ABSTRACT

A DYNAMIC SIMULATION OF WOOD
REQUIREMENTS FOR SINGLE-FAMILY HOMES
IN THE NORTH CENTRAL REGION

by Paul Vernon Ellefson

Most past appraisals of wood use have had two elements in common. First, they were nationwide in scope, and, second, they were based on static economic models which do not explicitly consider the determinants of past wood use. This study presents a dynamic model of wood use in single-family homes located in the North Central Region of the United States.

The model is composed of five sectors. The following sectors contain the basic determinants of wood use: (1) consumer, (2) builder, (3) technical, and (4) institutional. Elements in these sectors force change to occur in the model's fifth sector, namely, the structural sector.

The structural sector is composed of elements which reflect the physical make-up of the house. They are: (1) style, as defined by number of stories, (2) size, as defined by floor area, (3) technical design, as defined by engineering considerations

peculiar to house construction, and (4) material blend, as defined by the mixture of materials used in the house.

Data portraying lumber use per house were obtained from a 1968 sample of 100 homes in the North Central Region. The mean lumber volume used per sample house was 17,614 board feet. Plywood use per sample house was 6,890 square feet.

Single and multiple regression techniques are used to generate the model's various endogenous and exogenous variables.

Predictions of wood use to the year 1985 are provided for seven wood products: lumber, plywood, particleboard, hardboard, composition board, wood lath, and shakes and shingles. If past trends in material blend and technical design continue, total lumber and plywood use per house is expected to rise to 19,555 board feet and 7,252 square feet, respectively, by 1985.

Possible future trends in wood use per house are simulated based on differing assumptions about: (1) material blend, (2) technical design, and (3) structural size. A simulated material blend with a 25 percent and a 100 percent decline by 1985 in the use of lumber as a floor framing material shows that total lumber use per house in that year would be 18,318 board feet and 15,103 board feet, respectively. These two simulated levels of wood use are 1,237 board feet and 4,452 board feet less, respectively, than that expected in the same year if technical design and material blend conditions continue unchanged to 1985.

Removal of precut wall stud material at rates of 25 percent and 100 percent implies that total lumber volume will be 18,795 board feet and 16,527 board feet, respectively, in 1985.

Simulated trends in wood use stemming from a change in the structure's technical design are examined. Of major concern is the replacement of a conventional roof framing system with a trussed rafter system. If it is assumed that all 1985 homes will be constructed with a truss system, the total lumber volume per house will be 17,809 board feet in that year. This is roughly 1,746 board feet less than expected if past changes in technical design and material blend continue to 1985.

Simulated trends in wood use resulting from alternative rates of change in floor area are also examined. If floor area rises at rates of 22 and 47 square feet per year, the lumber volume expected per house in 1985 is 17,654 board feet and 21,456 board feet, respectively. The former volume is 9.75 percent less and the latter volume 9.75 percent more than that volume expected if the model's estimated floor area equation is used, and if trends continue in the technical design and material blend of the house.

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Forestry

1970

ACKNOWLEDGEMENTS

The author gratefully acknowledges the advice and encouragement of Dr. Robert S. Manthy, and the financial support of the United States Forest Service. Gratitude is also expressed to his parents without whose initial concern this educational endeavor might never have come true.

Most of all, the author wishes to express his gratitude to his wife, Peggy, for her constant encouragement and sacrifices which made the graduate study and thesis possible.

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INTRODUCTION

The ability of the Nation's timber reserves to supply future wood needs has been the subject of great interest to foresters since the turn of the century. As early as 1920, the U.S. Forest Service had undertaken reviews of the adequacy of existing forest inventories for meeting the demands that might be made upon them at some future date. Such appraisals normally have been national in scope and were structured in terms of independent static models of timber supply and timber demand. The majority of these studies assumed a continuation of past trends in the economic, social, and technological variables that determine wood use and availability.

Critics of past timber supply and demand studies have raised serious doubts as to the usefulness of static national models of the timber economy for the formulation of appropriate forest policy and programs (Vaux and Zivnuska, 1952; Zivnuska, 1964; Manthy, 1966; and Worrell, 1966). Suggestions to overcome problems inherent in national data aggregation and static economic models include: (1) use of regional analysis (Worrell, 1966), (2) combining independent supply and demand models (Zivnuska, 1964), and (3) construction of dynamic models of regional timber economies (Manthy, 1966).

This study is based on the assumption that regional models of the timber economy, which consider the dynamics of economic, social, and technological variables, will provide more accurate information to forest policy and program planners than conventional studies of timber supply and demand. It provides a beginning toward the development of comprehensive models of a regional timber market via the development of a dynamic model of potential wood use in single-family housing units in the North Central region. Estimates of the volume of major wood products likely to be consumed in the average single-family dwelling unit in the region are provided through 1985 under alternative assumptions about the dynamic factors that determine wood use in housing.

OBJECTIVES

The objectives of this study are centered around development of a dynamic model of regional wood use. Specifically, the study is designed so as to achieve the following objectives:

1. Develop a dynamic regional model capable of generating the quantity of various wood products required in the construction of new single-family housing units located in the North Central region of the United States.

2. Predict to the year 1985 the quantity of various wood products required of new single-family housing units located in the North Central region of the United States.

SCOPE

Three areas of interest will be of major concern during the course of the study. First, the wood requirements of the residential construction industry will receive major attention. Of specific interest will be the use of wood products in single-family homes. A constraint of this sort is imposed by reason of: (1) the need to condense the broad problem of defining wood requirements into a manageable and researchable form from which testable hypotheses can be drawn, and (2) the relative importance of residential construction as a demand source for wood. Lumber used in the construction of one and two-family dwelling units accounted for more than 28 percent or 11.8 billion board feet of the total amount of such material consumed in the United States in 1962. Of the total plywood and veneer consumed, that used in one and two-family units accounted for 26 percent or 3.2 billion square feet of the total (U.S. Forest Service, 1965). The construction industry is indeed a major consumer of wood products.

Second, the study will concern itself with houses financed in all manners, i.e., FHA insured, VA guaranteed, conventional mortgage, and cash. Past studies of wood use have emphasized FHA insured homes. Such homes have accounted for less than

25 percent of all homes constructed since 1963. In contrast, homes financed via conventional mortgages have accounted for a minimum of 57 percent of all forms of financing since 1963 (U.S. Department of Commerce, 1969). Further, FHA insured and conventional mortgage homes differ greatly in terms of size. During the years 1963 to 1968, the floor area of FHA insured homes averaged nearly 360 square feet less than those conventionally mortgaged. In 1967 and 1968 the difference was especially dramatic, i.e., 480 square feet and 455 square feet, respectively (U.S. Department of Commerce, 1969). These differences are especially relevant since house size can be an important reflector of wood use.

Third, the study will orient itself to regional wood requirements. The region of concern will be the North Central region, a region officially defined by the U.S. Department of Commerce (U.S. Department of Commerce, 1969). The twelve states included in the region are as follows: North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Indiana, Michigan and Ohio.

The study will deal with the following wood products as they are used in single-family homes:

lumber
plywood
particleboard
hardboard
composition board
wood lath
shakes and shingles

RELATED STUDIES

Past studies of wood use per house have been far from abundant. Those which have been undertaken are generally either of two types: (1) a survey study which provides wood use information for a current time period; or (2) a study which attempts to explain the system by which wood use per unit is determined in an attempt to make predictions of future wood use. Most studies have been of the former nature.

The Bureau of Labor Statistics was a pioneering agency in studying material used in new housing. Its earliest surveys described the physical features of housing in the 1929-38 period (Bureau of Labor Statistics, 1958). Thereafter, the Bureau's Division of Construction Statistics conducted surveys in 1954, 1955, 1956, and 1962 (Bureau of Labor Statistics, 1964). The major emphasis of these surveys was to define the proportion of new homes having certain physical features. For example, data was gathered on the proportion of homes constructed by number of stories, type of basement, exterior and interior wall construction, and window frame material. Floor area was also determined. Unfortunately, the scope of the study did not include estimates of wood volume in the various house systems. No attempts were made at predicting future house characteristics.

One of the first regional studies designed to specify the wood use system and to make estimates of future wood use per unit was undertaken by H. J. Vaux in 1946 (Vaux, 1950). Although the study's primary intent was to define California's aggregate demand for lumber in housing, this broad purpose entailed a rather thorough analysis of wood use per unit. Based on 1946 field survey data, wood use was regressed against the floor area of various dwelling types. The variables hypothesized as influencing wood use per unit included: type of dwelling unit (single or multiple), geographic location within the region, degree of urbanization, and structure size. It is worthy of note that the volume of lumber used per single-family dwelling was not sensitive to location within the region. Three basic estimating equations were defined: (1) lumber use in framing material, (2) lumber use in siding, and (3) lumber use in interior finish and trim. The lone independent variable in these equations was floor area. By estimating future floor area, future wood use per unit was defined. This was in turn combined with expected rates of new dwelling establishment to provide an estimate of future aggregate demand for lumber.

The Housing and Home Finance Agency (Housing and Home Finance Agency, 1953) studied national and regional characteristics of one-family FHA insured homes in 1950. Total lumber use per house was estimated at 9,318 board feet. This represents dimension and board lumber, finish flooring, and siding. Plywood of all thicknesses totaled 139 square feet per unit. Other quantity information provided by the study included the number of windows per house by type of material, the face area of steel and wood kitchen cabinets, and the number of doors per unit.

A major review of nationwide wood use to the year 2000 was completed by the Stanford Research Institute in 1952 (Stanford Research Institute, 1952). Again, wood use per house was only one phase of a broad study aimed at estimating aggregate wood volume in the residential construction industry. Wood use per unit was assumed to be a function of dwelling unit size (floor space and ceiling height), architecture employed, type of structure (single and multi-family), the number of stories, relative prices, technical characteristics, and consumer acceptance. Not all of these factors were explicitly considered in the study's model. The basic procedure was to first specify wood use in homes constructed in 1920, 1930, 1940 and 1950. Using 1920 as a base year, indexes of wood use for all remaining years were calculated. Trends in these indexes were apparently extrapolated into the future. They formed the base from which estimates of future wood use were inferred. This procedure was accomplished for each component within the house. The study estimates lumber use per house in 1970 to be 9, 123 board feet, in the year 1975 to be 8, 706 board feet, and in the year 2000 to be 8, 267 board feet per house.

Wood use in homes located in the New England region of the United States was the subject of a 1954 study (Zaremba, 1963). The primary intent of this study was one of relating various consumer oriented determinants to wood use in housing. The relationship between income and wood use was of special interest. A survey of consumers in two New England locations indicates that rising family incomes are associated with increases in wood use but at a declining rate. Wood use was very responsive to increases in income amongst families with incomes less than $10, 000 per year. Beyond this income, the rate of increase in wood use deminished rapidly. Presumably, the more gradual rise in wood use at higher incomes suggests that the consumer's desire for those items which reflect wood use (house size, type of material, etc.) have been satisfied, and that additional income is allocated to household operations or non-housing expenditures. The study points out that the wood use-income relationship is quite stable over time. In fact, families with identical nominal incomes in 1940 and 1954 purchased homes with the same quantity of wood. This implies that the <u>cetris-paribus</u> assumption inherent in the relationship is fairly realistic. Further, it lends weight to the use of cross-sectional data for making predictions of future wood use.

The United Nations published a study of European wood use per house in 1957 (United Nations, 1957). Its primary intent was to review the status of knowledge with regard to this subject. The only American study referred to is that completed by the Stanford Research Institute (Stanford Research Institute, 1952).

One of the most thorough surveys of wood use in FHA insured homes was undertaken in 1959 and 1962 by the U.S. Forest Service (Phelps, 1966). The surveys were regional in nature and provided quantity estimates of various wood products used in single-family houses. Wood products included in the study were lumber, plywood, hardboard, insulation board, particle board, and shakes and shingles. Each of these products were categorized by major end uses such as framing, sheathing, flooring, and by house systems such as walls, roofs, foundations and millwork. The study's nature was strictly one of a survey. No attempt was made to determine why wood use existed at various levels, nor what the future levels of consumption might be.

A study of aggregate wood use to the year 2000 was undertaken by the U.S. Forest Service in 1965 (U.S. Forest Service, 1965). One aspect of this study revolved around wood use per house. The study anticipates a decline in lumber required of one-and-two family homes in the period 1962 to 2000. Specifically, the predicted use of lumber per unit in 1970 is set at 10,740 board feet while the level by the year 2000 is posted at 9,950 board feet. Part of this decline is assumed to stem from the displacement of lumber by plywood and building boards. Plywood use was projected at 3,970 square feet per house in 1970 and at 2,000 square feet in the year 2000. The prediction method is not presented in the study report.

STRUCTURE OF THE SYSTEM

The model of wood requirements for residential construction is modular in nature. It is composed of various sectors each of which encompasses certain variables and relationships that are related to the same general topic. Interconnections and feedbacks are minimal. Thus, individual sectors can be removed, studied, and expanded upon without making major changes in the entire model. The modular nature also reduces the overall complexity of the system, thus making it more easily understood.

SECTORS OF THE MODEL

Variations in the amount of wood material required of a new single-family house stem from a host of economic, social, technical, and institution influences. As a means of furthering the understanding of this complex system and to facilitate the ease with which it can be analyzed, the sources of variation are grouped into those which are the primary or basic sources of variation and those upon which the basic sources act. This two stage approach is basic to the model.

The basic sources of variation make up four of the model's five sectors. They are: (1) the consumer sector, (2) the builder or producer sector, (3) the technical sector, and (4) the institutional sector. Figure 1 illustrates these four sectors. Determinants located in these sectors ultimately control the amount of wood material that will be used in the new single-family house. Their role is one of forcing change to occur in a group of intermediate determinants here defined as the structural sector of the model.

The structural sector of the model encompasses those easily identified physical features of a house upon which the consumer, producer, technical, and institutional determinants act. This sector acts as a converter, in that it transforms changes in abstract variables such as income and cost to changes in the amount of wood material that is used in the new house.

Structural Sector

The structural sector of the model is divided into four elements, a change in any of which will cause a change in the amount of wood material used in a new house. These elements are:

1. Structural style
2. Structural size
3. Technical design
4. Material blend

Structural Style--The structural style of the house and its influence on wood volume is best understood if it is further divided

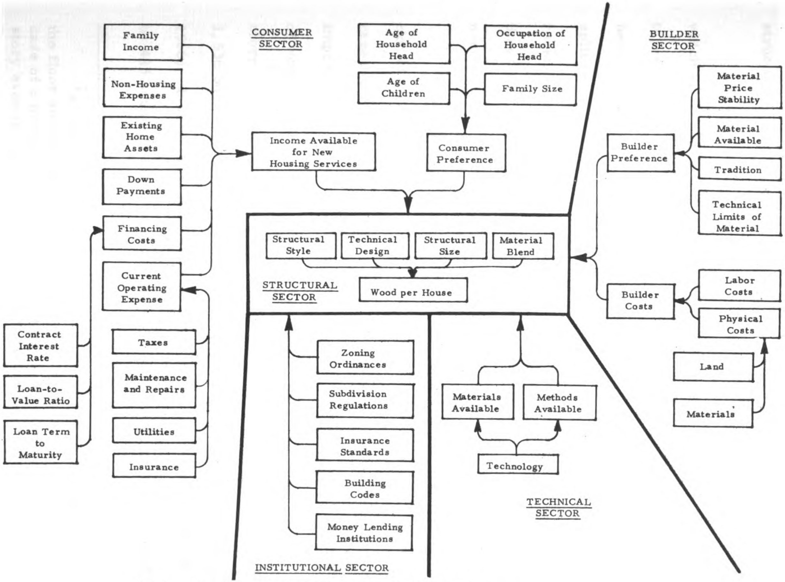

Figure 1. Flow chart of system defining wood use in single-family homes.

into two areas. These areas are: (1) the architectural type of structure, and (2) the architectural design of the structure.

The architectural type is defined by the number of stories which are found in the house. Although as many as eight different types can be identified (Figure 2), only three are considered as being important in explaining wood use: one story, two story, and split level.[1] These three styles have dominated the market in recent years (U.S. Department of Commerce, 1969). Further, they form strata which show the greatest differences in wood volume used per unit (Phelps, 1966).

The quantity of various wood products used in the construction of a house varies from one architectural type to another. Because of this source of variation in wood use, changes in the relative importance of an architectural type can have an affect on the amount of wood required of the single-family home market. In 1962, two story FHA insured homes in the Lake-Central States region required 1,536 board feet of lumber more than one story homes (Phelps, 1966). In the same year and region, the amount of plywood differed by 483 square feet between the same two architectural types. Wood

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[1]A story is defined as that portion of a building between the floor and the ceiling or roof, or the next floor above in the case of a multistory house. A basement is not counted as a story even if it is finished as a den or recreation room (U.S. Department of Commerce, 1969).

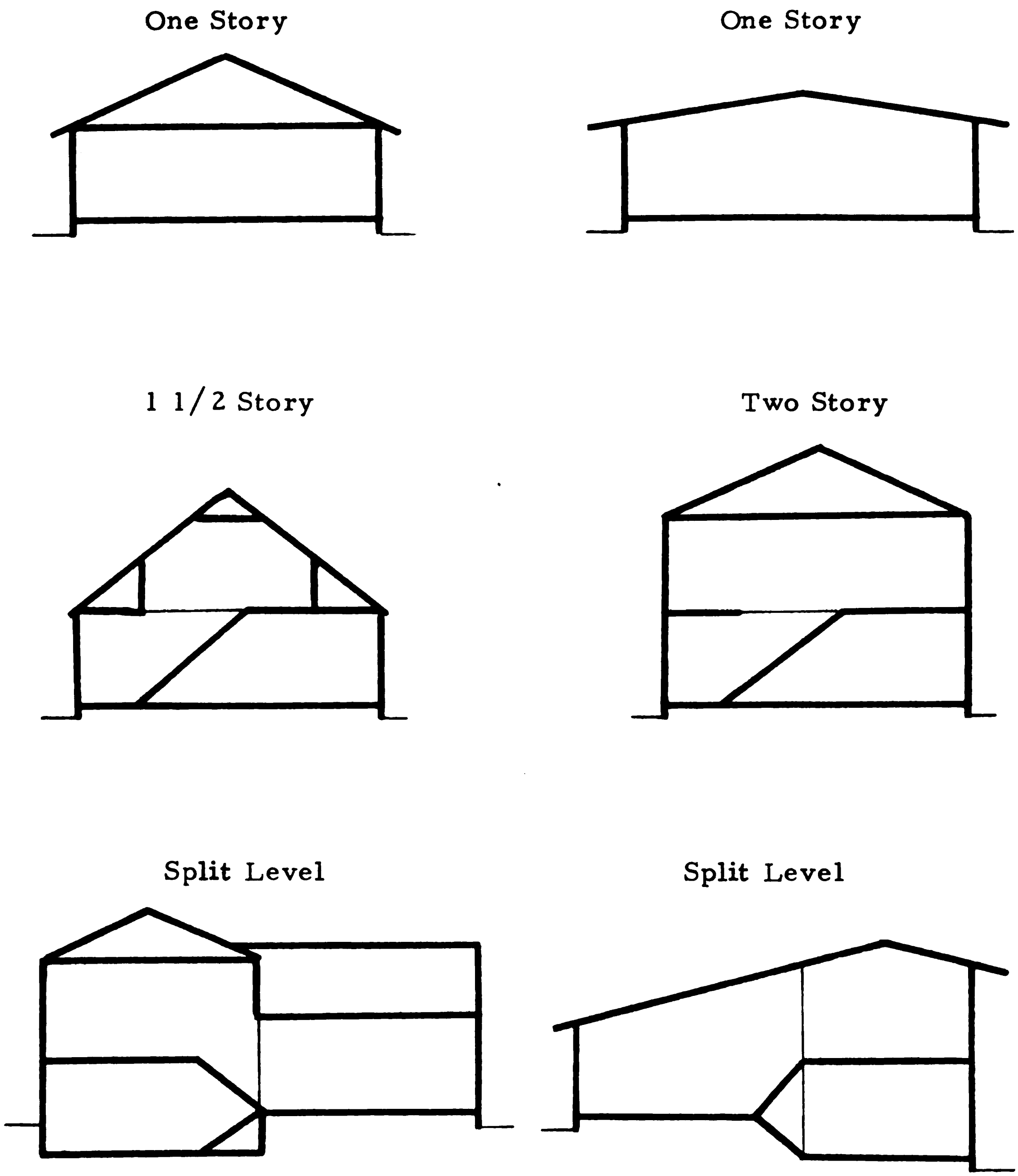

Figure 2. Basic architectural types. (Source: National Lumber Manufacturers Association. The UNICOM method of house construction, design principles. UNICOM Manual No. 1, 122 pp., illus., 1964.)

use per square foot of floor area also varies by architectural type. One story homes required 9.1 board feet of lumber per square foot of floor area, while two story homes required somewhat less, namely, 7.6 board feet. Similar differences exist for plywood, hardboard, and insulation board.

Recent trends in architectural type have been rather remarkable, especially at the regional level. Not only have changes occurred in the proportion of the market commanded by each architectural type, the number of homes of each type has also made some dramatic changes. Regarding the nationwide market mix, (1) there has been a general decline in the percentage of one story homes constructed, a decline which probably begain prior to 1959; (2) a general rise in the proportion of two story homes has occurred; and (3) split level homes have maintained a fairly stable share of the market (Table 1). The Southern region has shown the least change.

The trends in architectural type are most noticeable in the North Central region. Although continuing to maintain its number one position in the market, the percentage of one story homes in the North Central market declined from 65 percent to 48 percent between 1964 and 1968--a drop of seventeen percentage points (Figure 3). Two story homes have more than doubled in importance, rising from 13 percent in 1964 to 30 percent in 1968. Split level homes have occupied 23 to 25 percent of the market since 1964. Their hold on the market has been dropping since 1966. Changes in

Table 1. Single-family house sales, by number of stories, United States and regions, 1964-1968.

Number of Stories and Year of Sale	Percent Distribution by Number of Stories				
	United States	Regions			
		Northeast	North Central	South	West
	Percent				
One Story					
1964	71	39	65	84	81
1965	68	38	59	83	73
1966	65	36	53	83	73
1967	64	28	49	82	73
1968	63	28	48	80	74
Two Story					
1964	17	44	13	10	13
1965	20	44	18	11	18
1966	23	48	22	11	21
1967	23	52	26	11	19
1968	24	55	30	13	19
Split Level					
1964	12	17	23	6	6
1965	13	18	23	6	8
1966	12	16	25	6	7
1967	13	20	24	6	8
1968	12	17	23	7	7

Source: U.S. Department of Commerce, Bureau of the Census. Housing Sales, Sales of New One-Family Homes, Annual Statistics, 1968. Construction Reports-Series C25, 293 pp., illus., 1969.

