thus necessitating a concentrated market area (McMeekin, 1966). The factory may be either fixed or mobile, depending on the concentration of work. It has been reported that the resulting monetary saving in actual in-place cost is often small or non-existent (Webb and Legget, 1967). Nevertheless, some European systems do claim a 10 to 20 per cent savings over traditional methods plus an additional five per cent through shortened construction financing (Platts, 1968a).
Classes of Industrialized Building

Different degrees of industrialized building can be recognized, depending on the amount of work actually performed in the factory:

(a) on-site construction with the employment of some factory-built components;

(b) component packages manufactured in a plant and shipped to the site for assembly (excluding interior finishing);

(c) the manufacture of complete housing units in one or several sections (including interior finishing), requiring only final erection, coupling of the sections, and hooking up of utilities.

The first of these is the form that has evolved in the house building industry over the past decade or more in Canada, and is now very common. In 1968 it was reported that over 90 per cent of all house builders in Canada were using pre-built components in some form (Financial Post, 1968c). This has been primarily in single- and two-family houses, while multi-family wood frame dwellings have employed components also, but to a lesser extent.

The second form has been adopted to a lesser yet significant extent in Canada, and is exemplified by house packages of wood frame construction. It was recently reported that 20 per cent of the Canadian market for single-family dwellings is accounted for by both packages of factory-made components (Mathias, 1969). Most of the European systems developed also belong in this category.

The final category, sectional housing, is the most advanced form of factory-built dwelling units. This type of dwelling has only been manufactured to a very limited extent, either in Europe or in North America.
(Although mobile homes are often considered in this category, the codes which regulate their construction are not building codes, and they will not be considered here. It is reasonable to assume that the appearance and cost structure of mobile homes; built to building code standards, would be very similar to that of factory-produced sectional houses.) A variant of completely finished dwelling units is the production of completely finished core units (bathrooms and kitchens), in which all plumbing and utilities are installed in the factory and the unit put in place as a component at the building site. These are presently being produced both in Europe and in North America.

The development of industrialized housing in Canada, and some of the more recent developments in this area, are discussed below, emphasizing those aspects which bear on the question of type of materials employed.

On-site Building With Limited Use of Components

The increasing use of components in traditional on-site construction has been an important factor in holding down the prices of single-family houses in Canada. Dickens (1969) has indicated that, over the 1949-65 period, the costs of materials and labour increased by 51 and 136 per cent, respectively, while house construction costs rose by only 44 per cent. He also cited a study of a typical site-built house carried out in 1965 by the Division of Building Research (NRC). It was found that site labour constituted only 24 per cent of on-site costs as opposed to 40 to 50 per cent once commonly assumed, a reflection of the increasing use of components.
The use of components in house construction has been proclaimed the most widely accepted innovation in this industry (Rich, 1965). Employing them reduces on-site and total construction time, reduces the need for highly-paid tradesmen, and reduces material waste. Components received on the site ready for installation include pre-fit windows, kitchen cabinets, pre-hung doors, pre-finished panelling, and roof trusses, as well as other items (McCance, 1969a). The advantage which on-site builders have (whether using components or not) is the ability to increase or decrease production with minimal disruption of the operation, as opposed to the producer of factory-built houses who relies on a steady volume of business (McCance, 1969a). It is generally agreed that components will continue to play an increasing role in on-site wood frame residential construction, with higher priced and custom built dwellings retaining the highest degree of traditional on-site construction methods.

Prefabricated Component Packages

The concept of using wood frame construction for "factory-built" or "prefabricated" house packages is not new; the initial attempts having been made in the middle 1920's (Platts, 1964b). Emergency housing and veterans' housing, during and immediately following World War II, followed by summer cottages, were the forerunners of today's wood frame factory-built packaged houses. Platts' (1964b) definition of a "prefabricated house" -- a house wherein prefabricated components compose at least the major portion of the house shell -- will be used here. For a number of years, the typical supplier of house packages was an "open-market prefabricator" who sold largely to owner-builders in rural areas. Around 1956-59,
more intensive prefabrication began with the entry of "project prefabricators" who manufacture house packages for their own projects on developed land. (Platts, 1964b). The use of house packages is reported to have increased from three per cent (of single-family houses) in 1957, to 15 per cent in 1964, to 20 per cent at the present time. (Financial Post, 1970a).