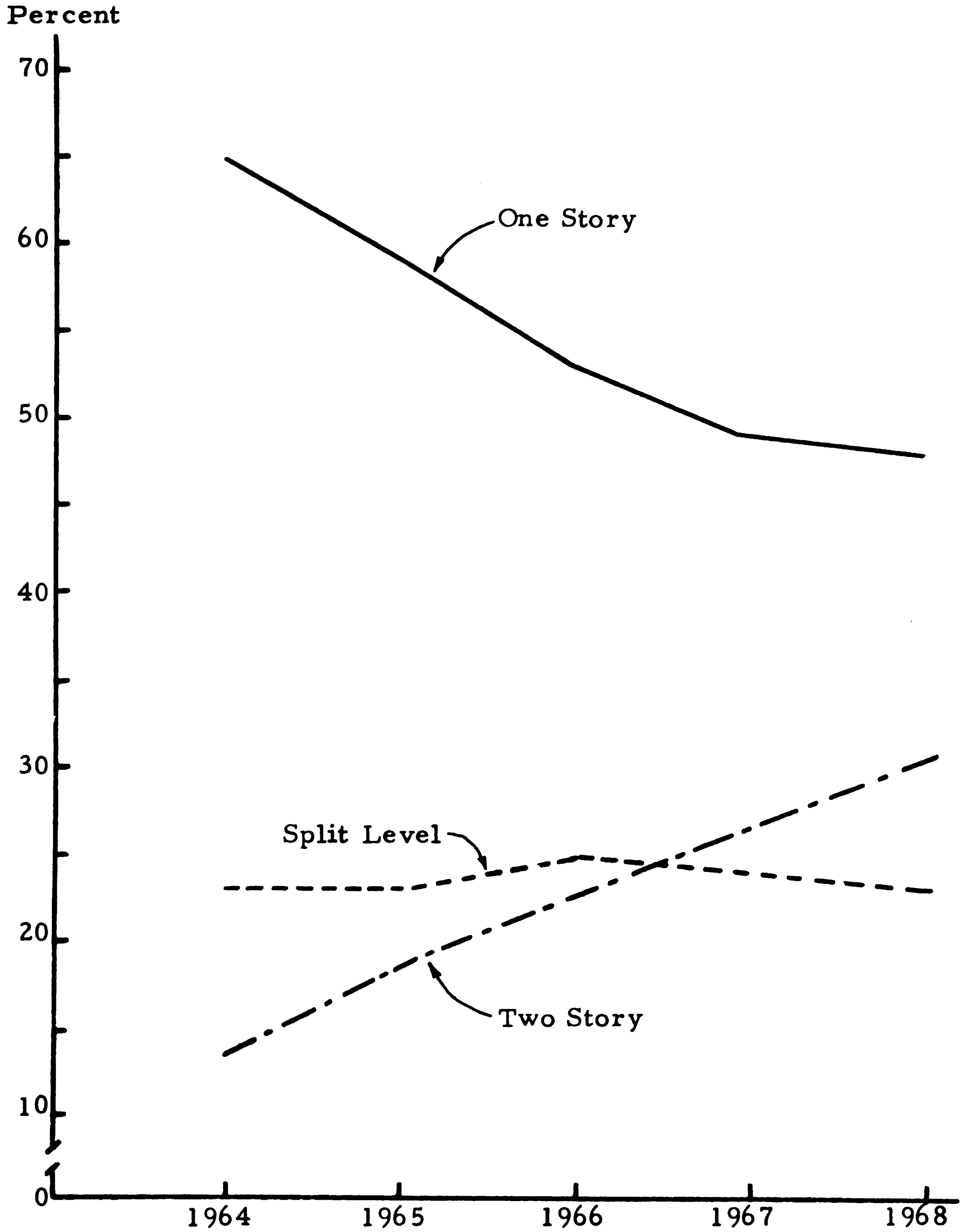

Figure 3. Percent single-family homes, by number of stories, North Central Region, 1964-1968. (Source: U.S. Department of Commerce, Bureau of the Census. Housing sales, Sales of one-family homes, Annual statistics, 1968. Construction Reports-Series C25, 293 pp., illus., 1969.)

the same direction have occurred in terms of the number of houses of various types in the North Central Region (Figure 4).

Similar changes in the importance of various architectural types are evident for FHA insured homes. At the national level, the proportion of one story homes constructed between 1940 and 1950 rose from 67 percent to 86 percent (U.S. Department of Housing and Urban Development, 1967 and Federal Housing Administration, 1968). They occupied 87 percent of the market in 1956. For the same years, two story homes declined in importance from 33 percent to 6 percent. One story homes probably reached their maximum market penetration during the period 1956 to 1959. Since 1959 there has been a continuous downward trend in the percentage of one story FHA homes in the market (Table 2). From a high of 90.8 percent in 1959, one story homes have declined to 82.7 percent in 1967. Although declining, they remain dominant in the market place.

Architectural design is the second element making up the structural style of the house. It is here defined as the artistic and decorative features of a structure which are not closely correlated with the number of stories. The range of designs causing variation in wood use is immense. At one extreme is the pattern used on a particular interior molding and at the other is the type (hip or gable) and pitch of the roof system. Other design features which can influence wood use are: presence of porches and terraces; the style of sash and window units, the wood carving in a main entrance door,

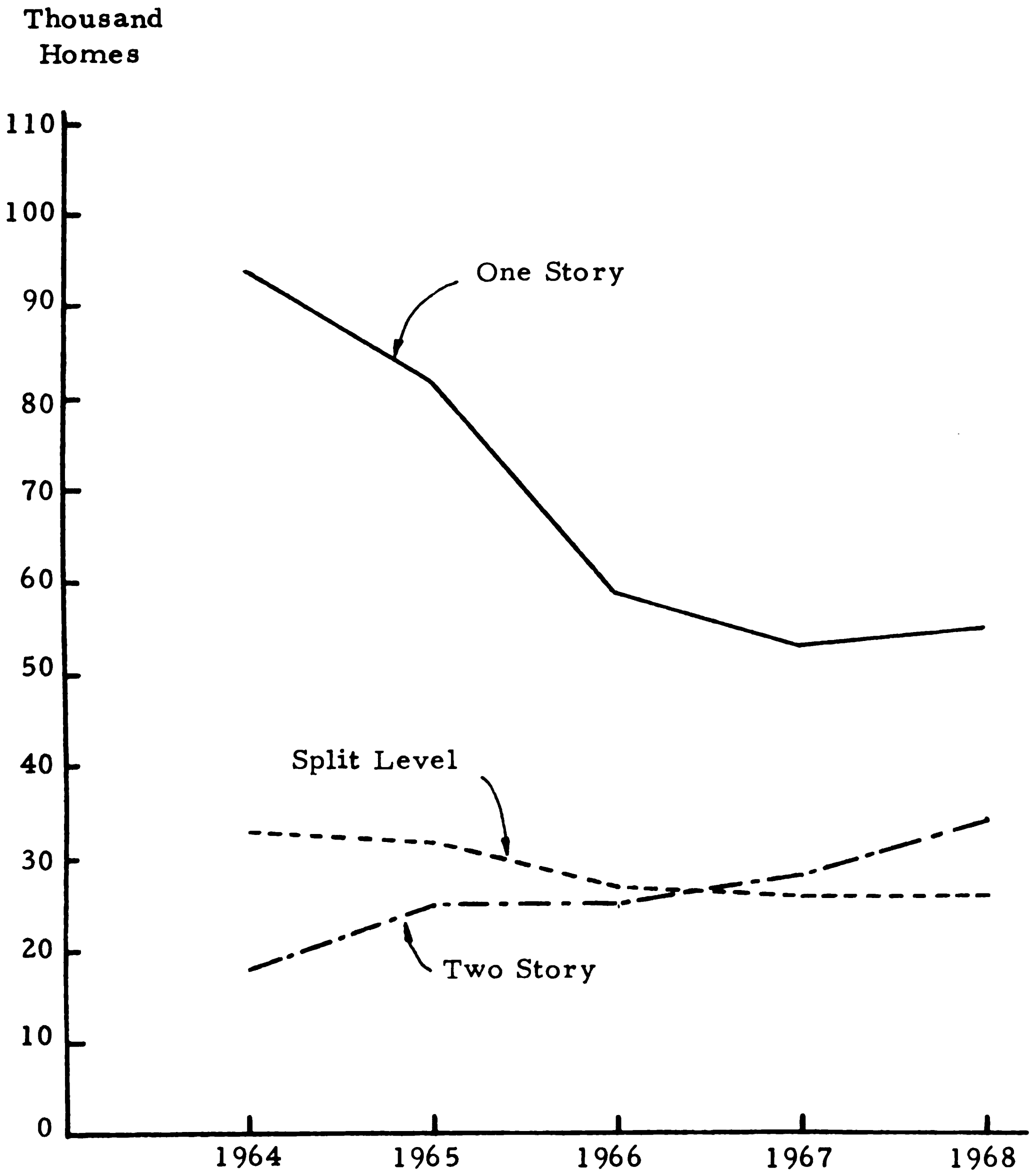

Figure 4. Number of single-family homes, by number of stories, North Central Region, 1964-1968. (Source: U.S. Department of Commerce, Bureau of the Census. Housing sales, Sales of one-family homes, Annual statistics, 1968. Construction Reports-Series C25, 293 pp., illus., 1969.)

Table 2. Percent one-family FHA homes constructed with one story, United States, 1959-1967.

Year	One Story FHA Homes
	Percent
1959	90.8
1960	89.6
1961	89.2
1962	88.2
1963	88.3
1964	85.5
1965	84.2
1966	81.6
1967	82.7

Source: 1959-1966 from U.S. Department of Housing and Urban Development. Statistical Yearbook, 1966, 415 pp., illus., 1967. 1967 from Federal Housing Administration Annual Statistical Summary, 1967. 90 pp., 1968.

the presence of an attached garage or carport; and the design of the kitchen cabinets.

The amount of wood required of a structure will often times vary greatly given different architectural designs. Consider the slope or pitch of a gable type roof system. As the unit rise of the roof increases from three inches to ten inches, the plywood roof sheathing required varies from 1,650 square feet to 2,083 square feet (Table 3). Changes in the unit pitch will also force change in both the volume of rafter material in the roof frame and the wood material required for gable studs.

Structural Size--The amount of wood material required in the construction of a single-family structure is presumed to be a function of the structure's "size." Any change in the "size" of the house will supposedly reflect a change in wood use. Although an extremely obvious relationship, the choice of definition used to describe structure "size" is crucial to predicting wood use. To date, no less than nine definitions of structure size are formally recognized (Building Research Institute, 1962). For purposes of exposing variations in wood use given a change in certain dimensions of the structure, four definitions of size appear useful: (1) the number and lineal dimensions of individual wood items used in the house; (2) total surface area of the sturcture; (3) floor area; and (4) total volume of the structure. Although a potential candidate, total structure volume has not been used previously as a basis from

Table 3. Plywood roof sheathing requirements, by roof pitch.

Unit Rise	Plywood Requirements[a]
Inch	Square Feet
3	1650
4	1688
5	1733
6	1789
7	1853
8	1923
9	2000
10	2083

[a]Plywood required of a house with 1600 square feet of floor area.

Source: Gary Moselle. National Construction Estimator, 1969-70. Los Angeles: Craftsman Book Co. 1969.

which to study variation in wood use per structure and, therefore, will be excused from this discussion.

Ideally, the length, width, height, and number of wood items might be used as the basis for defining structure size. Such dimensions and their changes over time would give an almost exact account of wood use. Unfortunately, such a definition must be discarded since data of this nature are not readily available for analysis. A similar situation forces one to discard total surface area as a definition of structure size. Such a definition implies that as the linear dimensions of the structure change, so would its total surface area and consequently the volume of wood used.

Floor area is the most commonly used definition of structure size. It is in essence a proxy for the length, width, and height measurements of each wood item used in the house. The use of this definition implies that changes in the volume of wood material used will be adequately reflected by changes in floor area. Past studies indicate this assumption to be a valid one (Lundgren and Beazley, 1961 and Vaux, 1950). Further, the inaccuracy found in estimates of wood use based on floor area is thought to be negligible in relation to the savings in cost (Lundgren and Beazley, 1961). Because of the ease with which estimates of floor area can be obtained, and of its accuracy as an estimator of wood volume used, floor area will be used as the definition of the structure size throughout this study.[2]

The use of floor area as a predictor of wood volume in a structure does imply certain problems which must be recognized at the onset. First, floor area does not adequately predict variation in wood volume stemming from changes in the height dimension of the structure. For example, floor area might never detect a change in wood volume stemming from changes in ceiling height nor changes in roof pitch.

Second, changes in wood volume stemming from changes in the number and length of interior partitions might not be satisfactorily reflected by floor area. Identical floor areas can be divided in many ways, the result of which may be a different number of partition

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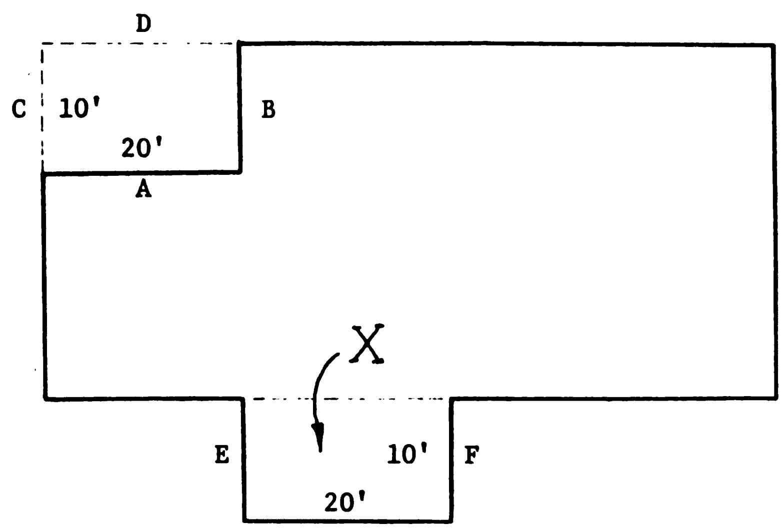
[2]The confusion resulting from the various methods of measuring floor area has compelled the Federal Housing Administration to establish a standard definition. Since 1966, FHA statistics on floor area reflect "improved floor area" defined as:

> Improved floor area: includes all improved areas in a house, such as living room, dining room, or dining area, kitchen, baths, bedrooms, halls, closets, foyers, vestibules, bays, dormers, cantilevered overhang of rooms, family rooms, and improved recreation and attic rooms. Measurements are taken to the outside of exterior walls (Federal Housing Administration, 1966).

The Bureau of the Census, Construction Statistics Division has used a similar definition in gathering statistics on floor area since 1963 (U.S. Department of Commerce, 1969).

walls and total partition length. Changes in wood use due to a trend toward a more open type interior design might be missed completely if floor area is used as the only predictor of wood volume.

A third problem of using floor area as a predictor of wood volume centers around its inability to adequately reflect changes in wood volume resulting from changes in the structure's perimeter. Structures of equal floor area can have quite different perimeters and consequently quite different wood volumes, especially exterior wall volume (Browning, 1961). The plan below illustrates this problem. If exterior wall A and B are replaced by C and D (a gain of



200 square feet) and projection X is omitted, the floor area of the structure will remain the same, yet the wall sections E and F have been deleted. The structure's perimeter has been reduced by 20 lineal feet. Admittedly, the perimeter reduction may force an increase in the amount of interior partitioning required, thus causing little or no change in wood use. Regardless of whether or not a net gain or loss in wood volume occurs, the change will not be reflected by change in floor area.

The quantity of various wood products used in a structure has been shown to vary with changes in floor size. As early as 1946 it was noted that single-family structures located in California required an additional 3.5 thousand board feet of construction lumber for every thousand square foot increase in floor area (Vaux, 1950). Similar relationships were noted between floor area and other wood products, notably, wood siding and interior trim (Vaux, 1950). More recently, a study of wood use per unit in 1962 indicated that approximately nine board feet of lumber was required per square foot of floor area in a one story house located in the Lake-North Central region (Phelps, 1966). Two story homes required considerably less volume per square foot of floor area--7.6 board feet--while split levels required 9.6 board feet per square foot of area in the same year and region.

The trend in floor area has, for the most part, been on the rise in recent years. Consider nation-wide data on FHA insured homes. From a median of 838 square feet in 1950, the floor area of FHA insured homes increased to a high of 1,167 square feet in 1965 (Figure 5). During the years 1957 to 1963, floor area hovered around the 1,100 square foot mark. Since 1965, floor area has declined slightly.

There has been a rather remarkable rise in the median floor area of homes financed in all manners since 1963. At the national level, the median floor area rose from 1,365 square feet of floor area in 1963 to 1,605 square feet of area in 1968 (Figure 6). In the North Central region, floor area rose from 1,250 square feet in 1963 to a high of 1,640 square feet in 1967. A decline is noted between 1967 and 1968.

The floor area of most architectural types has increased in recent years. Between 1959 and 1962, the floor area of one story FHA insured homes located in the Lake-Central region increased approximately 43 square feet (Table 4). The floor area of one-and-a-half and two story FHA insured homes increased 253 square feet during the same period. A rise of 52 square feet is noted for split level homes.

Trends in floor area by type of structure are not readily available for homes financed by means other than FHA insured mortgages. An indication of the distribution is shown from a sample of homes built in 1968 in the North Central Region.[3] In that

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[3] The sample was undertaken for this study. Its source is discussed later in this report.

Figure 5. Median floor area of FHA single-family homes, United States, 1950, 1952, 1954-1967. (Source: 1950, 1952, 1954-1966 from U.S. Department of Housing and Urban Development. Statistical Yearbook, 1966. 415 pp., illus., 1967. 1967 from Federal Housing Administration. Annual Statistical Summary, 1967. 90 pp., 1968.)

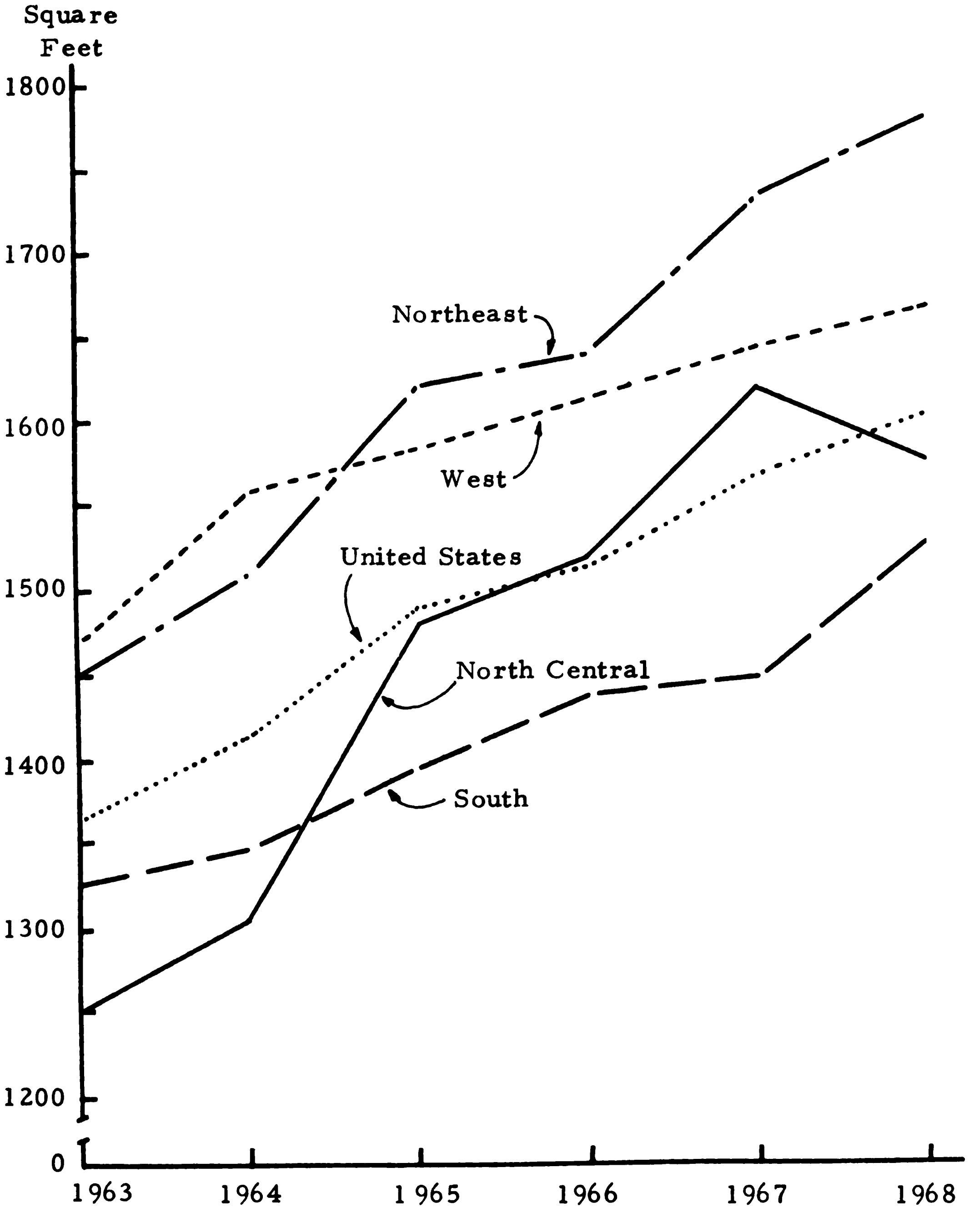

Figure 6. Floor area of single-family homes, by region and United States, 1963-1968. (Source: U.S. Department of Commerce, Bureau of the Census. Housing sales, Sales of one-family homes, Annual Statistics, 1968. Construction Reports-Series C25, 293 pp., illus., 1969.)

Table 4. Floor area of new FHA insured single-family homes, by number of stories and region, 1959 and 1962.

Number of Stories and Year	Region		
	Lake States Region	Central States Region	Lake-Central States Region[a]
	- - - - - - - Square Feet - - - - - - - - -		
One Story			
1959	1027	1069	1057
1962	1063	1127	1110
1 1/2 and Two Story			
1959	1392	1075	1265
1962	1389	1613	1518
Split Level			
1959	1122	1237	1209
1962	1049	1301	1261

[a]Average of Lake States and Central States Regions.

Source: Robert B. Phelps, Wood products used in single-family houses inspected by the Federal Housing Administration, 1959 and 1962. U.S. Forest Service, Statistical Bulletin No. 366, 32 pp., illus., 1966.

year, one story homes had a median of 1,517 square feet of floor area, two story homes a median of 2,502 square feet, and split level homes a median of 1,804 square feet of floor area. The median floor area of all structural types was 1,678 square feet.

Technical Design--The technical design of a structure is here defined as the arrangement and size composition of the various materials used in the structure. Attention is focused on changes in wood volume stemming from: (1) the various manners in which material can be assembled to form a component of the structure, and (2) the more efficient use of wood materials, i.e., use of smaller sizes.

Typical examples of technical designs which cause variation in the amount of wood used in a structure include: truss system in place of a rafter joist system; sandwich wall panels versus framed wall systems; elimination of corner bracing when using plywood or fiber board sheathing; roof trusses on 24 inch centers rather than 16 inch centers; 2 x 4 inch studs on 24 inch centers for non bearing partitions; 4 x 4 inch studding 48 inches on center; and slab versus non slab foundation.

Variation in technical design will cause variation in wood use. For example, 2 x 12 inch floor joists spaced 16 inches on center require approximately 205 board feet of lumber per 100 square feet of floor area (Moselle, 1969). If the design of the floor system is changed such that the same size joists are placed 24 inches on center, the amount of wood required declines almost 40 board feet to 156 board feet per 100 square feet of floor area. Similar volume changes occur when the size of the joist is decreased 2 inches in depth to form a 2 x 8. A 2 x 10 joist system 16 inches on center requires 35 board feet more lumber per 100 square feet of floor area than the same system composed of 2 x 8 inch joists.