Although wood frame prefabrication shops do not use advanced technology or a high degree of automation, it is claimed that the productivity of labour can be doubled by bringing the worker inside, supervising him, and keeping materials and jobs organized and at hand (Platts, 1964b).

Dickens (1969) has stated that the wood frame system is not readily amenable to highly mechanized production (due to the number of pieces and variability of material) and that the productivity gains of prefabricators in Canada has been primarily achieved through sheltered, organized working conditions, rather than mechanization. He has also claimed that with a shop labour content of 15 to 30 per cent (already common in Canada), further stages of prefabrication do not automatically bring additional labour savings using the wood frame system. The implication here is that higher levels of prefabrication may not be practicable for wood frame construction, with the result that innovations in systems building which are adaptable to a higher level of prefabrication, may eventually provide significant competition for the wood frame system. This viewpoint (held by the Division of Building Research, NRC) is opposed by supporters of the concept of sectional houses of wood frame construction.

The Division of Building Research claims that significant savings are only attainable by prefabricating the completed, pre-finished shell
and cabinetry, and at least some services. However, the winter building advantage, fast turnover, control of costs, time and quality are said to be as important as cost reduction (Platts, 1964b). Transportation costs usually limit the selling radius to 200 to 350 miles from the factory. It is significant that prefabricators are adapting their systems to include multi-family units which can easily be used in three-storey multiple housing. This requires the introduction of special handling equipment such as truck-mounted cranes (Platts, 1964b).

It was concluded by Dickens (1969) that wood frame construction will remain difficult for proposed innovations to equal in both cost and quality. He also concluded that the proven efficiency of prefabricated wood frame systems should result in their continued wide use in both single-family dwellings and certain low-rise forms of multiple housing.

Sectional House Construction

The ultimate in industrialized housing is the "sectional" house in which the exterior and interior of the house (or dwelling unit for multiple structures) is completely finished in the factory and only requires transportation of the sections to the building site, the joining of the sections in place, and connecting of utilities. Until the present time, this method has not been widely adopted but the concept has roused much interest. In the case of transportable sections, the additional savings through approaching 100 per cent shop labour have to be balanced against the much higher transportation costs of moving the sections to the site, the larger plant required, plus the cost of heavy equipment to
lift the sections into place. The position taken by the Division of Building Research (NRC) is that, with wood frame systems, the gains achieved by producing such finished house sections are negligible if they exist at all (Platts, 1964b).

The idea of producing houses in complete transportable sections is not new in Canada, the first such venture dating back to the early 1930's. Successful operations include wood frame transportable units for RCAF projects in remote bases and a few other ventures in isolated northern areas (Platts, 1964b). The Nuway Company in London, Ontario is reported to have successful produced sectional houses on a small-scale basis since 1947 in conventional housing markets. A number of other companies have either attempted to produce completely manufactured houses and failed, or have investigated the possibility and decided against it. Among those that have not succeeded are Lustron Corporation and Fairchild Aircraft.

In the U.S.A., General Motors has investigated factory-built housing on an assembly-line basis several times since 1930 and decided against entry, and Chrysler Corporation was also recently reported to be investigating the potential (Financial Post, 1970a). The same source also indicated that a number of major U.S. corporations are either operating, building, or planning to build plants to produce sectional housing, including: Boise Cascade, Occidental Petroleum, Penn Central, U.S. Plywood-Champion Papers, American Standard, and International Telephone and Telegraph.

The most significant development along these lines in Canada is the house factory operated by Alcan Design Homes (a subsidiary of Alcan)
at Woodstock, Ontario. Operating since mid-1968, the plant has an ultimate capacity of 2,400 houses per year (Holroyd, 1969). It is reported that the plant is able to produce two-storey, semi-detached, and townhouses as well as single-family dwellings. Completed units are transported up to 150 miles for erection. These houses, which meet National Building Code regulations and qualify for NHA financing, are priced as low as $14,900 including furniture, a full basement, lot and site costs (Holroyd, 1969). The significance of this operation is that the houses are of wood frame construction (as have been all commercial attempts at sectional housing in this country). Although it is too early to determine the success of this venture, it is claimed that the technical production problems have been solved (Financial Post, 1970a), which appears to support the position that wood frame construction can be successfully employed in complete factory-built conventionally-designed houses. Whether costs are significantly reduced below those that would be incurred using a factory-built component package and site assembly is debatable. However, the sectional house does provide a much faster building time and hence a faster recovery of funds sunk in the dwelling unit. As noted, this is an important consideration for most builders.

According to Platts (1968c), Israel has used the concrete box approach to some extent and the USSR still does. In Europe, concrete boxes have been employed for the high-service core areas such as bathrooms and kitchens. The weight of these units (eight tons or more) has led to attempts to develop wood frame core units on a concrete floor slab. In both Canada and the U.S.A., complete and partial bathroom core units of
glass fibre reinforced plastics have very recently become available.

Hill, A. W. (1966) described two concrete box systems developed in Great Britain which are suitable for both low- and high-rise apartments: the WILMAC system, which uses seven boxes per housing unit, and the TRUSCON system, which employs 10 sections per dwelling unit. The competitive position of these systems was not discussed. A 500-room, 21-storey hotel was constructed in Texas two years ago of completed concrete boxes, the first major venture of this type in North America (Architectural Record, 1968).

More recently, the Jones and Laughlin Steel Corporation of Pittsburgh and Donn Products of Cleveland formed a new company, Jal-Donn Modular Buildings, Incorporated, to produce steel apartment house modules which can be stacked three storeys high without additional support (Engineering News-Record, 1969). Each dwelling unit is composed of two sections, the total cost of which is about $14,000 to $17,000. Slayter (1966) described the development program of a steel frame sectional house in the U.S.A. which began in 1962. With the co-operation of U.S. Steel, 10 residential buildings were constructed in a pilot-plant operation. It was concluded that this system, using a steel space-frame as the structural base, was both technically feasible and economically practical.

Influence of Building Codes

Building codes, previously discussed with respect to innovations, have also provided an impediment to advanced industrialization. According to Platts (1964b), local building codes do not seriously hinder or raise the costs of site-built houses or the typical partially prefabricated house. However, they do restrict additional shop content in many areas and are a
major block to systems that include innovations in structure or materials, especially where a large market area is required to achieve economic volumes. Here, the lack of uniformity between codes prevents large scale factory production of a uniform product. The result has been that house packages have been kept incomplete and have been sold primarily in rural areas. Increasing pressures from all segments of the building industry for the adoption of a uniform building code across Canada will probably lead at least to regional uniformity in the near future. Such a development will undoubtedly promote a wider adoption of factory-built housing of all types.

Included in the question of codes is the matter of factory versus on-site inspection of houses by local building inspectors. Factory inspection will probably be achieved more easily than uniformity, as exemplified by the success of Alcan Design Homes in obtaining it through special arrangements in areas where the National Building Code is administered. Moreover, it is the policy of the Associate Committee on the National Building Code that this code should be written to apply equally to factory and conventional building (Webb and Legget, 1967). It is also notable that a committee was formed over a year ago under the co-ordination of the Canadian Standards Association with the purpose of creating national standards for the inspection of houses on the factory assembly line rather than on site (Mathias, 1969). It would thus appear that the way is being paved both for innovations and more sophisticated, large scale systems of building.
European Building Systems

Much interest has been generated in the past few years in the many building systems which have been developed in Europe. As early as 1965, claims have been made of 250 to 400 different building systems in Europe (Engineering, 1965). Building systems in a variety of forms have now been widely adopted on that continent (factory systems produce up to 70 per cent of all housing in some Scandinavian centres), and have penetrated the U.S.A. to a lesser extent.

One prominent feature of these systems is that many of the successful ones are based on precast concrete load bearing panels (Hill, A. W., 1966). Most of these concrete building systems have been for multi-family dwellings, but Hill reported that they have also been used successfully in two and three storey houses. Platts has attributed the success of large-panel concrete systems to their inherent simplicity; a single low-cost material provides several functions: structural support, fire and sound resistance, and finish incorporated in a few large parts which can be quickly assembled.