Foundation type as a technical design factor also influences wood use. Consider slab versus nonslab foundations as they affect lumber use. In the Lake-Central region, homes constructed with slab foundations require 3.6 board feet of lumber less per square foot of floor area than homes built on nonslab foundations, i.e., 6.1 and 9.7 board feet per square foot, respectively (Phelps, 1966). Because of this difference, the total amount of lumber required of a house with 1,200 square feet of floor area can vary from 7,320 board feet to 11,640 board feet.

Material Blend--The material blend of a structure is here defined as the mixture of construction materials used in a house. As the blend changes, it is expected that there will be a change in the amount of wood required in its construction.

The material blend can change as a result of: (1) the replacement of wood products with other wood products (wood-for-wood substitution), or (2) the replacement of wood products with nonwood products (nonwood-for-wood substitution).[4] Examples of wood products

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[4]A third option is that of substituting wood for a nonwood product. A potential candidate for such a substitution is the use of wooden shakes and shingles for asphalt shingles.

being replaced by another wood product are: the use of veneers, plywoods, composition boards, and laminates in place of the more conventional wood products such as tongue and groved sheathing or redwood siding. Nonwood material substitution for wood material includes: steel siding; the use of steel joists and studs in place of wooden joists and studs; or the replacement of wooden millwork with various plastic materials.

The change in the wood requirements of a structure due to a change in the material blend can be sizeable. Consider first the replacement of one wood product by another. One hundred square feet of floor area requires approximately 121 board feet of 1 x 8 shiplap lumber installed horizontally. This is equivalent to about 10.1 cubic feet of wood per 100 square feet of floor area. The alternative to shiplap subflooring is 5/8 inch fir plywood. Use of the latter implies that only 5.2 cubic feet of wood are required to cover 100 square feet of floor area. This is nearly a 50 percent reduction in wood volume resulting from the substitution of one wood product for another. Similar changes in wood volume can occur when nonwood materials are substituted for wood materials. For example, if a steel joist is substituted for a 2 x 8 inch wood joist (16 inches on center), the wood volume loss per 100 square feet of floor area is approximately 136 board feet. Likewise, if aluminum siding is used in place of 1/2 x 8 inch bevel siding, the amount of wood deleated from the structure is approximately 123 board feet per 100 square feet of wall area (Moselle, 1969).

Consumer Sector

Around the consumer or final user of the house revolve a host of factors which play a role in determining the direction and amount of change that will occur in the various elements of the structural sector. Of major concern are those variables which form the consumer's preference for the physical features of the house and those which temper his preferences, such as income (Figure 1).

The variables which influence the consumer's preference for certain physical feature of the house are many. One important relationship deserves comment. The position that a family finds itself in with regard to the family life cycle will influence to a large extent the preference exhibited for house size. A young couple typically does not have need of a large size home with many rooms. In contrast, the expanding family with children may prefer a much larger house. The contracting family and the retired individual probably have a preference for house size that is similar to the young couple (Beyer,1965). The relationship between preference for floor space and the family life cycle is illustrated in Figure 7. The mortgagers whose ages are less than 30 or more than 50 purchased homes which are considerably smaller in size than that purchased by the 30 to 50 age group. This variation in floor size can in fact be explained by the consumer's preference for houses of different size as he moves through the family life cycle. However, not all the variation in floor size can be attributed to the consumer's preference

Figure 7. Floor area of FHA single-family homes by age of principal mortgager, United States, 1962. (Source: U.S. Housing and Home Finance Agency. Annual Report, 1962. 409 pp., illus., 1963.)

for space alone. A large part is explained by income as it tempers preferences.

The consumer's preference also plays a role in defining the architectural type of house to be consumed, the blend of materials to be used (especially materials directly visable to the consumer), and in some respects it can play a role in determining the technical design of the structure (Zaremba, 1963). The decision to occupy a home with a full basement rather than one with a slab type foundation is an example of the latter.

The consumer is generally unable to exercise his preferences in a vacuum. His desires are generally tempered by his income. As portrayed in Figure 1, the income available for housing is linked to the various elements of the structural sector. The amount of income available for a new structure will be determined by such factors as the total income available to the consumer, the magnitude of non-housing expenses as dictated by such things as family size and age of children, the assets accumulated from previous home ownership, the financing costs, and the expenses necessary to operate the house. These elements define available income which in turn reacts with preferences to, in part, define the physical makeup of the house.

Increases in income permit the consumer to satisfy a desire for a larger size house. For FHA homes, floor areas of less than 1, 000 square feet were common for families with median incomes of $8, 500 or less in 1967 (Table 5). As income continues to rise, the

Table 5. Floor area of new FHA insured single-family homes, by median family income, United States, 1967.

Median Family Income	Floor Area
Dollars	Square Feet
6,620	less than 800
7,478	800-899
8,457	900-999
9,012	1000-1099
9,487	1100-1199
10,046	1200-1299
10,286	1300-1399
11,032	1400-1499
11,708	1500-1599
12,300	1600-1799
13,068	1800-1999
14,734	2000 or more

Source: Federal Housing Administration. Annual Statistical Summary, 1967. 90 pp., 1968.

floor area consumed is also noted to be rising. Similar results have been noted at the regional level, notably the New England region (Zaremba, 1963).

Income available for new housing services is also assumed to play a role in defining other elements in the structural sector. Rises in income undoubtedly allow the consumer greater leaway in defining the structure's material blend. It also enters into the decision as to the architectural type that will be purchased. If the cost difference between one and two story homes is large, a rise in income will allow the consumer the option of purchasing the more expensive house. There is little doubt that the consumer's ability to define the physical structure of his house stems in large part from the income he has available for new housing services.

Builder Sector

The producer or builder of a house also plays an important role in defining the physical makeup of the house. Two sources of influence appear most important, namely: (1) the builder's preference for construction materials and methods; and (2) the costs he must incur to produce the house.

The factors which define the builder's preference for materials and methods of construction are many. Some of the more obvious will be mentioned here. Europeans have found that violent fluctuations in price of wood products have produced a prejudice against the use of such material (United Nations, 1957). Year-to-year price changes greater than 19% have been fairly common amongst European timber products. In contrast, price fluctuations of more than 5% are a rare occurrence in the cement, steel and brick industries. It is concluded that recollections of unhappy consequences of past violent fluctuations, and the fears of future sharp changes in wood prices, have created in the minds of builders a definite bias against wood materials. The importance of this factor to builders in the United States is uncertain. Undoubtedly it has played a role.

Other factors which appear prominent in defining the builder's choice of materials and methods include: (1) the element of tradition; (2) the availability of various wood materials when and where they are needed; and (3) the technical limits of the material in performing a function in the house. European studies hint at this latter element (United Nations, 1957). They define the technical advantages and disadvantages of wood and its rivals in an attempt to determine whether wood use has declined as a result of the technical superiority of other nonwood products. It is speculated that these real and imagined limits influence the builder's choice of material. Unfortunately, the study results are inconclusive.

The builder's choice of material and how it will be combined to form a finished product is not determined entirely on the basis of preferences alone. The cost of materials and methods serves as a damper in this choice. Builder's costs are generally of two types: (1) labor costs and (2) physical costs. Land and material costs are most important in defining the latter. To place the role of costs in a proper perspective it is worthwhile to consider a breakdown of the major costs of a housing unit (Table 6). The physical costs, which are made up of the lot and material costs, account for slightly less than 60 percent of the total cost of the house. Labor costs run slightly less than 16 percent of the total cost. Combined, these three elements make up roughly three quarters of the total house cost. As changes occur in any of these costs, we would expect a change in total builder costs and consequently a pressure placed on the elements of the structural sector. Conceivably, rising builder costs combined with unchanging conditions in all the other sectors could lead to a reduction in structure size or a change to a material blend that is more favorable to the builder. One can only hypothesize as to the importance of the builder sector in defining change in the elements of the structural sector. This is an area of much needed study.

Technical Sector

A change in technology which precipitates new methods and materials for construction is another factor which further defines the physical features of a house. In most cases, a technological innovation is adopted because it results in a definite cost differential between two or more methods or materials. The builder recognizes

Table 6. Total house cost, by type of cost

Cost Item	Percent	
Physical Costs		
Lot	22.5	
Materials	36.7	
Total physical costs		59.2
Labor Costs		15.8
Miscellaneous Costs		
Sales cost	5.0	
Financing and closing cost	8.0	
Overhead and indirect cost and profit	12.0	
Total miscellaneous costs		25.0
Total Cost		100.0

Source: President's Committee on Urban Housing. The Report of the President's Committee on Urban Housing, Technical Studies, Vol. 2. 420 pp., illus., 1968.

this difference and supposedly adopts the one of lesser cost. This choice can then precipitate a change in one of the elements of the structural sector, the ultimate consequence of which may be a change in wood use (Figure 1).

New methods available to the construction industry have certainly played a role in defining the status of the structural sector, especially the technical design element. The introduction of a truss roof system is a classic example. It is estimated that the cost of a truss roof system for a Washington, D.C.house, with 1,120 square feet of floor area, is approximately $271 (President's Committee on Urban Housing, 1968). In contrast, the cost of a conventional rafter-joist roof system is $393 or $122 more than the truss system. This cost difference may encourage the builder toward other building practices, the result of which may be a change in any of the elements of the structural sector. More importantly, there is an immediate change in the technical design of the house, a change which implies a reduction of nearly 1,800 board feet of wood.

Prefab stair assemblies are another example of a new method which influences wood use. For the house mentioned above, the cost of a site built stair system is approximately $199, while the cost of prefabricated stairs is $104. A saving of $95 is realized from the prefab system.

The influence that the above mentioned technical designs have on wood use is difficult to assess. One can only speculate as to whether or not the builder will use the cost advantage so as to cause change in the other elements of the structural sector. Other examples of new methods that might have an impact on wood use include, modular dimensioning, component utilization, the use of subassemblies such as cornices, gables and overhangs, and the use of shop-fabricated kitchen cabinetry.

New methods of construction stemming from advances in technology do not always imply a reduction in total wood use. The Nu-frame house designed and tested by the Forest Products Laboratory of the U.S. Department of Agriculture is a case in point (Anderson, 1968). The Nu-house incorporates a host of new wall and roof framing types plus new methods of covering exterior walls and roof and interior walls and ceiling. This new system has not markedly influenced total wood use although it has resulted in a reduction of nearly $300 in total material cost (Table 7). Note that the Nu-frame system required an additional 2,375 board feet of dimension and board wood relative to the conventional framing method, yet the savings in the cost of dimension and board wood is upwards of $120 in favor of the Nu-frame system. The use of low grade, lower cost material probably explains this difference. The Nu-house and its Nu-frame system does use less wood than conventional systems in specific systems of the house. A decline of 1,845 board feet is noted for those systems considered (Table 8). This is clearly an indication of how changes in technology

Table 7. Conventional and Nu-frame house, by type, quantity, and cost of material.

Material Type	Conventional House		Nu-Frame House	
	Quantity	Cost	Quantity	Cost
	Board or Square Feet	Dollars	Board or Square Feet	Dollars
Wood (Dimension & Boards)	4585	890	6960	770
Wood Products (Plywood & Insulation Board)	5220	436	3900	343
Non-Wood Products (Gypsum board & Insulation)	5240	280	4140	197
Total	15045	1606	15000	1310

Source: L. O. Anderson. Construction of Nu-Frame Research House Utilizing New Wood-Frame System. U. S. Forest Service Forest Products Laboratory, Research Paper FPL 88, 38 pp., illus., 1968.

Table 8. Conventional and Nu-frame house, by type, quantity, and cost of material and by house system.

House System	Conventional House		Nu-Frame House	
	Quantity	Cost	Quantity	Cost
	Board Feet	Dollars	Board Feet	Dollars
Outside walls	975	117	860	93
Inside walls	980	120	520	52
Trusses	970	184	700	96
Gable end and rake	160	19	160	19
Total	3085	440	2240	260

Source: L. O. Anderson. Construction of Nu-frame research house utilizing new wood-frame system. U.S. Forest Service Forest Products Laboratory, Research Paper 88, 33 pp., illus., 1968.

will precipitate a change in the technical design and material blend of a house, the ultimate consequence of which is a reduction in wood volume.

New construction methods are not the only factor which stem from technical advances. New materials are also important. They most certainly affect the material blend found in the house. Again, consider the Washington, D. C. house mentioned earlier (President's Committee on Urban Housing, 1968). Single layer siding-sheathing-reverse board and batten-5/8 inch rough cut with stain cost approximately $243. In contrast, composite siding - 1/2 inch insulation board 1 x 10 bevel siding with two coats of paint cost $427 or nearly $184 more. We can only speculate as to what this means for wood use. If the lower cost siding requires less wood and it is the choice of the builder, it is obvious that a decline in wood use will occur.

Other examples of what can happen to wood use when material blend changes were pointed out in the previous discussion on material blend. Examples of new materials coming of age as a result of new technology are endless. Some of the more important are aluminum siding, light gauge adjustable steel elements, vertically laminated wood beams, particleboard, vinyl tiles, indoor-outdoor carpeting, and fiberglass and aluminum screens and shutters.

Institutional Sector

There are a number of institutional factors which play a role in defining the physical features of a house. Unfortunately, it is extremely difficult to relate them directly to the structural sector. For the most part, one can only hypothesize as to their affect. Although institutional factors are presumed to affect the structural sector via their influence on the consumer and builder sectors, it is here assumed that they work as a group which acts directly on the structural sector (Figure 1). This is done to expedite analysis.

An institutional factor which has been debated at great lengths is building codes. These discussions have centered primarily on the affect that building codes have on construction costs. As previously discussed, construction costs play a role in defining the structural sector via their affect on the builder. Some arguments contend that building codes do not permit the use of advanced technical knowledge in construction, and consequently their effect is to unnecessarily raise input costs (President's Committee on Urban Housing, 1968). For example, nearly two-thirds of the nation's localities prohibit 2 x 4 studs on 24 inch centers for nonbearing partitions (National Association of Home Builders, 1963). If this restriction was removed, we would expect a definite change in wood use stemming from a change in technical design.

Arguments have also been made that the lack of building code uniformity amongst localities may be inhibiting scale economies and reducing competition, since some builders may be hesitant to enter local markets with unfamiliar codes. Building inspection requirements may also unduly limit the opportunities for prefabrication, a process which requires rapid mass production methods. Further, building concepts may be so new and revolutionary that they may not conform to any known building code and are, in effect, denied to the housing industry (Structural Plastics Associates, 1960). Such is the case with plastic houses.

The results of certain research on building codes sheds a degree of doubt on the above arguments. In the San Francisco Bay area, Maisel (Maisel, 1953) concluded that "less than one percent of the money spent for housing was attributed to known code inefficiencies." Further, the President's Commission on Urban Housing concludes that many communities could be identified where the code system curtails the use of new construction methods and materials (President's Commission on Urban Housing, 1968). But, the Commission indicates that this does not change the more general conclusion that the removal of restrictive codes is not likely to have a significant affect on construction costs for the nation as a whole. In light of these conflicting arguments about the affect of building codes on construction activities in general, it would seem especially hazardous to speculate as to the affect of building codes on wood use.

Organized labor is another institutional factor which plays a role in defining change in the structural sector. Again, the manner and magnitude of organized labor's affect is subject to debate. It has often been speculated that labor unions are frequently resistant to technological change, especially when the technical advances lower the demand for labor or modify the skill mix required. Direct evidence bearing on this question is sparse (President's Commission on Urban Housing, 1968), making speculation as to labor's affect on wood use hazardous.

Zoning is another institutional element that may be important in defining the physical makeup of the house. It is of interest because of: (1) its ability to control land use and development; and (2) its control over the bulk, height, and area covered by a building. Those zoning ordinances which specifically limit the number of stories in a house or its floor size play a very direct role in defining the physical makeup of the house. Other zoning factors operate in a more subtle manner. A good example is minimum lot size zoning. A minimum lot size, which is not in accord with the public's preference, could force a family to purchase a lot much larger than desired. This added land cost implies less revenue to expend on the house, the ultimate consequence of which is some modification of the physical features of the house, probably size. What this specifically implies for wood use is unknown.

Institutional factors such as building codes, zoning ordinances, and labor institutions are but three of a vast number of institutional factors which could conceivably affect wood use. Other factors include, subdivision regulations, insurance standards, and the standards set by financing institutions. These elements surely play a role in defining change in the structural sector. The direction and magnitude of that change has yet to be studied.

Dynamics of the Model

The model of wood use is dynamic in that it explicitly considers many of the forces which are thought to have determined past rates of wood use (Hamilton, et al, 1968). The forces or relationships explicitly considered by the model are two-fold in nature. First, the model defines the relationships that exists between the elements of the structural sector and the determinants located in the consumer, builder, technical and institutional sectors. And secondly, it defines in an exact manner how changes in the elements of the structural sector affect wood use in the average house. For example, the model defines how a change in income precipitates a change in structure size which in turn affects wood used in various segments of the average house. By defining these relationships explicitly, the model is capable of capturing the dynamic nature of the wood use system.

The dynamics of the model are best described by a hypothetical example. Consider first a prediction of lumber use for 1985 that is based on the extrapolated trend in lumber use which occurred between 1960 and 1968 (Figure 8). Such a prediction is frequently labeled as "static," since it does not explicitly take into account

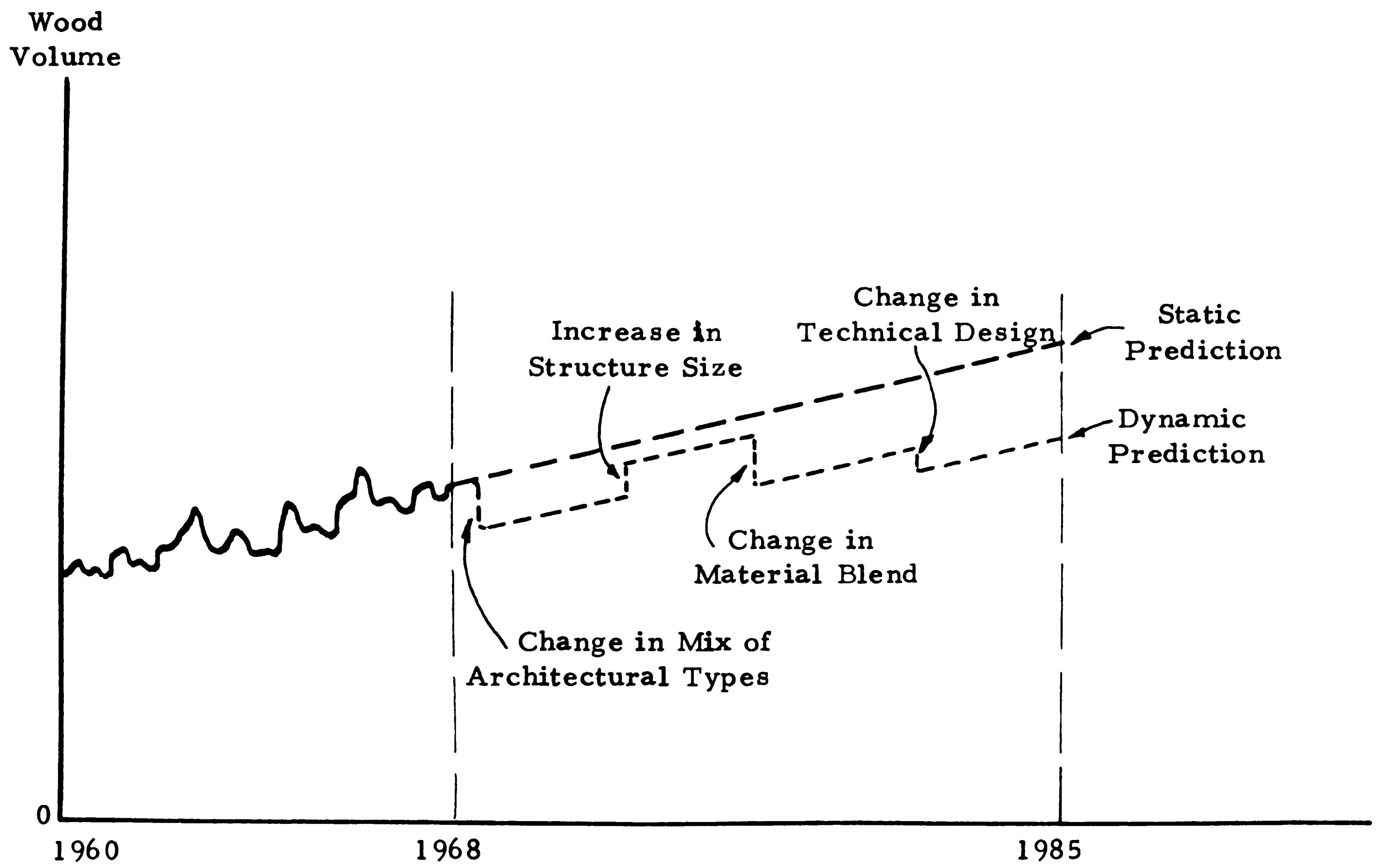

Figure 8. Comparison of static and dynamic hypothetical predictions of wood use per house.

the determinants of past wood use. In contrast, consider the "dynamic" prediction of lumber use for 1985 (Figure 8). Such a prediction relies on the well defined interaction of wood use determinants. First, there was a decline in wood use which stemmed from a change in the market mix of architectural styles. Conceivably, one story homes could have become more important in the market place at the expense of two story homes, the former of which generally require less lumber per unit. Secondly, an increase in the size of the structure resulted in increased wood use. Thirdly, because of a change in the structure's material blend, the amount of wood required per house declined markedly. This may have been the result of nonwood products replacing wood products in the wall or floor system of the house. And fourth, a further decline in wood use occurred as a result of new technology which caused a change in the structure's technical design. Possibly truss roof systems became the dominant construction method at the expense of conventional roof systems. The end result is a prediction of 1985 lumber use which is considerably below the one given by the static approach. It should be noted that changes will be taking place in all elements of the structural sector at the same time.

ESTIMATION OF THE SYSTEM

GENERAL

Identifying determinants and hypothesizing as to their affect on wood use is but one step in the model building process. A second and equally important step is that of explicitly defining the relative importance of each factor in explaining variation in wood use. This step implies the use of tools commonly found in the world of statistics and econometrics.

Two specific relationships must be defined. First, the elements of the consumer, builder, technical and institutional sectors must be explicitly linked to the elements of the structural sector. For example, the exact role played by such abstract variables as income and cost in defining structural size and material blend must be specified. Second, the relationship between the elements of the structural sector and actual wood use must be explicitly recognized. By defining these relationships, a change in an abstract variable in either the consumer, builder, technical, or institutional sector can be related explicitly to a change in wood volume via the link with elements of the structural sector.

The process of defining relationships between elements of the structural sector and actual wood use, requires detailed information on wood use per house. To meet this need, a sample of homes constructed in the North Central region in 1968 was acquired.[5] The sample size was 100. It was drawn randomly from a parent population whose size is approximately 800 single-family homes. The criteria used to determine the sample size was strictly one of cost.

The sample permitted the relationship between wood use and two elements of the structural sector to be explicitly defined. These elements were structural size (floor area) and architectural type. Of the 100 homes sampled, 63 were one story, 27 two story, and 10 were split level. The floor size within each architectural type ranged from 768 square feet to 3,074 square feet for one story homes; 1,092 square feet to 3,650 square feet for two story homes; and 1,368 square feet to 2,484 square feet for split level homes. The remaining two elements of the structural sector--technical design and material blend--were not explicitly defined by the sample. Their relationship to wood use was inferred from close examination of methods and materials used in the construction of the sample houses, e.g., the proportion of sample homes using wood and nonwood siding.

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[5] Sample obtained from the Lumber Listing Service Bureau, Milwaukee, Wisconsin. Waste factors have been applied to all materials used in the house. The amount of various wood products by house system and architectural type for the sample is presented in Appendix B and Appendix C.

Changes in architectural type, structural size, technical design, and material blend have greater influence on certain segments of the house than on others. An obvious example is a change in material blend which encourages the use of steel studs at the expense of wood studs. The major affect of this change will be on the wall system of the structure. To capture similar outcomes stemming from changes in elements of the structural sector, the house was categorized into four systems (Appendix E):

Floor system
Wall system
Roof system
Millwork system

Each system was further divided according to end use or individual wood products and construction features that make up a house system (Appendix E). To expedite analysis, some of the more specific features of the house were aggregated. For example, finish flooring is an aggregate category made up of oak flooring, ranch plank flooring and parquet flooring.

Certain assumptions about the nature of the sample data must be recognized at the onset. First, it is assumed that the sample homes are representative of those commonly constructed in the North Central region. This is a crucial assumption indeed. The parent population from which the sample was drawn is dominated by homes constructed in the states of Wisconsin and Illinois. At least half of the sample originated in the latter two states. The remaining portion were constructed in Indiana, Michigan, Minnesota and Iowa. Consequently, to make inferences about wood use in the entire North Central region on the basis of such a geographically biased sample may prove to be very hazardous. On the other hand, the amount of wood use per sample house agrees fairly well with data from past studies. The lumber per sample house averaged 17,614 board feet. In 1962, the lumber volume per house averaged 10,508 board feet (Phelps, 1966). This is not a large discrepancy if one considers that the latter figure does not reflect recent rises in floor area nor does it adequately represent the conventionally mortgaged home, a home which has been more than 360 square larger in area than FHA insured homes. In this light, the sample homes may in fact adequately reflect wood use in the North Central region.

A second assumption revolves around the comparability of two floor size estimates. First, floor area predictions developed later in the study are based on estimates obtained from Bureau of Census samples taken in the North Central region (U.S. Department of Commerce, 1969). In contrast, the relationship between wood use in a house system and floor area (also developed later in the study) is based on the sample of 100 homes located in the North Central region. For purposes of estimating changes in wood use, the floor area estimates provided by the above two sources are assumed comparable. If this is not the case, the substitution of predicted floor area (based on U.S. Department of Commerce samples) for the floor area used in defining the wood use in a specific house system (based on sample of 100 homes) may also be hazardous. Some indication of their comparability can be gained by examining the median floor size provided by the two samples. The Bureau of the Census estimated the median floor size of homes in the North Central region to be 1,552 square feet in 1968 (U.S. Department of Commerce, 1969). In contrast, the median floor area for the sample of 100 homes was 1,678 square feet. A difference of 126 square feet exists. Given the form of the data, it is impossible to determine whether or not this is a statistically significant difference. If not, the homes in each sample are from the same parent population and we would expect the construction material and methods of each sample to be the same.

A third assumption of importance concerns floor and roof sheathing material. The sample of 100 homes provides an estimate of the amount of lumber (1 x 8 boards) or plywood required to cover roof and floor surfaces. The estimates assume only one or the other of the materials will be used. Unfortunately, the sample does not define the number of homes which actually used each material type. As such, it is assumed that 95 percent of the homes in the North Central region used plywood as roof and floor sheathing material, while only 5% of the homes use boards for the same purpose. The appropriateness of this assumption is attested to by past trends in use of the above materials. Approximately 48 percent of the homes in the Lake-Central region used plywood as a floor sheathing material in 1959 (Phelps, 1966).[6] In this same year, 52 percent of the homes used boards for such purposes. By 1962, the use of plywood had become dominant, namely, 65 percent of the homes used plywood for floor sheathing. The use of boards had declined to 35 percent. If the rate of change between these two years (1959 and 1962) has continued, it is expected that more than 95 percent of the homes in 1968 used plywood floor sheathing material in the North Central region. A similar change has occurred in roof sheathing materials. If such changes have indeed occurred, the assumed rate of board and plywood use for roof and floor sheathing may not be unrealistic.

The sample of 100 homes provided complete estimates of wood use in all house systems except the millwork-trim system. Estimates were not provided for kitchen cabinets, windows, doors, and certain exterior and interior trim mouldings. The volume of wood material used in these elements was calculated on the basis of the following information provided for each sample house: the number and size of eight different window types; the number and

[6] This percentage is a weighted average for the combined Central and Lake States region. It is weighted by the number of homes constructed in each region.

size of interior, exterior, and garage doors; the lineal feet of kitchen soffit as an index of kitchen cabinet length; and the lineal feet of moulding of various types. This information combined with standard millwork sizes and construction methods (Lloyd, 1966 and Zinnikas, 1967) formed a base from which to calculate the missing data. For the millwork-trim system, the average amount of lumber and plywood calculated per house was 1, 984 board feet and 901 square feet, respectively. This compares with a 1962 estimate for FHA homes of 1, 566 board feet of lumber and 384 square feet of plywood (Phelps, 1966). Again, the FHA estimates do not reflect trends in house size since 1962, nor are they representative of the larger size conventionally mortgaged homes.

PREDICTING EQUATIONS

Structural Size

Floor area is defined by a complex system of determinants. Its analysis is complicated not only by the large number of potential forces impinging on floor area, but also by the interdependence of some of these factors. The question of immediate concern is which determinants play a significant role in explaining variation in floor size. Unfortunately, many of the determinants are eliminated from contention at the onset, since data are not available to represent them. This is especially true for those factors located in the institutional and technical design sectors.

Among the determinants which are hypothesized to have an affect on floor area are the following:

Regional index of median family income
National median age of household head.
Regional index of average union hourly wage rates in the building trades.
National FHA ratio of site value to structure value.
National FHA index of site value.
National credit variable for conventional first mortgage loan, composed of contract interest rate, loan term to maturity, and loan-to-value ratio.
National softwood lumber wholesale price index.
National hardwood lumber wholesale price index.
National plywood wholesale price index.
National softwood plywood wholesale price index.
National building paper and board wholesale price index.
E. H. Boeckh and Associates national construction cost index for residences.
Department of Commerce national composite construction cost index.

The estimated equation used to predict median floor area is presented in Table 9.[7] Shown are the standard errors for each coefficient and a "t" ratio. The "t" ratio is used to test the hypothesis that the true value of the coefficients are zero (McKillop, 1967). If the coefficient's "t" ratio is greater than the critical value, the hypothesis that the true value of the coefficient is zero is rejected at the 90 percent level. It should be noted that all of the coefficients were of the "correct" sign and that none of the simple correlations

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[7]This and all subsequent equations were calculated on a CDC 3600 computer (Ruble, 1968).

Table 9. Estimated floor area equation

Variable[a]	Coefficient	Standard Error	t ratio[b]
Logarithm of index of median family income, North Central region	+3428.14870	189.32882	18.10685
National credit variable	-978.74754	259.46652	3.77215
Index of national softwood plywood wholesale price	-12.53264	2.03168	6.16861

[a]Constant term = -4490.44420 (standard error = 341.00641), squared multiple correlation coefficient (R^2) = 0.9942, critical student's t value = 2.920 where degrees of freedom = n-k-1 = 2, standard error of estimate = 17.94328.

[b]Ratio of coefficient to its standard error.

Source: (a) 1963-1968 Median Floor Area of Homes in the North Central Region from U.S. Department of Commerce, Bureau of the Census. Housing Sales, Sales of New One-Family Homes, Annual Statistics, 1968. Construction Reports-Series C25, 293 pp., illus., 1969.

(b) 1953-1968 Index of Median Family Income in the North Central Region from U.S. Department of Commerce, Bureau of the Census. Income on Families and Persons in the United States. Current Population Reports: Consumer Income-Series P60. 1954-1969.

(c) 1956-1968 Softwood Plywood Wholesale Price Index from U.S. Department of Commerce, Business and Defense Services Administration, Construction Review. 1957-1969.

(d) 1963-1968 National Contract Interest Rate, Loan Term To Maturity, and Loan-to-Value Ratio from Federal Home Loan Bank Board, 33d Annual Report and 36th Annual Report. 1965 and 1968.

between independent variables exceeded 0.5296. The dependent variable predicted by the equation is median square feet of floor area for houses of the North Central region.

The independent variables included in the equation deserve comment. First, it should be noted that the relationship between median floor area and median family income is logarithmic. Such a relationship implies that as income rises there is a less than proportional rise in floor area. A similar relationship is known to exist in other regions (Zaremba, 1963 and Wheaton, 1966). As income rises, consumers tend to spend proportionally less on housing.

Secondly, the credit variable warrents an explanation. It is a composite of three other variables, namely, interest rate, length of loan, and loan-to-value ratio. These three variables are combined in the following manner (Grebler and Maisel, 1964):

$$\text{Credit variable} = \frac{\text{Interest rate}}{(\text{Length of loan}) \times (\text{Loan-to-value ratio})}$$

A rise in interest rates will raise the value of the credit variable, while an increase in the length of loan or the loan-to-value ratio will decrease it. Thus the higher the credit variable, the tighter are credit terms and vice versa.

The last variable in the equation is an index of national plywood price. As with the credit variable, it exhibits a linear relationship with floor size.

The actual median floor area and that predicted by the equation are presented in Figure 9.

Architectural Type

The proportion of the market dominated by each architectural type is also defined by a host of forces. Again, concern is to specify which variables are significant in defining this proportion. Determinants similar to those hypothesized as affecting floor area were again scrutinized as to their affect on architectural type.

The estimated equations used to predict the proportion of one and two story homes are as follows:

One story[8]

$$\log(Y_1) = 2.22279 - 1.12639 \log(X_1)$$

where

Y_1 = proportion one story homes in market

X_1 = index of site value

[8] Standard error of coefficient = 0.24878, "t" ratio (ratio of coefficient to its standard error) = 4.52773, critical student's "t" = 2.353 at the 90% level with degrees of freedom = n-k-1 = 3. Standard error of constant = 0.54935. Squared multiple correlation coefficient = 0.8723. Simple correlation coefficient = -0.9340, standard error of estimate = 0.02294 (log form).

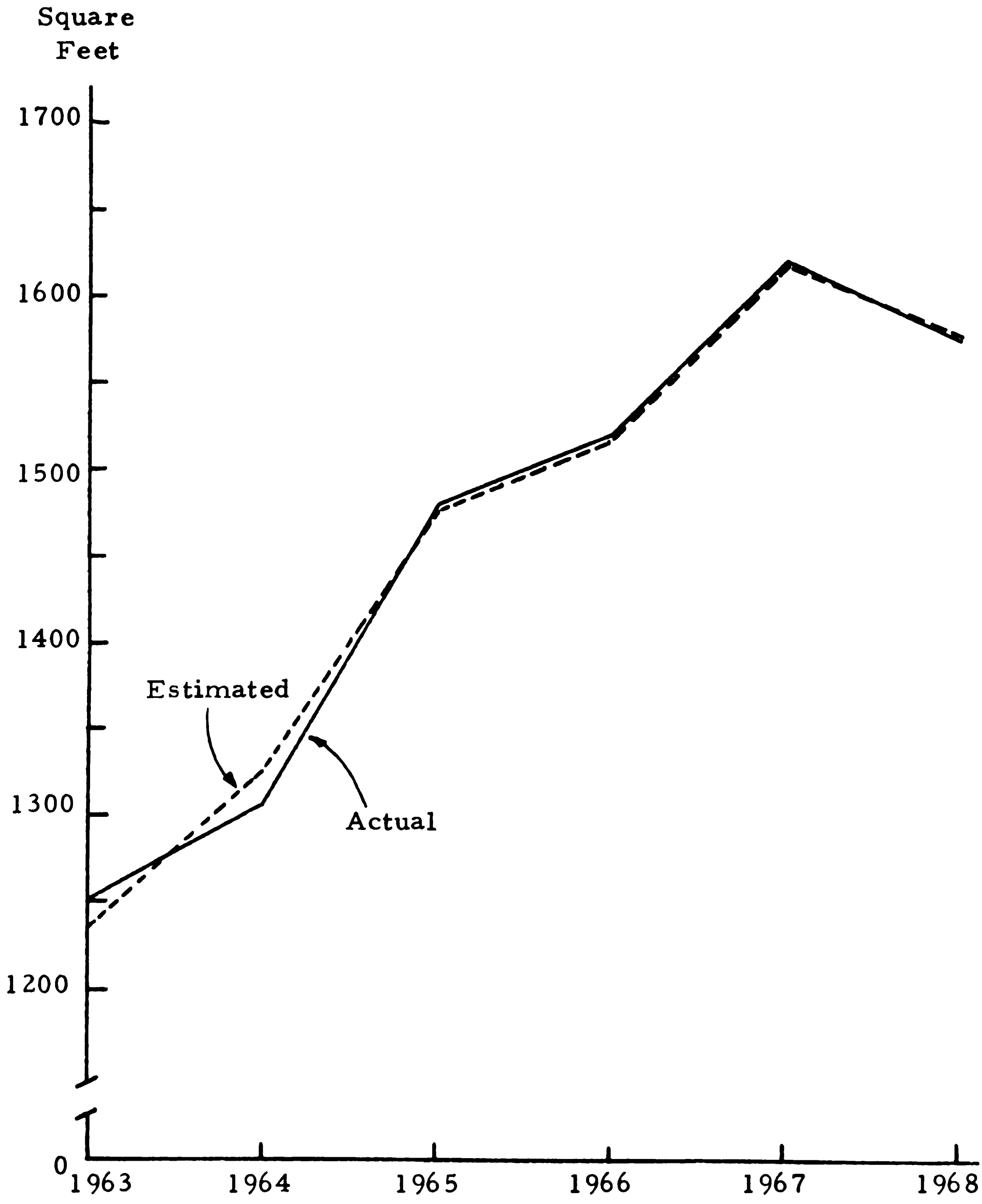

Figure 9. Actual and estimated median floor area of single-family home, North Central region, 1963-1968. (Source: U.S. Department of Commerce, Bureau of Census. Housing sales, Sales of one-family homes Annual statistics, 1968. Construction Reports-Series C25, 293 pp., illus., 1969.)

Two story[9]

$$Y_2 = -0.39203 + 0.00374\,(X_2)$$

where

Y_2 = proportion two story homes in market

X_2 = index of site value

The dependent variable in both of the above equations is the proportion of one and two story homes in the North Central region (U. S. Department of Commerce, 1969). In both equations, the national FHA index of site value is the sole independent variable (U. S. Department of Housing and Urban Development, 1967 and Federal Housing Administration, 1968). The equated relationship for one story homes indicates that rises in land costs restrict lot size and force the expanding demand for floor space toward a two level structure. The opposite is true in the two story equation.

The proportion of the market captured by split level homes is simply the residual which occurs after the proportion of one and two story homes have been defined. The relationship is as follows:

Proportion split level = 1.00 - (Proportion one story + proportion two story).

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[9]Standard error of coefficient = 0.00031, "t" ratio (ratio of coefficient to its standard error) = 12.03541, critical student's "t" = 2.353 at the 90% level with degrees of freedom = n-k-1 = 3. Standard error of constant = 0.05092. Squared multiple correlation coefficient = 0.9797. Simple correlation coefficient = +0.9898. Standard error of estimate = 0.01094.

The actual and predicted levels attained by the various architectural types is presented in Figure 10.

Wood by End Use

A crucial segment of the model is that which relates changes in wood use to changes in the various elements of the structural sector. By examining the sample of 100 houses, it was possible to tie two of the structural sector's elements directly to wood use. These two elements were structural size (floor area) and architectural type.

The first step in defining these relationships was to define logical end uses of wood in each system of the house (Appendix E). For example, the floor system is composed of a mud sill, floor joists, bridging, and nine other end uses. Similarly, the millwork and trim system is composed of windows, doors, wall paneling and eleven other end uses.

Once the end uses were defined for each system, the next step was to relate, via least squares technique, the amount of wood material in each end use to the floor area of each architectural type. A typical relationship for plywood subfloor sheathing in one story homes is as follows:

$$Y = \underset{(203.57762)}{-177.28506} + \underset{(0.12381)}{1.20752}\,(X)$$

$$R = 0.7806$$

$$R^2 = 0.6093$$

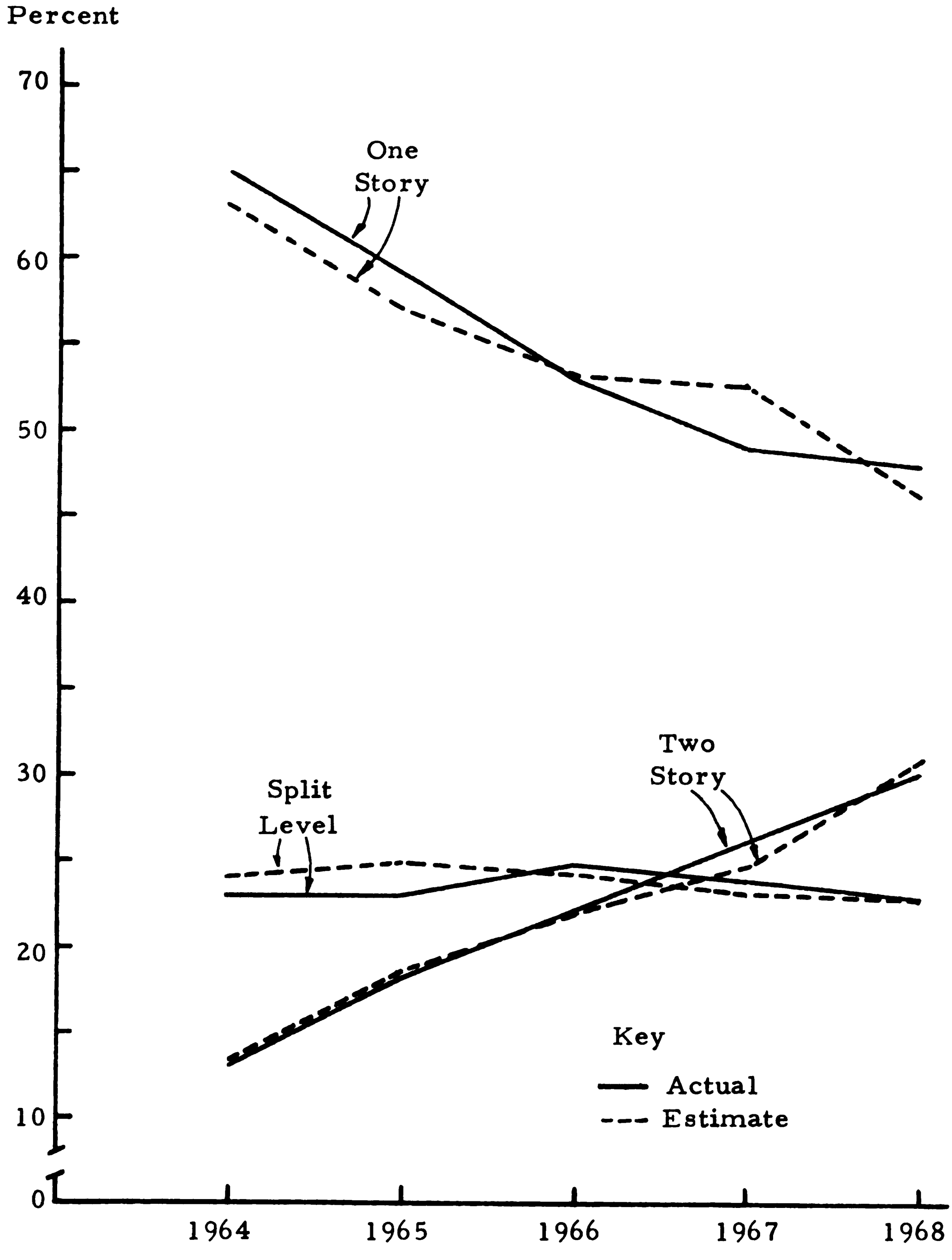

Figure 10. Actual and estimated percent single-family homes, by by architectural type, North Central region, 1964-1968. (Source: Actual data from U.S. Department of Commerce, Bureau of Census. Housing sales, Sales of one-family homes, Annual statistics, 1968. Construction Reports-Series C25, 293 pp., illus., 1969.)

where[10]

Y = square feet of plywood

X = floor size of one story house in square feet

The number of estimated equations totals 152 (Appendix F). This is somewhat less than the total number of end uses existing for each architectural type and system therein. A number of reasons exists for this disparity. First, where the number of houses having a particular end use element was three or less, floor size was not used as an independent variable explaining wood use in that element. A simple mean was used as an estimate. Secondly, no equation existed when the sample houses of an architectural type did not exhibit a wood volume in a particular end use. Third, in the case of the split level's floor system, three end uses were aggregated into one to produce a more reliable estimating equation.

The reliability of the estimated equations varied widely. Approximately 55 percent had a correlation coefficient (R value) greater than or equal to 0.5000 (Table 10). Further, floor area explained at least 50 percent of the variation in wood use in 28 percent of the equations, although the range was wide. The greatest amount of variation in wood volume as explained by floor area occurred in the case of two story precut wall studs, i.e., 92 percent. In contrast, floor area explained less than one percent of variation

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[10] Parenthesis contain standard errors of constant and coefficient terms.

Table 10. Percent wood-use equations, by correlation coefficient and coefficient of determination greater than 0.50, and by architectural type.

Architectural Type	Equations with an R value equal to or greater than 0.5000[a]	Equations with an R^2 value equal to or greater than 0.5000[b]	Number of equations
	Percent	Percent	
One Story	58	35	55
Two Story	59	32	54
Split Level	44	16	43
All Types	55	28	152

[a] "R" denotes correlation coefficient

[b] "R^2" denotes coefficient of determination

in the wood volume found in the mud sill of split level homes.

The reliability of each equation's parameters also varied greatly. Of the 152 equations, 55 percent had a floor area coefficient which was significant at the 90 percent level or greater (Table 11). Approximately 39 percent had a constant term which was significant at a similar level or greater.

All of the 152 equations were examined for nonlinear tendencies by reviewing the residuals in either numerical or graphical form. Both methods were used in cases where large wood volumes were encountered, e.g., floor joists and precut wall studs. These examinations did not expose any nonlinear tendencies that would be of significance in defining wood use. Consequently, all equations were specified in a linear form.

EXOGENOUS VARIABLE PREDICTIONS

There are certain variables which influence the system by which wood use in single-family homes is determined, but which are not in turn affected by the system. These are the exogenous variables. They are predetermined outside the system in question. The model of wood use must cope with four basic exogenous variables, namely:

1. Index of median family income, North Central region
2. Credit variable composed of:
    a. National interest rate
    b. National length of loan
    c. National loan-to-value ratio
3. Index of national wholesale plywood price
4. Index of national FHA site value

Table 11. Percent wood-use equations, by constant and coefficient terms significant at the 90 percent level or greater, and by architectural type.

Architectural Type	Equations with constant term significant at 90 percent level or greater	Equations with coefficient term significant at 90 percent level or greater	Number of equations
	Percent	Percent	
One Story	53	69	55
Two Story	28	61	54
Split Level	35	28	43
All Types	39	55	152

Before future floor areas and architectural mixes can be estimated, the future level of the above exogenous variables must be determined. The basic procedure was to examine past trends in the exogenous variables and to extrapolate these trends into the future. The trends were fitted against time by least squares (Table 12).