The movement toward industrialized building in Europe was due largely to a high housing demand, particularly for multi-family structures in densely populated areas. (Concentrated demand is one of the essential requirements for the success of high volume building systems, particularly where heavy component systems and a high capital investment are required.) European ventures have also been widely fostered by political-economic attitudes which encourage effective pre-planning, national performance codes, standardization, market continuity and the rational use of land (Platts, 1968b).
Canadian interest in European industrialized building, and the upsurge in multi-family dwellings in Canada, resulted in a thorough investigation of a number of building systems in Northern European countries where Canadian building conditions are most nearly approximated. The study of field and factory operations carried out by the Division of Building Research, NRC, in a 12-month period during 1966–67, reviewed several systems in depth plus several in less detail, with the objective of assessing the potentials and problems from the Canadian viewpoint (Platts, 1968c).

The largest building contractors in Europe are now heavily committed to systems building using central plants to form the components which are then shipped to the site for erection, a process which is, in effect, an extension of the plant assembly line (Platts, 1968a). Large-panel concrete systems include, in precast form, all crosswalls and gables, floors, elevator shafts, stairs, ducts and sometimes unit bathrooms and partial kitchens, and even precast foundations and basements.

Interiors and services are now frequently advanced subsystems including precise light partitions, doors, cabinetry, trim and closet walls, prefinished in vinyl film or baked enamels, and unit cores (Platts, 1968a). Most often, the producer of the main structural system purchases the interior system desired from a variety offered on the open market; such interior systems are suitable for use within steel frame systems as well. It may also be noted that the technical soundness of Scandinavian systems surpasses most Canadian apartment construction.

The successful total systems builders are most often large heavy engineering contractors with top level management, planning and technical
forces, and adequate capital; seldom are materials groups involved. Two other unrelated features are worth noting. First, low-rise housing developments are becoming increasingly common in Scandinavia despite increasing urban pressures (Platts, 1968c). Second, wood systems have been used successfully throughout interiors of multi-family housing blocks, and prefinished panels of wood frame or other light construction are common in exterior walls.

Concrete Building Systems in Canada

The relevance of Northern European systems to Canada depends on their adaptability to this country. Their introduction to Canada has already begun, but their success is yet to be proven. The prime target of these systems is at present the apartment market in the Toronto area. Should they prove successful there, expansion to other high density population centres can be anticipated. A brief outline of their nature and progress follows.

Jespersen-Kay Systems Limited (a Canadian company) holds exclusive rights to the Jespersen building system for Canada, the U.S.A., the Bahamas and the Caribbean countries (Escott, 1969). This system, of Danish origin, has been successfully used in England, Sweden, Denmark and Israel. The first factory for the production of precast concrete panels using the Jespersen method was completed just northeast of Toronto in December, 1969 (Financial Post, 1970b) and, by agreement, a second plant will be built somewhere in Canada in the near future. The shipping radius from the plant is about 50 miles and the company is investigating portable plants (Canadian Builder, 1969d). The computer-regulated production equipment has a capacity of about 2,500 living units annually, including
both high and low forms of multiple housing (Escott, 1969). The first commercial project to be undertaken is a 184-suite apartment in Toronto.

Modular Precast Concrete Structures Limited has also constructed a factory for the production of precast concrete panels in the Toronto area (Canadian Builder, 1969d). The factory has an initial capacity of 1,000 units per year and is to be doubled in size in 1971. According to Hanson (1969), this company is jointly owned by five of Canada's major development companies (presently responsible for a large percentage of the higher-priced housing developments in Toronto) and Wates Limited of London, England which has over 25 years' experience in precast concrete system building methods. He also indicated that the Wates System is used for both low- and high-rise forms of multiple housing. Modular Precast will produce both for open market operations and the consortium which was formed as assurance of a steady market.

Bramalea Consolidated Developments Limited also has plans to build a factory for the production of precast concrete panels in the Toronto area, subject to the successful acceptance of an 89-unit apartment block at Bramalea, Ontario (Financial Post, 1970b). The Swedish Skarne System is the one under consideration. As a result of constant evolution, the Skarne System now comprises five different element methods (Smith, H. D., 1969). Both central and portable factories are used to produce the concrete panels. This system can also produce both low- and high-rise multiple dwellings.

A fourth system, the No-Fines Concrete System, has been promoted among members of the Canadian building industry, but has not yet been employed in other than pilot projects (Giddens, 1969). Unlike the above
methods, the No-Fines System uses on-site production of the structural shell with a high degree of prefabrication of internal components. It has been claimed that this method has comprised about 50 per cent of the entire industrialized housing programs in the United Kingdom (Giddens, 1969). It is also suitable for low- and high-rise developments.