A relatively poor fit was obtained for the following variables: length of loan, loan-to-value ratio, and index of plywood price. In all cases these variables have shown very erratic movement during the sampled years. The regressions did yield what can be considered a plausible estimate. The predicted values of the exogenous variables are presented in Appendix D.

ENDOGENOUS VARIABLE PREDICTIONS

The system generates two basic endogenous variables which when defined affect one or more other variables in the system.[11] These variables are floor area and the mix of architectural types. As with exogenous variables, future levels of these endogenous variables must be defined if estimates of future wood use are to precipitate from the model.

Estimates of future floor areas were determined by inserting the appropriate exogenous variables into the estimated equation which defines floor area. The nature of this equation was previously

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[11]The volume of wood estimated by the system can be considered a third endogenous variable.

Table 12. Estimated exogenous variable equations

Variable	Constant term	Coefficient term	R^2 [a]
Index of median family income, North Central region	-10716.15426	+5.52691	0.9368
Credit variable			
(a) National interest rate	-488.06608	+0.25135	0.8929
(b) National length of loan	-334.68914	+0.18257	0.1771
(c) National loan-to-value ratio	3.11206	-0.00123	0.2456
Index of national wholesale plywood price	1347.95275	-0.63791	0.2732
Index of national FHA site value	-14813.34684	+7.61632	0.9872

[a] "R^2" denotes coefficient of determination

discussed. Since the equation does not provide an estimate of floor area by architectural type, a method of defining floor area by architectural type was devised. The procedure is as follows: First, a weighted average floor area for each year is calculated.

Architectural type	Mean floor area[12] in 1968 (sq. ft.)	Proportion of market by architectural type in 1969	Weighted average floor area in 1969 (sq. ft.)
One Story	1,588	0.472	750
Two Story	2,513	0.294	739
Split Level	1,893	0.234	443
	1,852	1.000	1,932

Secondly, the ratio of floor area defined by the sample of 100 homes to the above weighted average floor area was calculated for each architectural type.

$$\frac{\text{Mean 1968 one story floor area}}{\text{Weighted average floor area 1969}} = \frac{1588}{1932} = 0.821$$

$$\frac{\text{Mean 1968 two story floor area}}{\text{Weighted average floor area 1969}} = \frac{2513}{1932} = 1.300$$

$$\frac{\text{Mean 1968 split level floor area}}{\text{Weighted average floor area 1969}} = \frac{1893}{1932} = 0.979$$

Third, the ratios calculated above were then combined with the median floor area estimated by the equation to provide an estimate of floor area by architectural type. For 1969, the floor areas are as follows:

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[12]Determined from the sample of 100 homes previously discussed.

(0.821) x (1582) = 1301 square feet floor area in a one story house

(1.300) x (1582) = 2059 square feet floor area in a two story house

(0.979) x (1582) = 1551 square feet floor area in a split level house

The above procedure is used to calculate the predicted floor area of each architectural type for all years 1969 to 1985. As the proportion of one, two and split level homes is calculated for each year, the weighted average floor area in the first step changes accordingly. The effect of this change is percolated through the remaining steps. But, regardless of the year considered, the mean floor area by type remains the same in step one. This implies that the relationship between the floor areas of the three architectural types will remain the same through 1985. This is an important assumption, and one that will be only partly modified by the changes which occur in proportion of architectural types. The predicted floor areas are presented in Table 13.

Estimates of future mixes of architectural types were obtained by substituting estimates of future site value into equations defining the proportion of one and two story homes expected in the market. Again, these equations were previously discussed. The proportion of split level homes in the market was simply the value remaining after one and two story homes had captured their share of the market.

The predicted mix of architectural types is presented in Table 14.

Table 13. Median floor area of single-family homes, by architectural type, North Central region, 1963-1985.

Year	Median Floor Area: All Architectural Types	Architectural Type		
		One Story Floor Area	Two Story Floor Area	Split Level Floor Area
	------------ Square Feet --------------			
1963	1236	--	--	--
1964	1326	--	--	--
1965	1476	--	--	--
1966	1517	--	--	--
1967	1619	--	--	--
1968	1576	--	--	--
1969	1582	1301	2059	1551
1970	1627	1321	2091	1575
1971	1670	1340	2120	1597
1972	1712	1358	2148	1618
1973	1753	1375	2175	1638
1974	1792	1390	2199	1657
1975	1830	1405	2222	1674
1976	1868	1419	2244	1690
1977	1904	1431	2265	1706
1978	1939	1444	2284	1720
1979	1974	1455	2302	1734
1980	2008	1473	2330	1755
1981	2040	1491	2358	1776
1982	2073	1508	2386	1797
1983	2104	1526	2414	1818
1984	2135	1543	2441	1838
1985	2165	1559	2467	1858

Table 14. Percent of single-family housing market, by architectural type, North Central region, 1964-1985.

Year	All Architectural Types	Architectural Type		
		One Story	Two Story	Split Level
	- - - - - - - - - - - Percent	- - - - - - - - -	- - - - -	- - - - - -
1964	100	63	13	24
1965	100	57	18	25
1966	100	54	22	24
1967	100	53	24	23
1968	100	46	31	23
1969	100	47	29	23
1970	100	45	32	23
1971	100	43	35	22
1972	100	41	38	21
1973	100	40	41	20
1974	100	38	44	18
1975	100	37	47	17
1976	100	35	49	15
1977	100	34	52	14
1978	100	33	55	12
1979	100	32	58	10
1980	100	31	59	10
1981	100	30	60	10
1982	100	29	61	10
1983	100	28	62	10
1984	100	27	63	10
1985	100	27	63	10

The proportion of split level homes in the market was not allowed to attain a level less than 0.10. This constraint could have been eliminated if equations had been specified which would predict the absolute number of homes of each architectural type. This would involve a statistical evaluation of the quantity elements of the construction market, elements which define the rate at which new units are established. Such an effort was deemed outside the scope of this study.

SYSTEM OPERATION

The model's operation is basically one of combining cross-sectional and time-series information in such a manner that future wood use can be defined. The cross-sectional portion of the model is that which relates wood use in 1968 to the 1968 level of elements found in the structural sector. For example, the 1968 relationship between floor size and the volume of precut wall studs in a house is as follows:

$$Y_{1968} = b_o + b_1(X_{1968})$$

where

Y_{1968} = board feet in 1968

X_{1968} = floor area in 1968

The parameters b_o and b_1 depict the structure of the system as it exists in 1968.

The time-series portion of the model is that which relates past changes in structural sector elements to past changes in abstract variables located in other sectors of the model. For example, changes in floor area which have occurred between 1963 and 1968 can be related to changes which have occurred over a similar period in certain determinants of floor area. The following is an example:

$$Y_t = b_o + b_1(\log X_{1_t}) - b_2(X_{2_t}) - b_3(X_{3_t})$$

where,

Y_t = floor area

X_{1_t} = income

X_{2_t} = credit variable

X_{3_t} = plywood price index

t = years 1963 to 1968

The parameters b_o, b_1, b_2 and b_3 depict the structure of the system as it existed in the 1963 to 1968 time period.

The proper combination of time-series and cross-sectional relationships results in an estimate of future wood use. First, an estimate of exogenous variables X_1, X_2, and X_3 are determined for some future year. Secondly, using these estimates, an estimate of future floor area can be obtained from the time-series relationship. Thirdly, the future floor area estimated by the time-series relationship can be inserted into the 1968 cross-sectional relationship so as to attain an estimate of wood use in the chosen future time period.

The crucial assumption behind this process is that there will be no significant changes in the basic structure of the system, i.e., the parameters estimated for both the cross-section and the time-series relationships will remain the same in future time periods.

The actual mechanics of the model are straight forward. Seven major steps are executed.

First, the mix of architectural types is determined (Figure 11). As was previously discussed, this mix is defined by exact relationships between the percentage of homes with a given number of stories and the lot price.

The second major step is that of defining the floor area of the three architectural types considered. The floor area is determined by a mathematical relationship with family income, plywood price, and a credit variable, the latter of which is defined by interest rate, loan-to-value ratio, and the term of loan in years.

The third major step is to determine the amount of wood material in each architectural type. An unadjusted amount of a specific wood product is defined by a mathematical relationship between the wood volume in a certain end use within the house and the floor area of the house, e.g., square feet of plywood used for subflooring in a two story house of a given floor size. The unadjusted volume in each end use within the house is then adjusted to reflect the number of houses having wood in that particular end use. For example, if only one-third of the one story houses have wooden basement posts, then only one-third of the volume predicted by the relationship between post volume and floor size is carried forward to later steps.

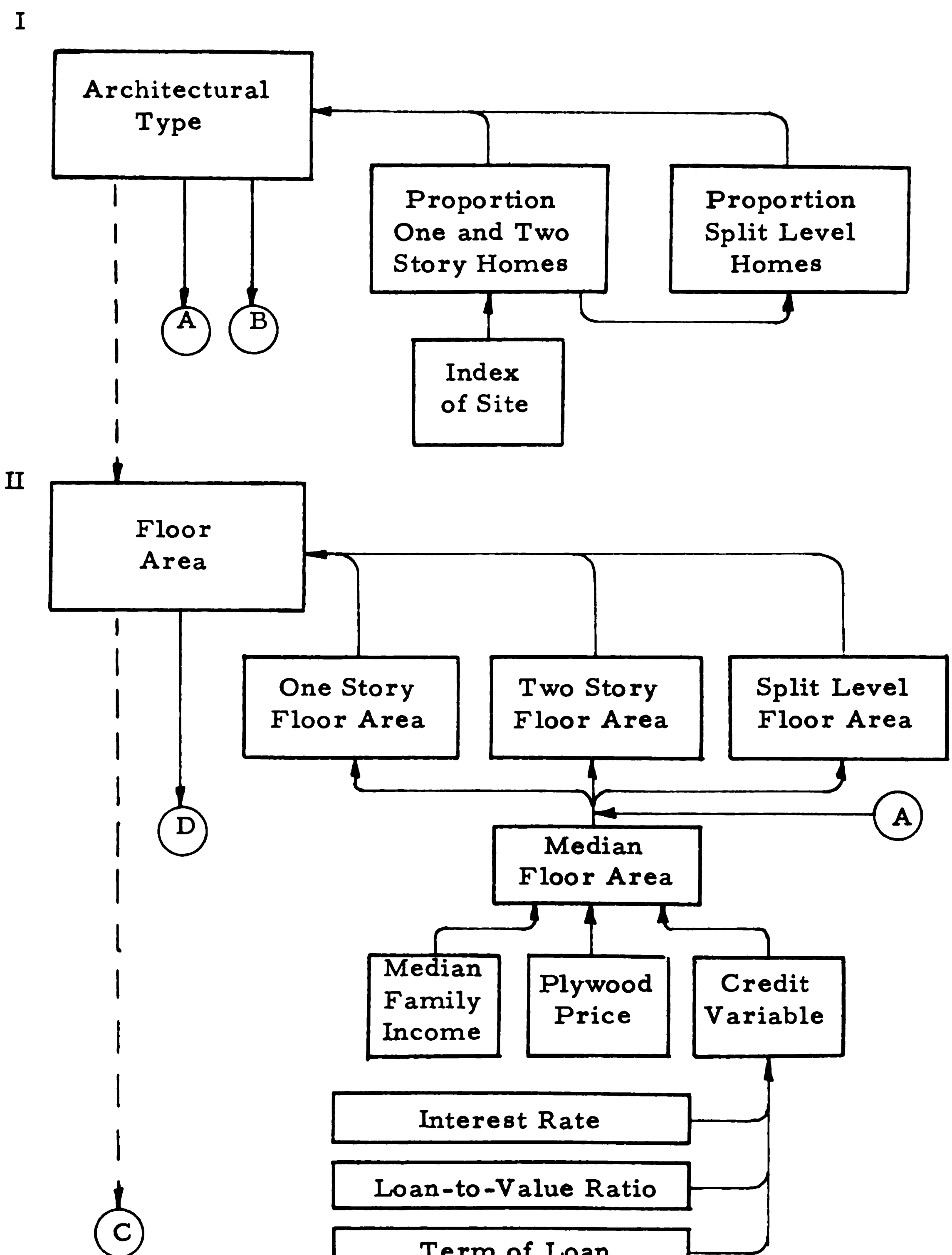


Figure 11. Flow chart of model's operation

Figure 11 (cont'd.)

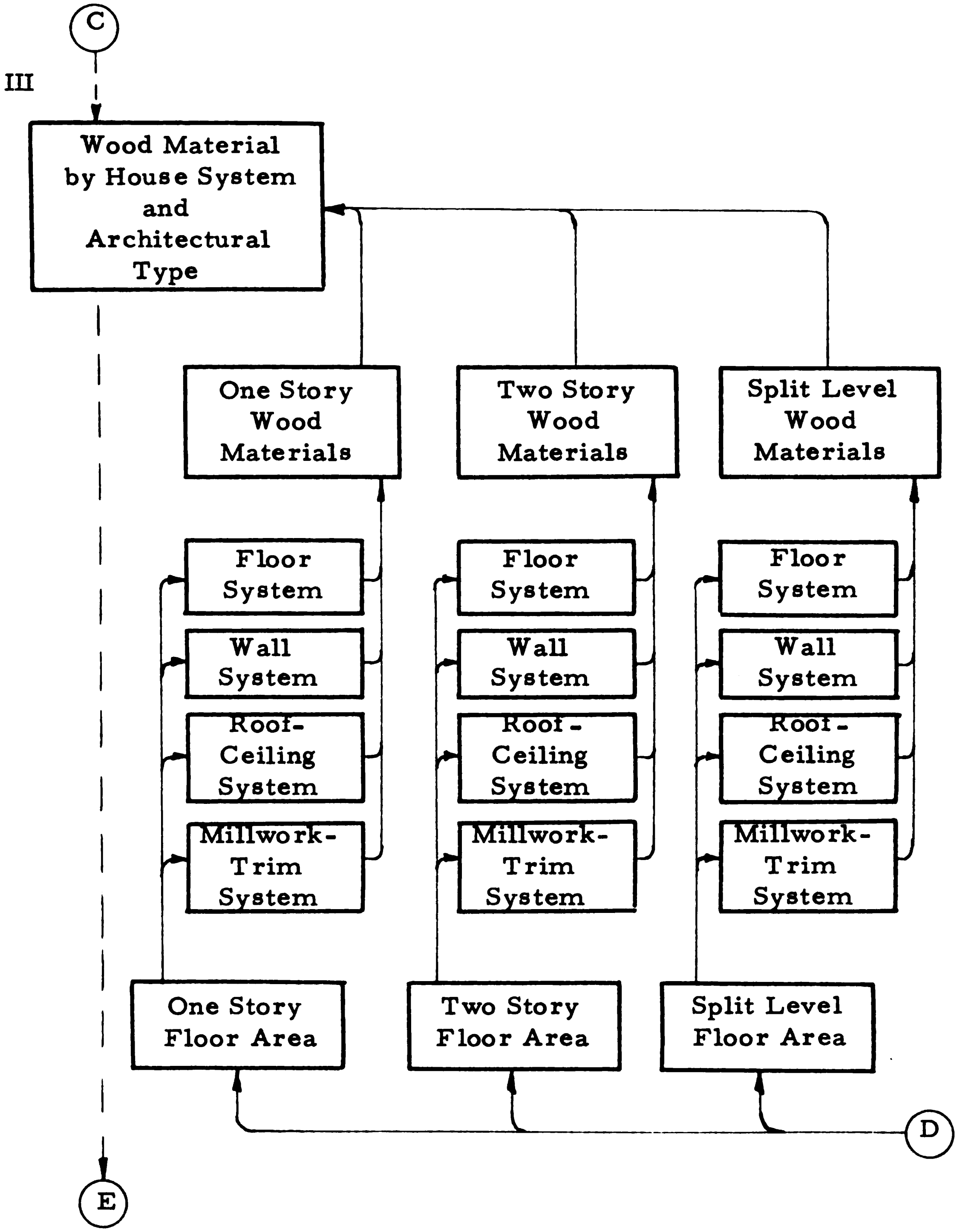
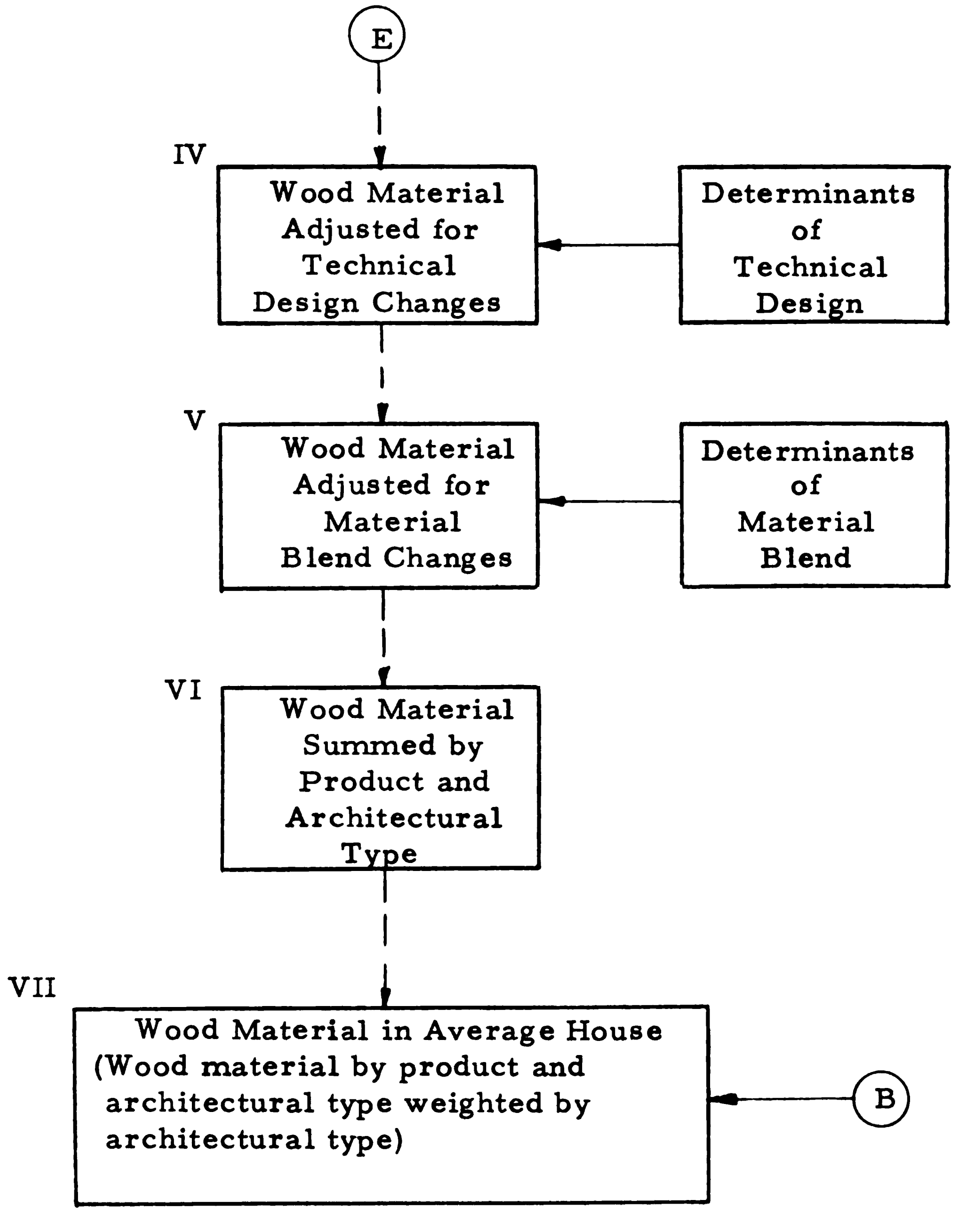


Figure 11 (cont'd)



The fourth major step is one of adding to or subtracting from the wood volume in accordance with anticipated changes in the technical design of the house. The decision rule as to how a change in technical design will affect wood use is defined by the relationship between the technical design element of the structural sector and the other model sectors, or it is defined by assumption.

The fifth step of defining the influence of changes in material blend on wood use is handled in a manner similar to that used in defining the effect of technical design changes.

The sixth major step is simply to sum the volume of wood found in each house system by architectural type.

Seventh, a weighted average volume is determined. This is the volume of various wood materials that will be found in an average house. The weights assigned to the volume of wood in each architectural type are the proportion of one and two story and split level homes founds in the market.

PROJECTIONS

GENERAL

The rate at which wood is used per house is defined by changes in the model's structural sector as directed by forces originating in the model's four remaining sectors. If it is assumed that the technical design and material blend elements remain unchanged during the 1969 to 1985 time span, an estimate of wood use per unit can be defined. The estimate that results when the model is constrainted in this manner is reflection of: (1) changes in the size of the structure as defined by income, credit conditions, and plywood price, and (2) changes in the mix of architectural types as defined by site value. A prediction of lumber and plywood use under such conditions is presented in Figure 12 and Figure 13.

Trends in total lumber use and lumber use by house system are predicted to rise (Figure 12). Between 1969 and 1985 total lumber use per unit rises by more than 4,700 board feet to a 1985 level of 19,555 board feet. Although the trend is upward, the actual rate of increase is declining. Between 1969 and 1970 wood use rises by 334 board feet while the gain has diminished to 250 board feet between 1984 and 1985.

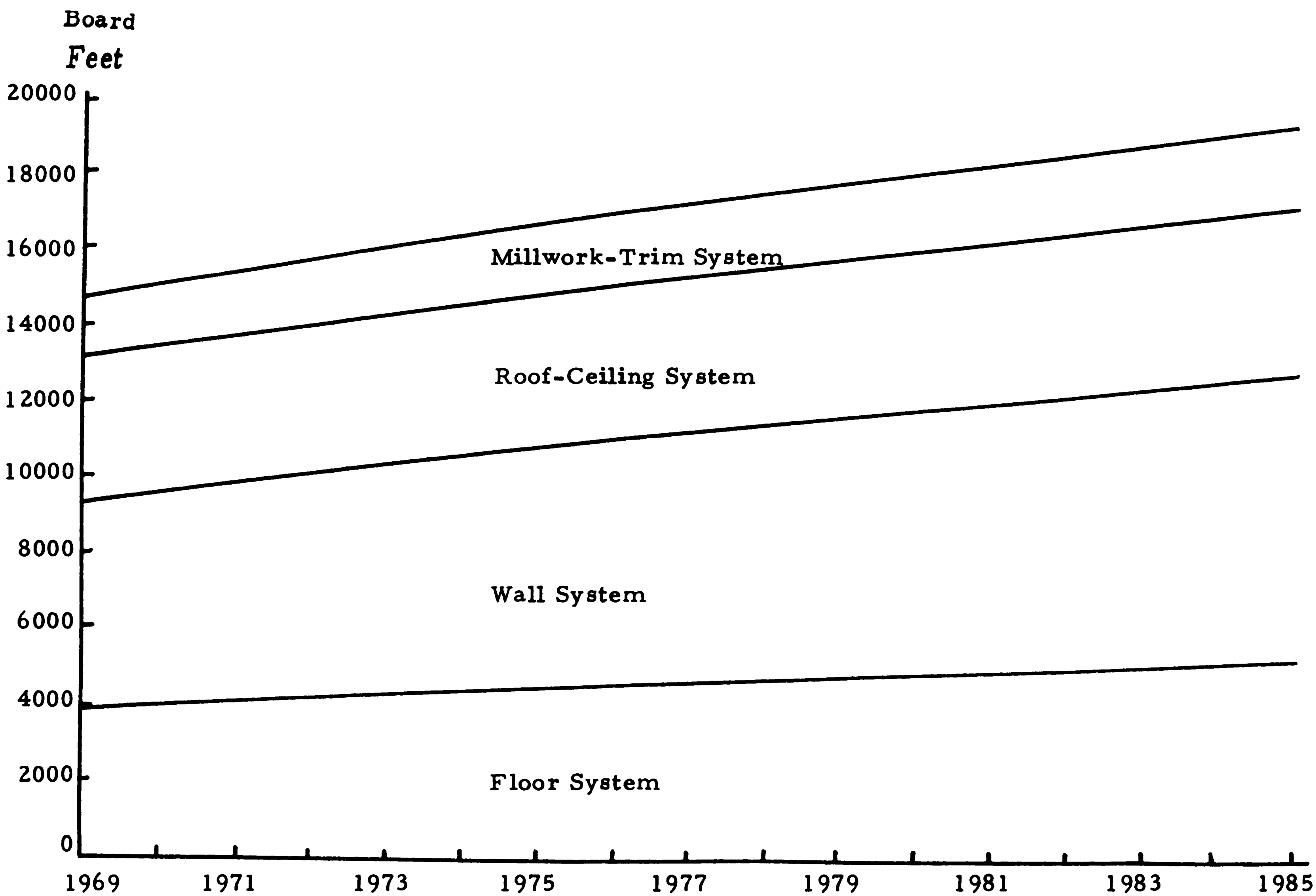


Figure 12. Lumber required per house, by house system, North Central region, 1969-1985.