As noted, another entry into systems building using precast concrete is Polymer, a Canadian petrochemical company which has purchased exclusive Canadian rights to the Uniment system of Stressed Structures, a large U.S. builder (Financial Post, 1970c). This system boasts strong prestressed (stated as "chemically" prestressed) concrete panels which can be as thin as two inches for walls, ceilings or floors, and is suitable for a wide range of single- and multi-family dwellings.

As far as the forest industries are concerned, the significance of these concrete panel building systems entering Canada lies primarily in the area of low-rise multiple dwellings. That industrialized building is here to stay is an accepted fact. That the above concrete systems are suitable for low-rise housing has been proven over many years in Europe. With claims of cost savings ranging from seven to 15 per cent over conventional methods, they appear to be quite competitive. Perhaps there is a question of consumer acceptance of standardized repetitive dwellings. In view of the present monotonous appearance of many of our suburbs, and the similarity of many box-like apartment buildings erected by conventional methods, any question of consumer acceptance on the basis of appearance is probably more academic than real. With greater architectural input and high volume production, the appearance of systems-built structures will probably not hinder their acceptance.
Concrete and other systems may only enter Canada gradually, but their acceptance could provide strong competition for wood frame systems in low-rise multi-family dwellings. With the present predominating position of wood frame construction in these units, the loss of some markets to concrete systems may be anticipated. However, this would still appear to lie in the distant future.

There have been few instances where concrete systems have been used for the production of single-family dwellings. One is the Concrete House Project developed by the Victorian Housing Commission in Australia (Howell, 1966). When this project first began, the output was primarily detached houses which were successfully produced, but later production swung toward multi-family dwellings. According to Matthews (1966), concrete is neither the best nor most economical structural material in single and two-storey dwellings. He contends that the advantage of concrete are most promising for multi-storey construction where apartments, schools, and hospitals present the best opportunities for industrialization. Even in Scandinavian countries, where precast concrete systems are prolific, various types of wood frame prefabrication systems are common for single-family houses. It would thus appear that wood frame construction in single-family houses will not be threatened by the advent of concrete panel systems to Canada.

Metal, Plastic, and Structural Clay Systems

Industrialized building systems using basic materials other than concrete (and wood) have also been developed in Europe as well as elsewhere, but have yet to achieve widespread use. Structural steel has not
been as successful in systems building as many of its advocates think it should have been. This is largely because it is purely a structural material unable to perform other necessary functions, and is still confronted with problems of corrosion and fire (McMeekin, 1966). Systems which have been developed to date use steel as a structural framework onto which lightweight panels of wood, plastic, or lightweight concrete are hung. Such systems still retain considerable complexity and require on-site construction of fire-protective and aesthetic coverings. One such system, known as the "Trusteel System," has reportedly been used in the U.K. in the construction of one and two-storey houses on a continual basis since 1945, and has proven competitive with traditional building methods (Hill, A. W., 1966). According to the same author, a second lightweight rigid steel frame system has also been used there to some extent. It may be noted that these were developed in the absence of wood frame housing in the U.K., where the latter has recently been successfully introduced. Whether these steel systems would be competitive in Canada, and whether they would meet building code requirements, is perhaps questionable, since no commercial steel systems for houses have yet entered this country.

Although plastics have been employed to some extent in European systems, they have normally been restricted to claddings and partitions. For example, Platts (1968b) has reported the use of load bearing exterior wall assemblies consisting of a moulded fibreglass plastic exterior on lightweight concrete in a 21-storey apartment block in England. McMeekin (1966) has expressed optimism over the use of plastics for claddings and
partitions but is doubtful of their use in load bearing capacities in the near future. Nevertheless, it has already been noted that bathroom core units using glass fibre reinforced plastics are now commercially available in North America.

Systems of industrialized building methods using structural ceramics (brick and tile) have been slow to develop. Bradshaw (1966) has reported the development of over 10 such systems using a variety of basic clay units, including solid and perforated bricks, and hollow blocks. These developments may be divided into two groups to include non-loadbearing brick veneer panels, and systems involving clay units faced with mortar, mosaic, or cast within in situ concrete.

In the first category, a Swedish system for housing of up to three storeys has been developed using sandwich panel construction composed of external facing brick separated from an inner partition block by 4-inch rock wool insulation. Prefabricated brick panels have also been developed in Holland, Germany, Switzerland, U.S.A., Denmark and Great Britain (Bradshaw, 1966).

The second group includes load bearing walls and floors. Several systems, primarily from France, were described by Bradshaw, all of which are more complex than precast concrete panels and often include a concrete surround to hold the clay blocks in place. It has been reported recently that a pilot plant in Canada is now producing brick panels (Globe and Mail, 1970b). The commercial development of such panels will probably help masonry maintain its present position in Canadian housing, but sufficient industrialization to result in replacement of wood frame construction is highly unlikely.
The Roles of Competing Materials

It is apparent from the brief descriptions of building systems above that a wide variety has been developed using a number of basic materials. It is interesting to note the types of basic materials used in projects accepted in the "Operations Breakthrough" housing program in the U.S.A. Timmins (1970) has indicated that they are as follows:

- Concrete 49 per cent
- Wood 26 per cent
- Metals 15 per cent
- Plastics 10 per cent

Although these figures include all forms of dwellings, the high proportion of metals and plastics systems represent significant developments in the use of these materials which have up to now been used sparingly in residential construction.

Silber (1966), in forecasting the use of materials in British housing, predicted that wood frame construction would predominate in low-rise housing, brickwork for apartments of four to 10 storeys, and concrete and steel for taller buildings. It is interesting that masonry construction has been traditionally used in low-rise housing in England, but that the recent introduction of Canadian wood frame house-building techniques to that country has been quite successful.

The implications of the above observations of present and potential developments in industrialized building is that within the foreseeable future, wood frame structures will continue to dominate for single-family and low-rise multi-family dwellings. Concrete systems will predominate in multi-family structures over three storeys. Masonry construction will
probably retain a minor role in single-family, and low- and medium-height multi-family dwellings. Metal building systems will probably enter both low- and high-rise housing markets to a limited extent, depending on their ability to reduce costs relative to other materials groups. Over the longer term it may be anticipated that wood frame systems will meet their strongest competition from precast concrete systems in low-rise multi-family dwellings.
CONCLUSIONS: IMPLICATIONS FOR THE FOREST INDUSTRIES

A number of implications can be drawn from developments in residential construction. Although a scarcity of data precludes making an accurate quantitative appraisal of past and possible future replacement of wood by substitute materials in housing, some interesting observations can be made on this whole question.

Trends in dwelling types, particularly towards apartment construction and away from single-family houses are a major cause of the loss of markets for wood products in residential construction. Using available data, it is only possible to make a rough estimate of the impact these trends have had on wood consumption in Canada. Such an estimate has been made using the data on dwelling unit completions from Table 5 and the wood consumption data from Table 10.

Consumption data for 1962 for two separate categories of dwelling units are shown in Table 10: (a) one and two family units; and (b) multi-family units. The difference between these two figures represents the decrease in wood consumption which occurs when a dwelling unit is realized as a multi-family unit rather than a one or two-family unit (i.e., a decrease in consumption of 6,690 bd. ft. of lumber, 1,210 sq. ft. of plywood and veneer, and 970 sq. ft. of building board). Applying these figures to the dwelling unit completions data in Table 5, the loss in consumption of wood products between 1960 and 1969 due to the trend towards apartment construction, has been determined. The accumulated loss of wood markets over this period has been estimated at 1,355
million bd. ft. of lumber, 245,075,000 sq. ft. of plywood and veneer, and 151,068,000 sq. ft. of building board. If one were to use a base year prior to 1960, the losses estimated would be even greater.

Using the same consumption data and an estimate of new residential construction to 1974, a prediction of the loss of wood markets due to the trend toward apartments in Canada can be made for the period 1969-74. Under 'Projections of Housing Demand', it was indicated that the federal government is committed to one million new dwelling units for the five-year period to 1974, or 200,000 units per year. Using this figure, and a projected increase in the relative rate of construction of multi-family units (from 54 per cent of total completions in 1970 to 62 per cent in 1974), an estimate of the effects of these trends on wood consumption has been made.

Still considering 1960 as the base year, the loss of markets for wood products over the 1969-74 period due to housing trends is estimated as follows: 1,947 million bd. ft. of lumber, 352,110,000 sq. ft. of plywood and veneer, and 282,270,000 sq. ft. of building board.