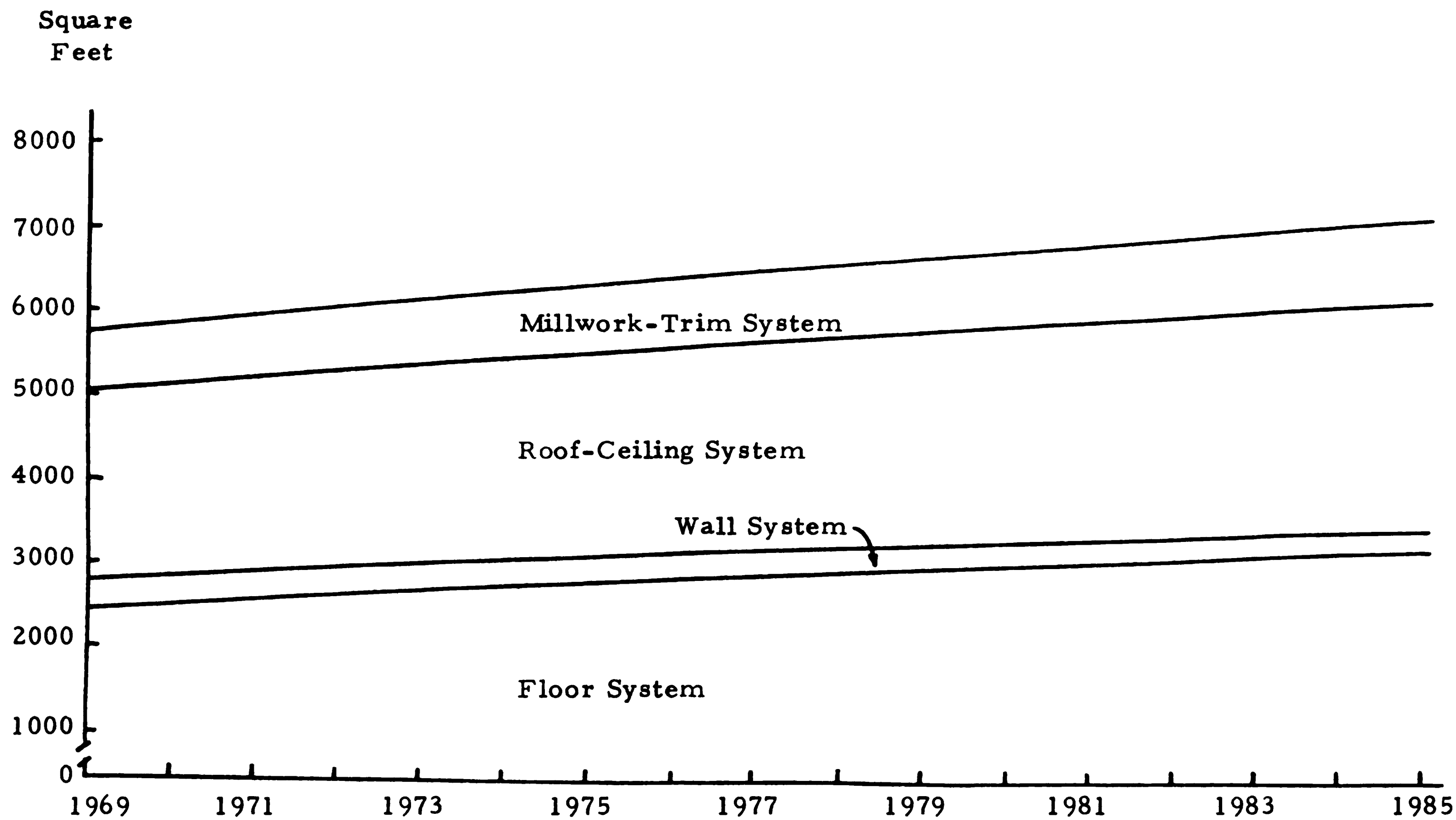


Figure 13. Plywood required per house, by house system, North Central region, 1969-1985.

Lumber used in each house system also is shown to increase (Figure 12). The greatest increase in wood use occurs in the wall system. Between 1969 and 1985, lumber use in the latter system increased more than 1,920 board feet. This is a 34 percent rise over the 1969 level. During the same period, the volume in the floor system rises nearly 38 percent of the 1969 level, an increase of almost 1,440 board feet. The remaining two systems increase approximately 20 percent over their 1969 levels. The millwork and trim system gains 486 board feet while the roof-ceiling system gains 887 board feet. Obviously, the greatest added contribution to total lumber use per unit came from the wall system, i.e., 1,920 board feet.

No major shifts are to be noted in any one system's contribution to total lumber use (Table 15). Between 1969 and 1985 the floor and wall systems accounted for an additional one percent of the total lumber volume per unit. This is apparently at the expense of the roof-ceiling system which declined 2 percent. The millwork-trim system remained the same at 12 percent of the total.

As with lumber, there are definite upward trends in plywood use (Figure 13). Consider total plywood use. For 1969, projected total plywood use is situated at 5,810 square feet. By 1985, it rises to 7,252 square feet, an increase of 1,442 square feet. A declining rate of increase is also noted for plywood.

Table 15. Percent lumber and plywood, by house system, North Central region, 1969 and 1985.

House System	Lumber		Plywood	
	1969	1985	1969	1985
	- - -Percent- - -		- - - Percent - - -	
Floor	26	27	43	46
Wall	38	39	6	4
Roof-Ceiling	24	22	38	38
Millwork-Trim	12	12	13	12
All Systems	100	100	100	100

Plywood use is noted to be rising in all systems except the wall system. From a level of 328 square feet of plywood in 1969, plywood use in the wall system declines to 257 square feet in 1981 and maintains such a rate during subsequent years. In terms of total plywood per house, the wall system is not a great contributor. Consequently, the decline is of minor significance. The greatest contribution to increase in total plywood use comes from the floor system.

The relative share that each system contributes to total plywood use per house changes little in the 1969 to 1985 time period (Table 15). The only shifts of significance occur in the floor and wall systems. The floor system contributes an additional three percent by 1985, a rise that is at the expense of a decline in the contribution made by the wall and millwork-trim systems.

The interval elasticity of total plywood and lumber use per house can be calculated for the period 1969 to 1985. As here defined, elasticity refers to the change in total lumber or plywood use in response to a one square foot increase in floor area. The interval elasticity for total lumber use is 8.8. For total plywood use it is 2.7.

Predicted values for the remaining wood products considered by the model are presented in Appendix A.

SIMULATION EXPERIMENTS

Many of the variables which are hypothesized as affecting wood use per unit have not been included explicitly in the model. These exclusions occur for two reasons: (1) data are not available to represent certain variables, a situation especially true of forces originating in the institutional and technical sectors of the model, and (2) it is extremely difficult to explicitly define how the technical design and material blend elements of the structural sector are tied to the remaining four sectors. Simulation is one means of alleviating these problems. It allows one to observe changes in wood per unit given an assumed level for the undefined variables and relationships. To this end, three basic simulation experiments were undertaken.

Material Blend Simulation

Simulated trends in wood use stemming from changes in the structure's material blend were made under two broad conditions. First, the rates at which the structure's material blend might change were simply assumed. Second, the rates at which the material blend might change were induced by the relative price of wood versus non-wood products.

Assumed rate of change--The framing segment of the floor system and the precut wall studs of the wall system were chosen as logical candidates to be involved in a material blend change. The assumption is that potential nonwood materials capable of serving the function now performed by these wood materials are or will be available.

The framing segment was defined as the following elements of the floor system, each of which requires lumber as a wood product:

Mud sill
Floor joist
Floor skirt
Bridging
I-beam blocking
Tile cleating
Basement posts

It was assumed that the proportion of the homes using wood for the above purposes would decline at rates of 25 percent, 50 percent, and 100 percent between 1969 and 1985. The results of these simulations are presented in Figure 14 along with the trend in wood use that would occur if the technical and material blend elements of the structural sector remain unchanged.

The use of precut wall studs was also assumed to decline at rates of 25 percent, 50 percent and 100 percent during the period 1969 to 1985. The results of this simulation are presented in Figure 15.

Price induced rate of change--Steel joists and steel studs were chosen as logical candidates to replace their counterparts in the floor and wall system of the house. Data problems excluded other products from consideration.

Two decision criteria were imposed on the model. First, nonwood materials became candidates for functions now performed

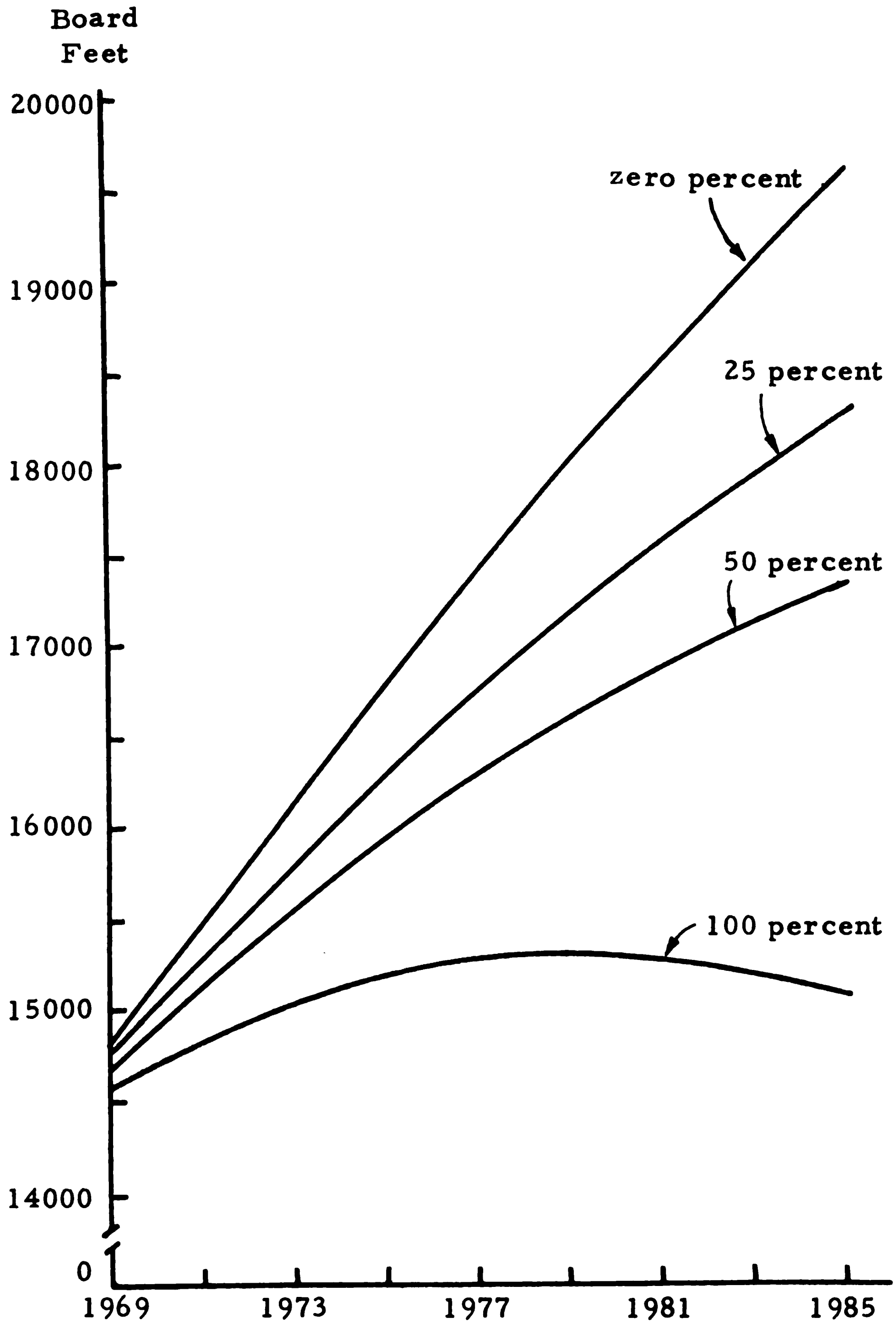


Figure 14. Simulated lumber volume required per house, by rate of decline in homes using wood in floor systems, North Central region, 1969-1985.

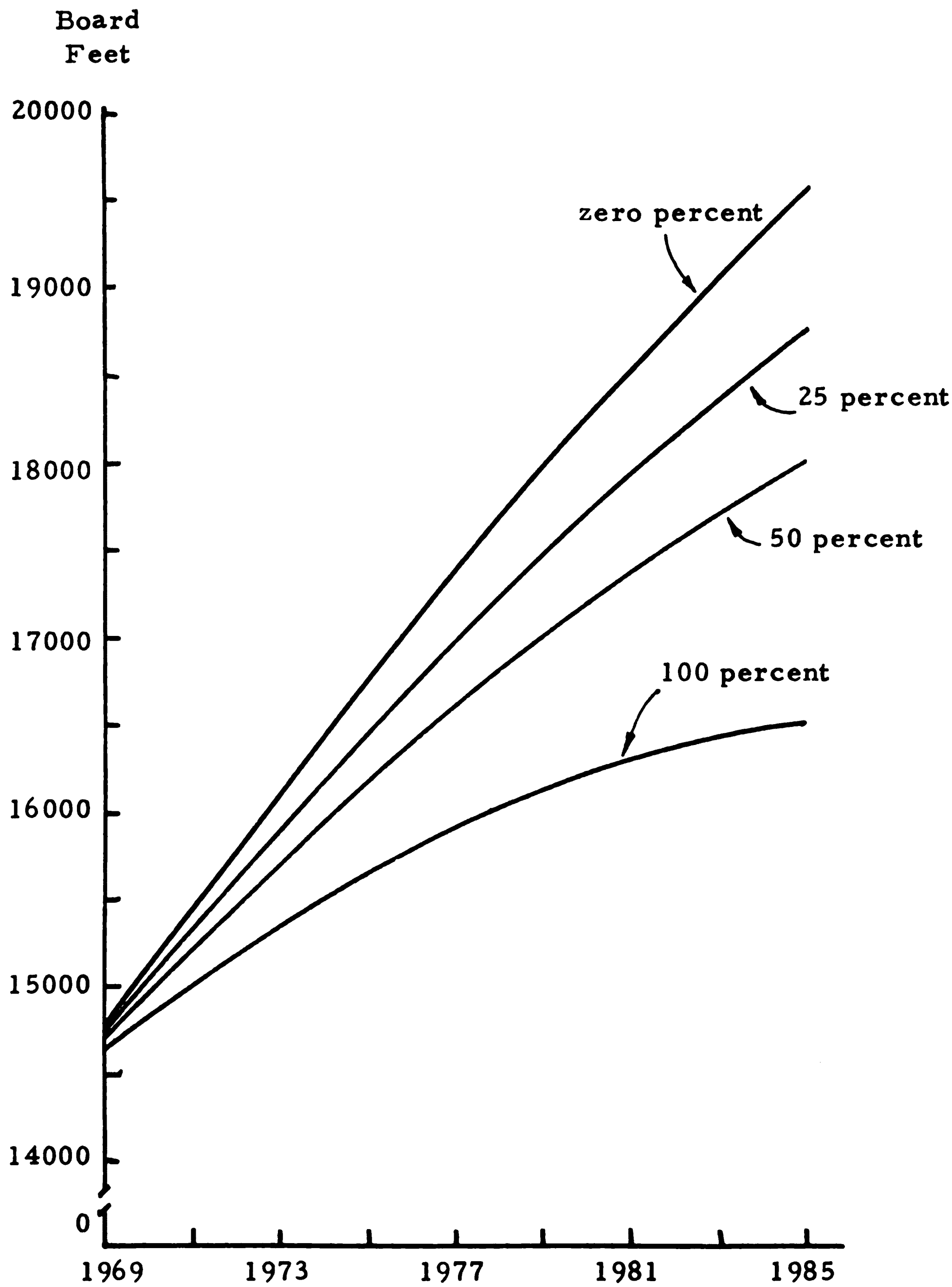


Figure 15. Simulated lumber volume required per house, by rate of decline in homes using wood precut wall studs, North Central region, 1969-1985.

by wood, when the two products became substitutes in terms of relative prices. Secondly, once the products became competitive in terms of relative prices, the proportion of homes using wood was assumed to decline at rates of 50 percent and 100 percent to 1985.

The price of steel and wood floor joists have shown distinct upward trends since 1957 (Figure 16). Graphical extrapolation of these trends indicates that the two products will become price substitutes by 1973. Extrapolation of similar trends observed in the price of steel and wood wall studding implies that these two products will become price substitutes by 1975.

The simulated lumber volume per house given that the steel stud and joist products are actually substituted for wood under the above assumptions is presented in Figure 17, and Figure 18.

Technical Design Simulation

Changes in the technical design element of the model's structural sector can precipitate marked changes in total wood use per house. Although many technical changes can be hypothesized, only the trussed rafter system was chosen for simulation purposes.

The general procedure for this simulation was to replace the more conventional roof framing system with a trussed rafter system. The lumber required of each system was determined, and the rate at which the truss system would replace the conventional system was established by assumption.

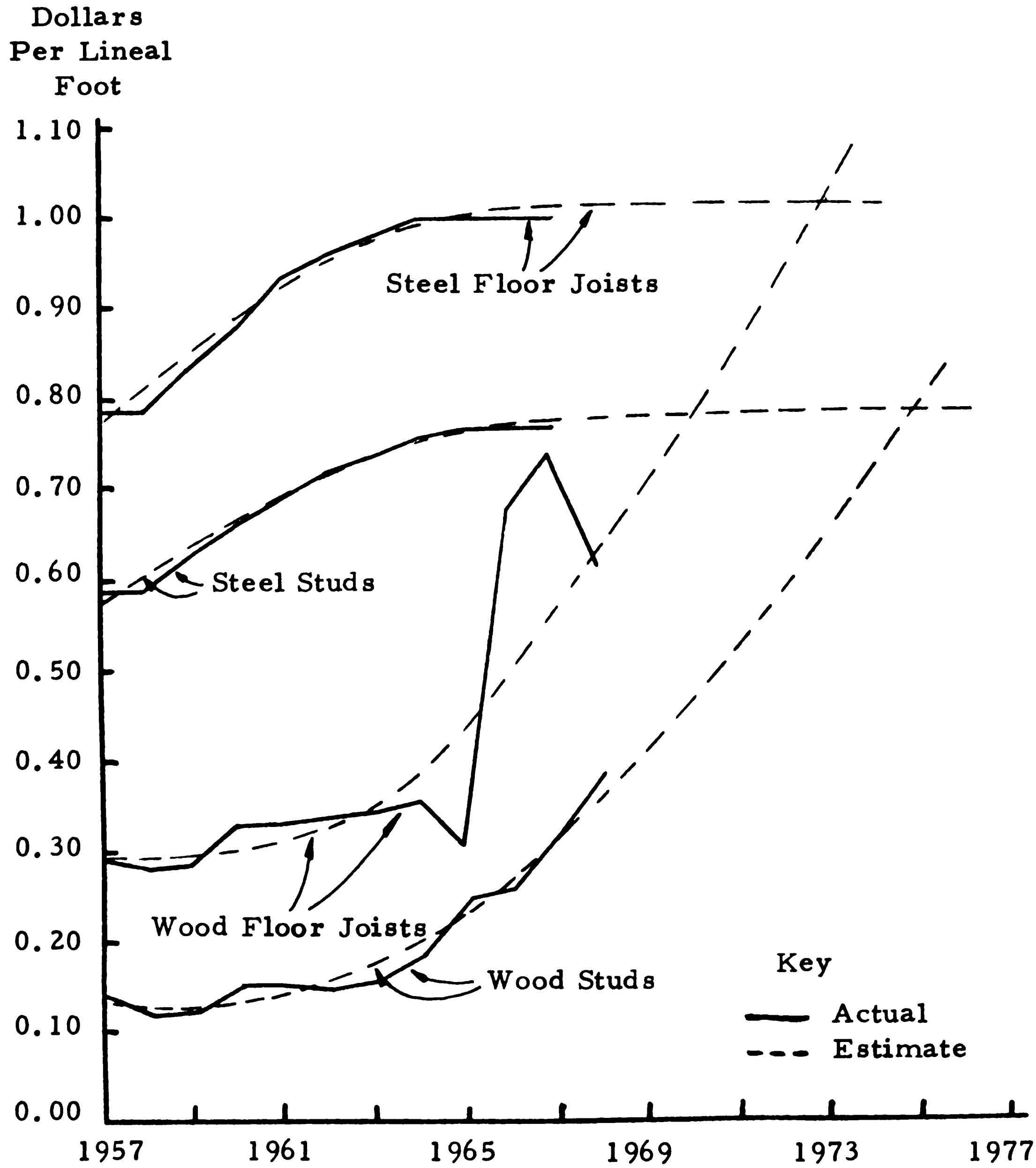


Figure 16. Actual and estimated in-place price of wood and steel floor joists and wood and steel wall studs, North Central region, 1957-1977. (Source: actual data from Gary Moselle. National Construction Estimator, 1958 to 1969-1970 Los Angeles: Craftsman Book Co. 1958-1970.)

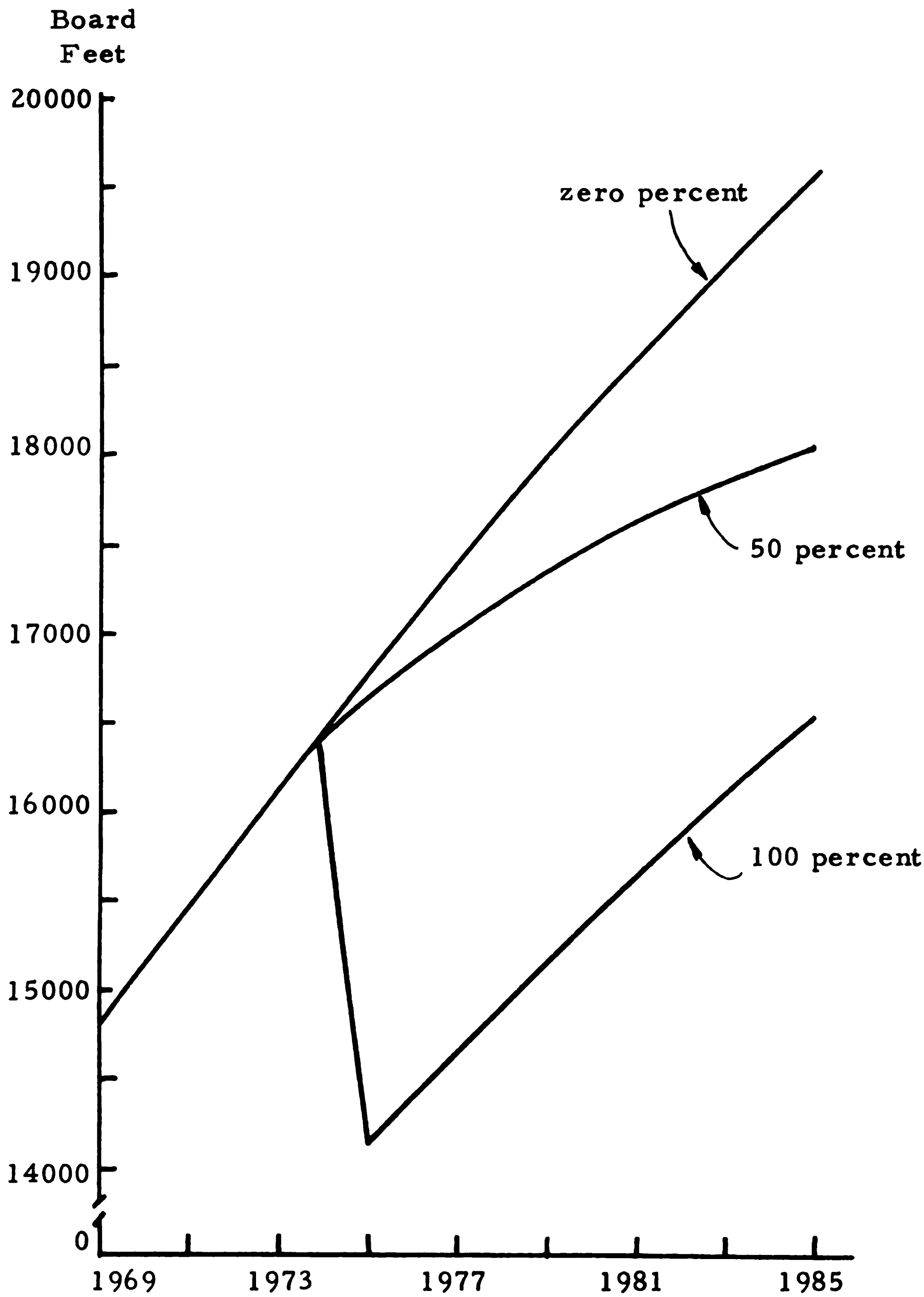


Figure 17. Simulated lumber volume required per house, by price induced rates of decline in homes using wood precut wall studs, North Central region, 1969-1985.

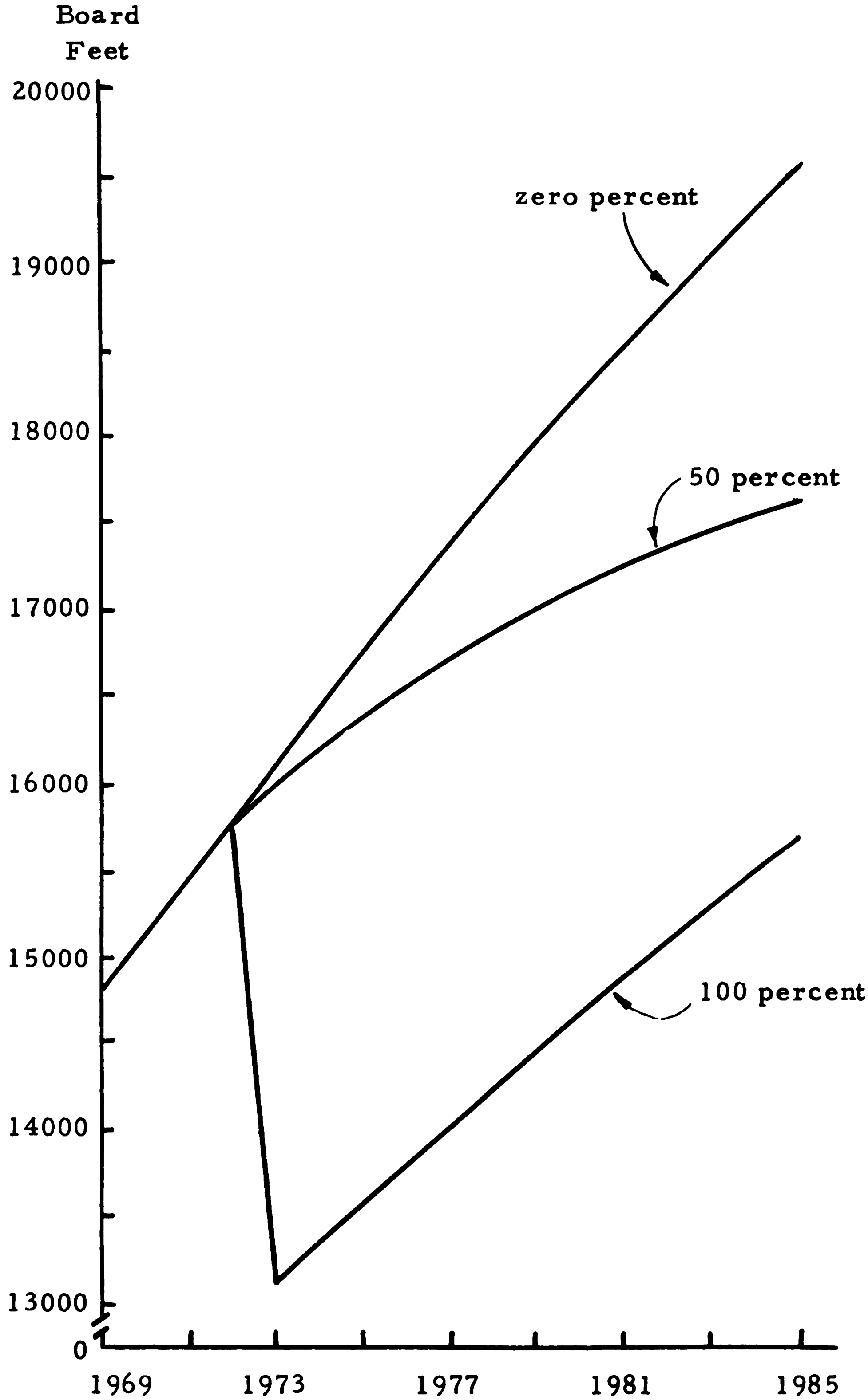


Figure 18. Simulated lumber volume required per house, by price induced rates of decline in homes using wood floor joists, North Central region, 1969-1985.

The lumber required of a conventional roof system was determined from the sample homes previously discussed. For a house of dimensions 50 feet by 30 feet, the materials and their volumes are as follows:

Ceiling joists	864
Garage collar ties	408
Common rafters	2,104
Rafter blocking	24
Collar ties	160
Knee wall studs and plates	341
Ridge board	43
Garage truss	95
Total	4,039 board feet

The lumber required of a truss system was calculated in two steps. First, the wood volume required of a standard W-truss was calculated (Smith, 1963 and National Lumber Manufacturers Association, 1963). The house of dimensions stated above required trusses 30 feet in length with a 12/5 slope and a 24 inch overhang. The materials and volume for such a truss are as follows:

Rafters	
2 pieces 2" x 6" by 18'6"	38.0
Bottom chord	
1 piece 2" x 4" by 30'4"	20.0
Tension webs	
2 pieces 1" x 8" by 8'4"	11.3
Compression webs	
2 pieces 2" x 4" by 4'0"	5.3
Compression web reinforcements	
2 pieces 1" x 6" by 4'0"	4.0
Splices	
4 pieces 1" x 4" by 4'0"	4.0
2 pieces 1" x 6" by 3'0"	3.0
1 piece 1" x 8" by 4'0"	2.6
Total	88.2 board feet

Second, the total volume of wood required of the entire truss rafter system was determined. Assuming trusses spaced 24 inches on center, 26 trusses are required for a house 50 feet long. At 88.2 board feet per truss, the total truss system required 2,293 board feet. This is approximately 1,746 board feet less than required of a conventional roof system for a comparable house.

Figure 19 depicts the simulated wood volume given the assumptions that 100 percent of the homes will use the truss system by either 1975 or 1985. No consideration was given to variation in truss system volume due to changes in floor size.

Floor Area Simulation

Floor area is also an important determinant of wood use per unit. Although predicted floor area is provided by the model's estimated equation, two alternative rates of change in floor area were simulated.

First, the median floor area for all architectural types was assumed to attain a level in 1985 that would be 24 percent higher than the 1968 level. This implied that median floor area would rise at a rate of 22 square feet per year to a level of 1,950 square feet in 1985. This level is 215 square feet or 10 percent less than the 1985 level (2,165 square feet) predicted by the model's estimated equation.

Second, the median floor area for all architectural types was assumed to attain a level in 1985 which would be 51 percent greater

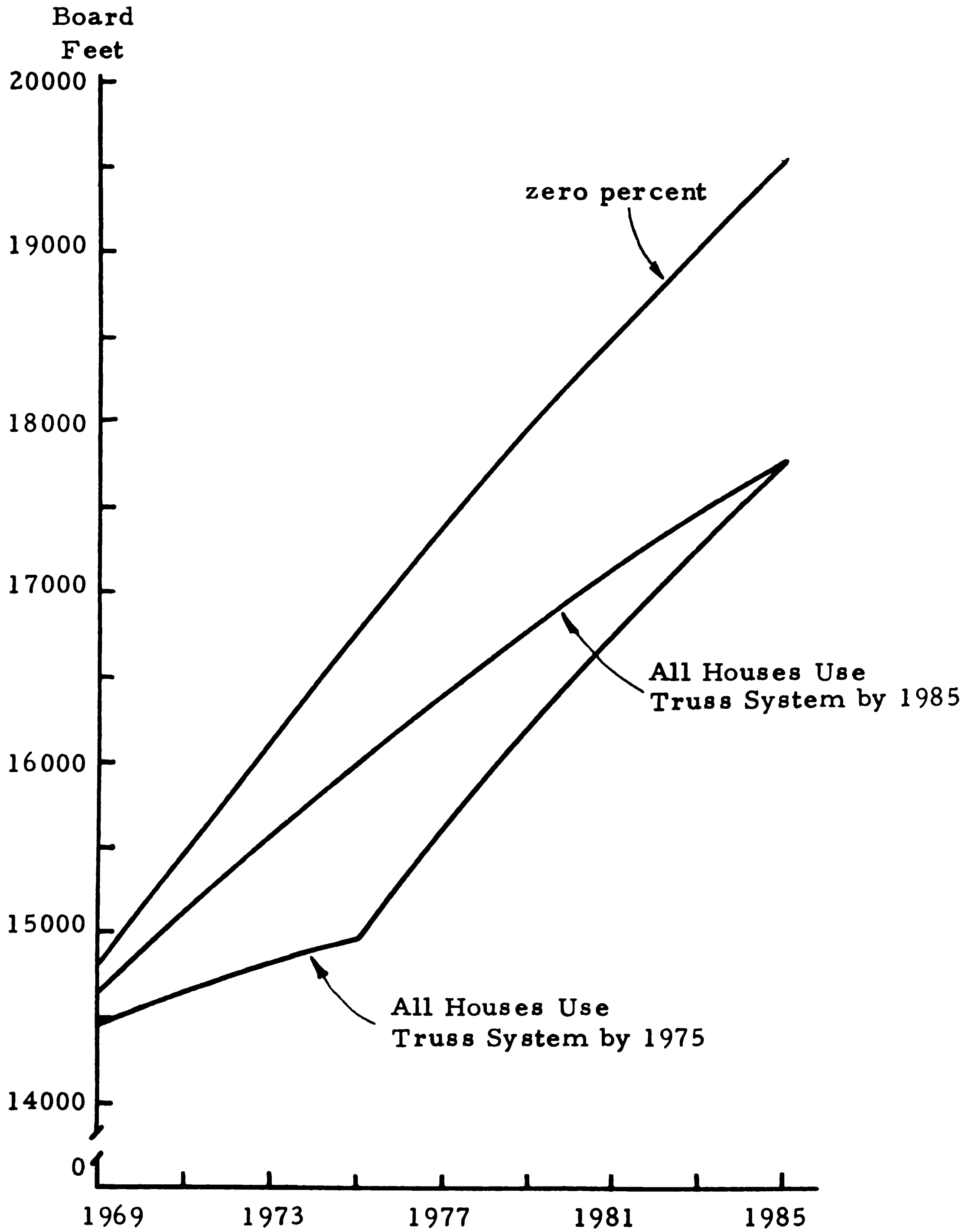


Figure 19. Simulated lumber volume required per house, by rate of increase in homes using truss rafter systems, North Central region, 1969-1985.

than the 1968 level. At this rate--47 square feet rise per year--the 1985 floor area would be 2,380 or 10 percent larger than that provided by the model's estimated equation for the same year.

The simulated results which reflect alternate rates of increase in floor area are presented in Figure 20 and Figure 21.

Examination of lumber use per house reveals that in 1985 a 10 percent decline in floor area reduced lumber use by 1,901 board feet or 9.75 percent less than lumber use based on floor area provided by the model's estimated equation. A floor area 10 percent larger in 1985 implies an additional 1,901 board feet or 9.75 percent more.

Similar results occur in the case of plywood (Figure 21). A 10 percent decline in 1985 floor area results in a decline of 651 square feet of plywood. Conversely, a 10 percent rise in floor area increases plywood use per unit in a like amount--651 square feet.

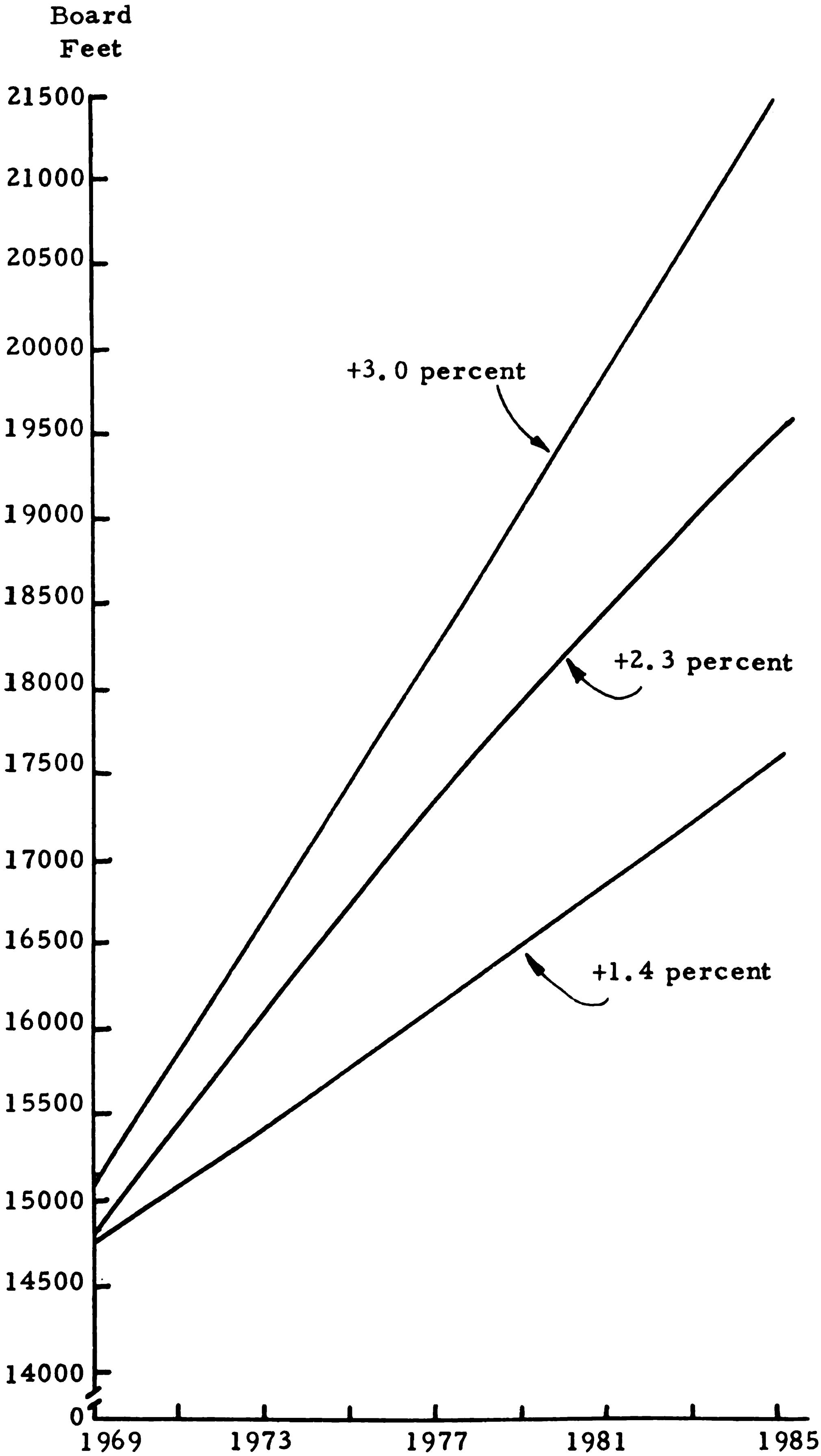


Figure 20. Simulated lumber volume required per house, by average yearly rate of change in floor area, North Central region, 1969-1985.

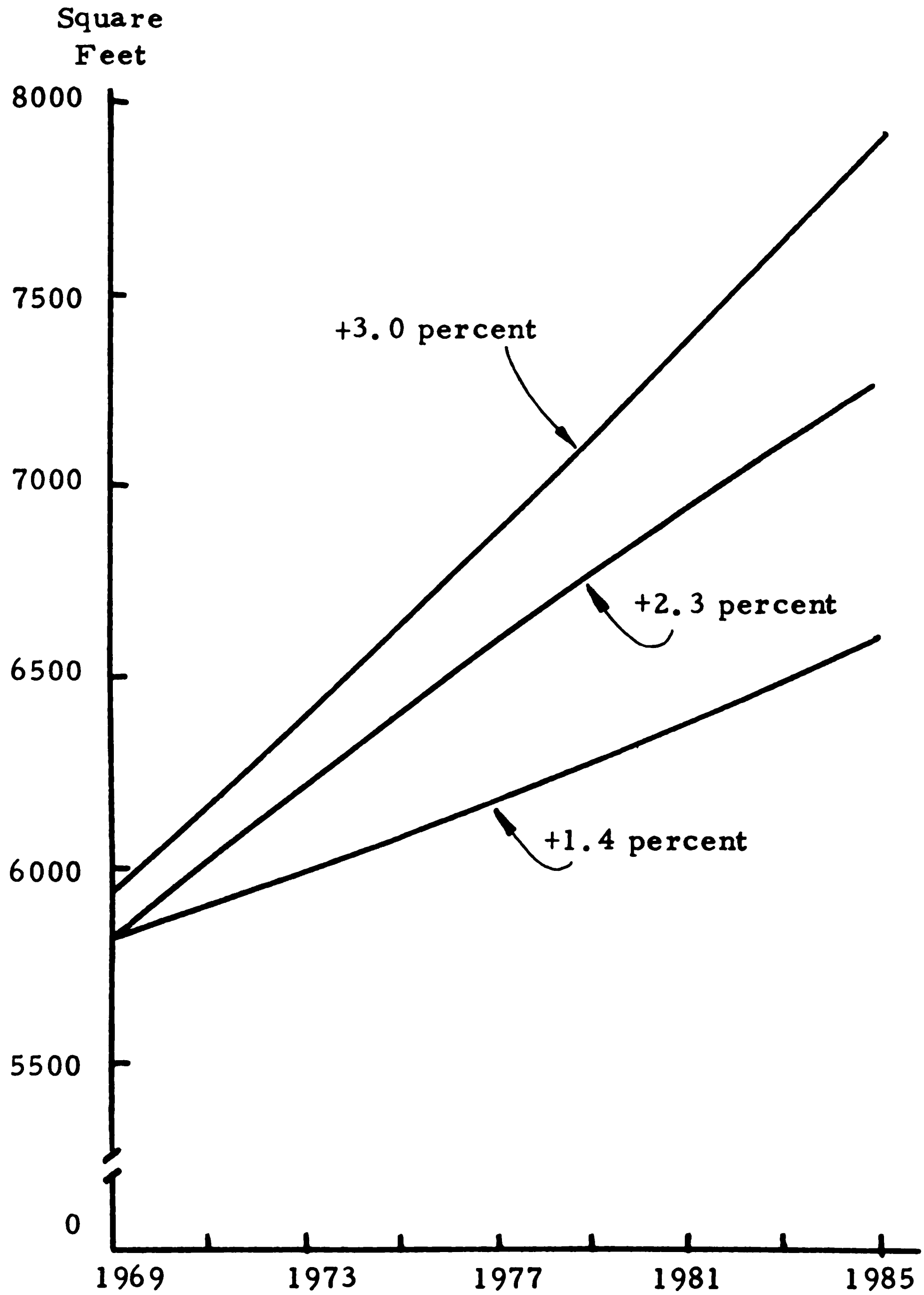


Figure 21. Simulated plywood requirements per house, by average yearly rate of change in median floor area, North Central region, 1969-1985.

SUMMARY AND CONCLUSIONS

A dynamic regional model of the system which defines wood use in new single-family homes was developed. It is composed of five sectors, four of which contain the basic determinants of wood use in new single-family houses. These basic sectors are: (1) the consumer sector, (2) the builder sector, (3) the technical sector, and (4) the institutional sector. These sectors contain wood use determinants, some of which are: the consumer's income available for housing and his preferences for the physical features of a house; the builder's preference for construction materials and methods and the cost of such materials and methods; the methods and materials available for housing as determined by advances in technology; and various institutional factors such as zoning ordinances and subdivision regulations. Such determinants are hypothesized as ultimately controlling the amount of wood material that will be used in a new single-family house. Their role is one of forcing change to occur in a group of intermediate determinants located in the model's fifth sector, the structural sector.

The structural sector of the model encompasses those easily identified physical features of the house upon which the consumer, producer, technical and institutional determinants act. This sector acts as a converter, in that it transforms changes in abstract variables such as income and cost to changes in the amount of wood material that is used in the new house.

The structural sector of the model is composed of four elements, a change in any of which will cause a change in the amount of wood material required in a new house. These elements are: (1) structural style as defined by number of stories, (2) structural size as defined by floor area, (3) technical design as defined by engineering considerations peculiar to house construction, and (4) material blend or mixture of construction materials used in the house.

The model explicitly defines the relationships between the determinants of wood use and the volume of wood used. These relationships were defined in two steps. First, the elements of the consumer, builder, technical, and institutional sectors were linked to the elements of the structural sector. And second, the elements of the structural sector were linked to actual wood use. By defining such relationships, the determinants located in the consumer, builder, technical, and institutional sectors were related explicitly to actual wood use via their link with elements of the structural sector.