Similar losses can be expected to continue to about 1980 when the trend to apartment construction will probably level off. There is some indication that the loss of wood markets due to these trends may not be as great as would be anticipated from using past data for future predictions. There is growing evidence that in Europe, the U.S.A., and more recently in Canada, low-rise multiple dwellings are becoming popular. If these dwellings make up an increasing share of total multiple dwellings in the future (as appears probable), the impact on wood consumption will
not be as great as could be expected should high-rise construction main-
tain or increase its relative importance.

Although it has been stated that trends in types of dwellings constructed are basically autonomously determined, there are two possible ways in which the forest industries can influence these trends. The first is to enter the residential construction field through vertical integra-
tion, as a large number of forest product companies have done recently in the U.S.A. Although this would ensure the construction of dwellings which consume large volumes of wood products, it is doubtful that the forest indus-
tries could control a sufficiently large portion of the residential con-
struction industry to significantly alter the trend in dwelling types.

The second way in which the forest industries could influence the trend in dwelling types is through a program of active promotion of wood-
based building systems. This could involve close co-operation between the wood industries and builders in an effort to improve the quality of wood frame structures, and reduce the cost of wood-based housing systems. By helping the builder reduce his costs, the forest industries will be able to ensure markets for their products. This could conceivably in-
volve the production of better manufactured products by the woods indus-
tries, and perhaps greater participation in cut-to-size operations. With the growing emphasis on industrialized building, the forest industries should research the needs of factory-built housing with respect to mater-
ials requirements, and be prepared to alter their manufacturing facilities to accommodate the changes evolving in building methods.

Direct replacement of wood by substitute materials has also had a significant impact on the consumption of wood by the residential construc-
tion industry. However, a quantitative estimate of the extent of such replacement is virtually impossible due to the lack of appropriate data.

On the basis of the foregoing discussion on substitution, there is evidence that the substitution of wood by other materials will continue at a rate equal to that in the past or at an even higher rate. Such factors as the increasing price of wood products relative to competing materials, higher R & D expenditures in competing industries, and the movement toward performance criteria in building codes, point to the development and acceptance of substitutes for wood in construction.

In order to combat the increasing competition from substitute materials, the forest products industries will have to increase their R & D effort in three directions. First, it is necessary to continuously develop new production techniques and equipment in order to increase productivity and reduce manufacturing costs, with the aim of keeping wood products prices competitive. Second, there must be a greater effort at developing new products and improving the properties of the basic wood material. For example, if satisfactory solutions could be found for two problem areas of wood, its combustibility and dimensional instability, the markets for wood products would be vastly expanded. The third area of research, market research, is one which is becoming essential due to the increasing competitiveness of the construction market.

The organization of forest products research in Canada is worthy of comment. The federal government and industry have been primary responsible for advances in wood products technology in the past, yet a major beneficiary has been the forest owners, i.e., the provincial publics. The
significance of the forestry sector to such provinces as Quebec, Ontario, and particularly British Columbia, warrants much greater participation by them in forest products research. This could be realized through greater support of university research programs, and through co-operative federal-provincial programs. In addition, a more co-ordinated effort in wood products research is needed to consolidate and plan research activities at the federal, provincial, industry, and university levels.

The relative size of the domestic residential construction market adds to the probable impact that increasing substitution will have on the Canadian forest industries. It is mandatory for the forest industries to search for more diverse markets and expand exports to many countries throughout the world. Export markets can offer considerable scope for the Canadian softwood lumber and plywood industries. With world demand for wood products forecast to increase substantially in the future, and the USSR and Canada holding the only major reserves of softwood timber, the future prospects of trade expansion appear to be good. The success of Canadian trade missions to Europe for the promotion of wood frame construction has already begun to materialize in the form of increased lumber and plywood exports to the U.K., the Netherlands, and other West European countries. Further efforts in this direction should be given major emphasis by the forest industries.

For long range planning purposes, it is necessary to be aware of changing markets and their nature. A decreasing consumption of wood products in residential construction, due to increasing substitution of competing materials, should not have a devastating effect on the forest
industries if it is anticipated beforehand. Increased effort in both product and market research can effectively curtail or slow down such trends, and effective planning can result in the development of alternative markets for wood based products.
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