Single and multiple regression techniques relate the elements of the structural sector to the other sectors. Of the variables hypothesized as affecting floor area, three were found to be significant. They are: median family income, the plywood wholesale price index, and a credit variable. More than 99 percent of the variation in floor area was explained by these three determinants. The credit variable was composed of the interest rate, the length of loan, and the loan-to-value ratio.

An index of site value (lot value) was determined to be significant in explaining variation in the proportion of one and two story homes found in the market. The proportion of split level homes was set as that proportion remaining after the proportion of one and two story homes had been accounted for.

The relationships between elements of the structural sector and actual wood use were defined for various end uses of wood within each system of the house. A sample of 100 new single-family homes located in the North Central region was instrumental in determining these relationships. Via regression techniques, the amount of wood used in various end uses within the house was related to floor area for each architectural type. Of the 152 equations estimated, an average of 28% of the variation in wood use was explained by floor area. Floor area was closely related to wood use in those end uses which account for a relatively large portion of the wood volume used per house, e.g., 92 percent in the case of two story precut wall studs.

The various sectors of the model were brought together in such a manner that the dynamic features of the system were preserved.

As the model moves through time, it explicitly considers many of the forces which are thought to have determined past rates of wood use. For example, changes in wood use stemming from changes in the structure's size are explicitly considered, as are the affects of changes in architectural type. Further, as changes occur in the structure's material blend, changes are made accordingly in the wood used per house. The affect of technical design is similarly accounted for. By considering all these forces explicitly and simultaneously, the model is capable of capturing the dynamics of the system which defines wood use per house.

Predictions of wood use to the year 1985 were made with the model. A base prediction of wood use was first defined. It assumes that the technical design and material blend sectors of the model will remain unchanged during the predicting period. As such, the predictions are reflective only of: (1) changes in the size of the structure and the determinants of size, and (2) changes in the mix of architectural types as defined by site value.

Constrained in the above manner, the model generates predictions of wood use per house which display definite upward trends. For the predicted years 1969 to 1985, total lumber use per house rises from 14,823 board feet to 19,555 board feet. Similarly, total plywood use rises from a predicted level of 5,810 square feet in 1969 to 7,252 square feet in 1985. Rising trends are also noted for the remaining five wood products considered by the model, i.e., particleboard, hardboard, composition board, wood lath, and shakes and shingles.

Although the trends in wood use as generated by the model are rising, the rate at which they increase is definitely declining. For example, between 1969 and 1970, lumber use per house increased by 334 board feet, while the gain diminished to 250 board feet between 1984 and 1985. This declining rate of increase is explained by the nonlinear nature of predicted trends in both the floor area of the house and the proportion of each architectural type existing in the market (i.e., one story and split level homes).

Certain complex relationships between the structural sector and the four remaining sectors are not explicitly defined in the model. Such is the case with forces originating in the institutional and technical design sectors. In such cases, simulated trends in wood use per house were made. Such trends are based on assumptions about: (1) material blend, (2) technical design, and (3) structural size.

Simulated trends in wood use stemming from changes in the structure's material blend were made under two broad conditions. First, the rates at which the structure's material blend might change were assumed. Under such conditions, the proportion of homes using wood material for (1) floor framing material and (2) for precut wall studs was assumed to decline by 25 percent, 50 percent, and 100 percent by 1985.

A 25 percent decline in floor framing material implies that total lumber use per house will rise to a level of 18,318 board feet by 1985. A 100 percent decline implies that lumber use per house will attain a level of 15,103 board feet by 1985. These two simulated levels are 1,237 board feet and 4,452 board feet less, respectively, than that expected in the same year if technical design and material blend conditions continue unchanged to 1985.

Removal of precut wall stud material at rates of 25 percent and 100 percent implies that total lumber volume will be 18,795 board feet and 16,527 board feet, respectively, in 1985. Thus a decline in the use of wood floor framing material has a greater affect on total lumber use than a similar decline in the use of precut wood wall studs.

The second broad condition under which material blend was changed assumed that such changes were induced by the relative price of wood and nonwood products. Wood and steel joist price trends indicate that these two products will become price substitutes by 1973. If after 1973, the use of wood joists declines to the 50 percent level, the total lumber volume per house in 1985 will be at a level of 17,630 board feet. Further, the trend in the price of steel and wood wall studs indicates that these two products will become price substitutes by 1975. The replacement of wood studs with steel studs after that date implies that the total lumber volume per house in 1985 will be 18,041 board feet.

Replacement of wood joists and studs with their steel counterparts results in 1,925 board feet and 1,514 board feet less in 1985, respectively, than the volume expected if past trends in material blend and technical design remain unchanged to 1985.

Simulated trends in wood use stemming from a change in the structure's technical design were examined. Of major concern was the replacement of a conventional roof framing system with a trussed rafter system. If all 1985 homes are constructed with a truss system, the total lumber volume per house will be 17,809 board feet in that year. This is 1,746 board feet less than expected if past changes in technical design and material blend continue to 1985.

Simulated trends in wood use resulting from alternative rates of change in floor area were also examined. If floor area rises at rates of 22 and 47 square feet per year, the lumber volume expected per house in 1985 is 17,654 board feet and 21,456 board feet, respectively. The former volume is 9.75 percent less and the latter volume 9.75 percent more than that volume expected if the model's estimated floor area equation is used, and if trends continue in the technical design and material blend of the house.

The objectives of the study required that a careful review be made of the system which defines wood use in single-family homes. This experience, and that subsequently gained during the model's construction and operation, should prove valuable in guiding future research work on similar topics. Five major considerations are listed below.

First, the model presents a base format from which to begin future studies of wood use in single-family homes. Its modular nature allows each sector to be removed and subsequently investigated as a separate study. The decision as to which sector to study can be guided by the sensitivity of wood use to the various sectors.

Second, the model presents only an introduction to the importance and complexity of the technical design and material blend elements of the structural sector. A more thorough review of how these elements are related to other sectors of the model is needed. Simulated trends in wood use have indicated that changes in technical design and material blend can have considerable impact on wood use.

Third, the technical and institutional sectors of the model also deserve more attention than offered them during the course of the study. Their role in defining wood use is largely unknown. Especially crucial are changes in technology which precipitate new technical designs. Componentized homes or "factory-produced" homes are an example of the latter.

Fourth, it is strongly suggested that the model be reviewed and updated as is deemed appropriate. Such a suggestion is made in light of the rather unusual conditions which have surrounded the construction market in recent years, e.g., relatively large increases in construction and financing costs (U.S. Congress, 1969).

Fifth, the method of analysis used in this study can be applied to other demand sectors within the forest economy (e.g., nonresidential construction, shipping materials, and manufactured products) and to supply. Such applications would result in comprehensive models of a regional timber market and could ultimately be used to evaluate national timber supply and demand relationships.[13]

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[13]This study was undertaken concurrently with a study of the rate at which new dwelling units are established (Simulated long-run housing requirements by type and region. A Doctor of Philosophy thesis by Thomas Marcin, on file with the Department of Forestry, Michigan State University. 1970.)

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APPENDIX

APPENDIX A

Table A1. Wood use per house, by product type, North Central region, 1969-1985.

Year	Wood Product						
	Lumber	Plywood	Particle-board	Hardboard	Composition Board	Wood Lath	Shakes and Shingles
	Board Feet	Square Feet	Square Feet	Square Feet	Square Feet	Bundles	Squares
1969	14824	5810	90	164	1585	1	2
1970	15157	5911	94	171	1612	1	2
1971	15485	6011	97	178	1639	1	2
1972	15808	6108	101	184	1666	2	2
1973	16127	6204	104	191	1693	2	2
1974	16442	6299	108	197	1720	2	2
1975	16754	6392	111	204	1746	2	3
1976	17063	6484	114	210	1773	2	3
1977	17370	6576	118	217	1799	2	3
1978	17674	6666	121	223	1826	2	3
1979	17975	6756	124	229	1852	2	3
1980	18254	6843	126	234	1870	2	3
1981	18525	6928	128	238	1886	2	3
1982	18790	7011	130	243	1902	2	3
1983	19050	7093	131	247	1918	2	3
1984	19305	7173	133	252	1933	2	3
1985	19555	7252	134	256	1948	2	3

APPENDIX B

Table A2. Wood use per house, by wood product, architectural type, and house system, North Central region, 1968.

House System and Wood Product	Architectural Type: One Story	Architectural Type: Two Story	Architectural Type: Split Level	All Architectural Types
Floor				
Lumber (board feet)	3782	6059	3448	4363
Plywood (square feet)	2582	3766	2120	2855
Particleboard (square feet)	92	182	83	115
Wall				
Lumber (board feet)	5573	8916	5943	6513
Plywood (square feet)	375	187	394	326
Composition Board (square feet)	1585	2201	1399	1732
Hardboard (square feet)	132	274	160	173
Lath & Plaster Grounds (bundles)	1	2	1	1
Roof-Ceiling				
Lumber (board feet)	4961	4838	3222	4754
Plywood (square feet)	2816	2958	2356	2808
Shakes & Shingles (squares)	*	5	0	1
Millwork-Trim				
Lumber (board feet)	1990	1989	1930	1984
Plywood (square feet)	889	959	816	901

*Less than one square

Source: Data are based on a sample of homes constructed in the North Central region in 1968.

APPENDIX C

Table A3. Wood use per house, by wood product and architectural type, North Central region, 1968.

Wood Product	Architectural Type			All Architectural Types
	One Story	Two Story	Split Level	
Lumber (board feet)	16306	21802	14543	17614
Plywood (square feet)	6662	7870	5686	6890
Particleboard (square feet)	92	182	83	115
Composition Board (square feet)	1585	2201	1399	1732
Hardboard (square feet)	132	274	160	173
Shakes & Shingles (squares)	*	5	0	1
Lath and Plaster Grounds (bundles)	1	2	1	1

*Less than one square

Source: Data are based on a sample of homes constructed in the North Central region in 1968.

APPENDIX D

Table A4. Exogenous variables, 1969-1985

Year	Index of median family income, North Central region (1957=100)	National contract interest rate (percent)	National loan term to maturity (years)	National loan-to-value ratio	National softwood plywood wholesale price index (1957-59=100)	National FHA index of site value (1952=100)
1969	166.3	6.8	24.8	0.693	91.9	183.2
1970	171.9	7.1	25.0	0.692	91.3	190.8
1971	177.4	7.3	25.2	0.691	90.6	198.4
1972	182.9	7.6	25.3	0.689	90.0	206.0
1973	188.4	7.8	25.5	0.688	89.3	213.6
1974	194.0	8.1	25.7	0.687	88.7	221.3
1975	199.5	8.3	25.9	0.686	88.1	228.9
1976	205.0	8.6	26.1	0.684	87.4	236.5
1977	210.6	8.8	26.2	0.683	86.8	244.1
1978	216.1	9.1	26.4	0.682	86.2	251.7
1979	221.6	9.4	26.6	0.681	85.5	259.3
1980	227.1	9.6	26.8	0.679	84.9	267.0
1981	232.7	9.8	27.0	0.678	84.2	274.6
1982	238.2	10.1	27.2	0.677	83.6	282.2
1983	243.7	10.4	27.4	0.676	83.0	289.8
1984	249.2	10.6	27.5	0.675	82.3	297.4
1985	254.8	10.9	27.7	0.673	81.7	305.0

APPENDIX E

End Uses of Wood Defined for Each House System

APPENDIX E

A. Floor System

1. Dimension lumber

   a. mud sill
   b. floor and platform joists
   c. floor skirt
   d. bridging (rough and solid)
   e. I-beam blocking
   f. tile cleating
   g. basemenet posts
   h. miscellaneous blocking

2. Subfloor sheathing

   a. boards
   b. plywood

3. Underlayment

   a. plywood
   b. particleboard

4. Finish flooring

   a. oak
   b. ranch plank
   c. parquet

B. Wall System

1. Dimension lumber

   a. precut exterior and partition wall studs
   b. shoulder studs
   c. gable stud
   d. garage studs
   e. bath wall studs
   f. miscellaneous studding
      (1) party walls
      (2) corridor walls
      (3) knee walls
      (4) load bearing partitions
      (5) basement stair studs
   g. exterior and interior partition wall plates
   h. bath wall plates
   i. miscellaneous plates
      (1) partition plates
      (2) basement stair plates

j. posts
    (1) wall posts
    (2) porch posts
    (3) porch post boxing
k. partition backing
l. miscellaneous blocking and furring
    (1) miscellaneous blocking and furring
    (2) outer wall ribbon
    (3) drop ceiling furring
    (4) plaster grounds
m. corner braces
n. headers
o. lath
p. frieze
q. beams
    (1) solid (dimension)
    (2) laminated

2. Exterior wall sheathing

    a. composition board
    b. plywood
    c. boards

3. Siding

    a. wood siding
        (1) bevel siding
        (2) T and G vertical paneling
        (3) rough cut red cedar
        (4) vertical grain redwood
        (5) battens
    b. plywood
        (1) reverse batten rough sawn plywood
        (2) exterior plywood
    c. hardboard
        (1) vinyl
        (2) masonite Weather-X
        (3) Tex 1-11 (Celotex)

C. Roof and Ceiling System

1. Dimension lumber
    a. ceiling joists
    b. rafters, rafter blocking, and chimney headers
        (1) common rafters
        (2) jack rafters

(3) cripple rafters
(4) hip and valley rafters
(5) rafter blocking
(6) chimney headers

c. collar ties
d. ridge boards
e. roof joist
f. garage collar ties and W-braces
g. mock beam blocking
h. rough cornice material
   (1) lookout ribbon (ledger)
   (2) lookouts
   (3) subfascia (rough)

2. Sheathing

   a. plywood
   b. boards

3. Shingles

   a. hand split shakes
   b. red cedar shingles

D. Millwork and Trim

1. Kitchen cabinets - lumber

2. Kitchen cabinets - plywood

3. Windows

   a. double-hung
   b. bow window
   c. sliding windows
   d. casement window
   e. awning window
   f. stationary window
   g. stationary triplet
   h. picture window

4. Doors

   a. interior
      (1) interior swing door
      (2) patio/sliding glass door
      (3) bifold door
      (4) pocket door

b. exterior
   (1) single swing door
   (2) double swing door
c. garage door (overhead door casing)

5. Soffit board (finish)

6. Soffit plywood (finish)

7. Fascia

8. Interior base moulding

9. Interior wall paneling

   a. V-grove knotty pine
   b. red cedar board

10. Miscellaneous exterior trim (board feet)

   a. rake board
   b. corner boards
   c. trim boards
   d. brick moulding
   e. bed moulding
   f. cove moulding
   g. rake moulding
   h. porch trellis
   i. planter box
   j. 3/4 round moulding
   k. 1/2 round moulding
   l. fence framing
   m. balcony railing and balcony brackets
   n. miscellaneous exterior trim
   o. shutters
   p. exterior porch ceiling boards
   q. duck boards

11. Miscellaneous exterior trim (square feet)

   a. exterior porch ceiling plywood
   b. exterior plywood trim panels
   c. gable extension and overhang

12. Stairs

    a. stair handrail
    b. stair stringers
    c. stair treads
    d. stair risers
    e. stair posts
    f. stair platform

APPENDIX F

Computer Program

APPENDIX F

```
      PROGRAM HOUSE (INPUT,OUTPUT)
C
C
C
C                          PROGRAM HOUSE
C                               BY
C                        PAUL V. ELLEFSON
C          DEPARTMENT OF FORESTRY, MICHIGAN STATE UNIVERSITY
C
C
C
      DIMENSION PSYS11(13),PSYS12(13),PSYS1S(13),PSYS21(21),PSYS22(21),
     1PSYS2S(21),PSYS31(12),PSYS32(12),PSYS3S(12),PSYS41(14),PSYS42(14)
     2,PSYS4S(14),VSYS11(13),VSYS12(13),VSYS1S(13),VSYS21(21),
     3VSYS22(21),VSYS2S(21),VSYS31(12),VSYS32(12),VSYS3S(12),
     4VSYS41(14),VSYS42(14),VSYS4S(14),A(3),B(5),C(3),D(2),E(3),F(5),
     5G(3),H(2),P(3),Q(5),R(3),S(2)
C
C     THE PERCENTAGE OF HOMES WHICH REGISTER A COMPONENT OF EACH HOUSE
C     SYSTEM IS STORED IN ARRAYS.  THE CODING OF THE ARRAYS IS AS FOLLOWS
C
C          PSYS11(I) .. FLOOR SYSTEM OF ONE STORY HOUSE
C          PSYS12(I) .. FLOOR SYSTEM OF TWO STORY HOUSE
C          PSYS1S(I) .. FLOOR SYSTEM OF A SPLIT LEVEL HOUSE
C          PSYS21(I) .. WALL SYSTEM OF ONE STORY HOUSE
C          PSYS22(I) .. WALL SYSTEM OF TWO STORY HOUSE
C          PSYS2S(I) .. WALL SYSTEM OF A SPLIT LEVEL HOUSE
C          PSYS31(I) .. ROOF-CEILING SYSTEM OF ONE STORY HOUSE
C          PSYS32(I) .. ROOF-CEILING SYSTEM OF TWO STORY HOUSE
C          PSYS3S(I) .. ROOF-CEILING SYSTEM OF A SPLIT LEVEL HOUSE
C          PSYS41(I) .. MILLWORK-TRIM SYSTEM OF ONE STORY HOUSE
C          PSYS42(I) .. MILLWORK-TRIM SYSTEM OF TWO STORY HOUSE
C          PSYS4S(I) .. MILLWORK-TRIM SYSTEM OF A SPLIT LEVEL HOUSE
C
```

```
C     THE AMOUNT OF WOOD MATERIAL REGISTERED IN A SPECIFIC COMPONENT OF
C     EACH HOUSE SYSTEM IS ALSO STORED IN ARRAYS.  THE CODING IS SIMILAR
C     TO THE ABOVE.
C
C              VSYS11(I) .. FLOOR SYSTEM OF ONE STORY HOUSE
C              VSYS12(I) .. FLOOR SYSTEM OF TWO STORY HOUSE
C              VSYS1S(I) .. FLOOR SYSTEM OF A SPLIT LEVEL HOUSE
C              VSYS21(I) .. WALL SYSTEM OF ONE STORY HOUSE
C              VSYS22(I) .. WALL SYSTEM OF TWO STORY HOUSE
C              VSYS2S(I) .. WALL SYSTEM OF A SPLIT LEVEL HOUSE
C              VSYS31(I) .. ROOF-CEILING SYSTEM OF ONE STORY HOUSE
C              VSYS32(I) .. ROOF-CEILING SYSTEM OF TWO STORY HOUSE
C              VSYS3S(I) .. ROOF-CEILING SYSTEM OF A SPLIT LEVEL HOUSE
C              VSYS41(I) .. MILLWORK-TRIM SYSTEM OF ONE STORY HOUSE
C              VSYS42(I) .. MILLWORK-TRIM SYSTEM OF TWO STORY HOUSE
C              VSYS4S(I) .. MILLWORK-TRIM SYSTEM OF A SPLIT LEVEL HOUSE
C
      DO 10 I=1,13
      READ 1,PSYS11(I),PSYS12(I),PSYS1S(I)
    1 FORMAT(3F6.4)
      VSYS11(I)=VSYS12(I)=VSYS1S(I)=0.0
   10 CONTINUE
      DO 11 I=1,21
      READ 2, PSYS21(I),PSYS22(I),PSYS2S(I)
    2 FORMAT(3F6.4)
      VSYS21(I)=VSYS22(I)=VSYS2S(I)=0.0
   11 CONTINUE
      DO 12 I=1,12
      READ 3,PSYS31(I),PSYS32(I),PSYS3S(I)
    3 FORMAT(3F6.4)
      VSYS31(I)=VSYS32(I)=VSYS3S(I)=0.0
   12 CONTINUE
      DO 13 I=1,14
      READ 4,PSYS41(I),PSYS42(I),PSYS4S(I)
    4 FORMAT(3F6.4)
```

```
      VSYS41(I)=VSYS42(I)=VSYS4S(I)=0.0
   13 CONTINUE
      FLAREA=FLAREA1=FLAREA2=FLAREAS=PROP1=PROP2=PROPSL=0.0
      DO 14 I=1,17
      YEAR=1968+I
      PRINT 5,YEAR
    5 FORMAT(1H1,10X*WOOD VOLUME PER HOUSE IN YEAR  *F5.0)
C
C     CALCULATING MIX OF ARCHITECTURAL TYPES
C
      CALL TYPE (YEAR,PROP1,PROP2,PROPSL)
C
C     CALCULATING FLOOR AREA BY ARCHITECTURAL TYPE
C
      CALL AREA (YEAR,FLAREA,FLAREA1,FLAREA2,FLAREAS,PROP1,PROP2,PROPSL)
C
C     CALCULATING AMOUNT OF WOOD MATERIAL IN FLOOR SYSTEM
C
      CALL SYS1 (FLAREA1,FLAREA2,FLAREAS,PSYS11,PSYS12,PSYS1S,
     1VSYS11,VSYS12,VSYS1S)
C
C     CALCULATING AMOUNT OF WOOD MATERIAL IN WALL SYSTEM
C
      CALL SYS2 (FLAREA1,FLAREA2,FLAREAS,PSYS21,PSYS22,PSYS2S,
     1VSYS21,VSYS22,VSYS2S)
C
C     CALCULATING AMOUNT OF WOOD MATERIAL IN ROOF-CEILING SYSTEM
C
      CALL SYS3 (FLAREA1,FLAREA2,FLAREAS,PSYS31,PSYS32,PSYS3S,
     1VSYS31,VSYS32,VSYS3S)
C
C     CALCULATING AMOUNT OF WOOD MATERIAL IN MILLWORK-TRIM SYSTEM
C
      CALL SYS4 (FLAREA1,FLAREA2,FLAREAS,PSYS41,PSYS42,PSYS4S,
     1VSYS41,VSYS42,VSYS4S)
C
C     CALCULATING INFLUENCE OF TECHNICAL DESIGN ON WOOD USE
```

```
C
      CALL TECH (YEAR)
C
C    CALCULATING INFLUENCE OF MATERIAL BLEND ON WOOD USE
C
      CALL BLEND (YEAR)
C
C   CALCULATING THE AMOUNT OF WOOD MATERIAL IN ONE STORY HOUSES
C
C    FLOOR SYSTEM
C
      BDFEET=PLYWOD=PARTBD=HARDBD=COMPBD=XLATH=SQRS=0.0
      DO 15 J=1,13
      IF(J.NE.9) GO TO 100
      PLYWOD=VSYS11(J)
      GO TO 15
  100 IF(J.NE.11) GO TO 101
      PLYWOD=PLYWOD+VSYS11(J)
      GO TO 15
  101 IF(J.NE.12) GO TO 102
      PARTBD=VSYS11(J)
      GO TO 15
  102 BDFEET=BDFEET+VSYS11(J)
   15 CONTINUE
      A(1)=BDFEET
      A(2)=PLYWOD
      A(3)=PARTBD
      BDFEET=PLYWOD=PARTBD=HARDBD=COMPBD=XLATH=SQRS=0.0
C
C    WALL SYSTEM
C
      DO 16 J=1,21
      IF(J.NE.15) GO TO 103
      XLATH=VSYS21(J)
      GO TO 16
```

```
  103 IF(J.NE.16) GO TO 104
      COMPBD=VSYS21(J)
      GO TO 16
  104 IF(J.NE.17) GO TO 105
      PLYWOD=VSYS21(J)
      GO TO 16
  105 IF(J.NE.19) GO TO 106
      PLYWOD=PLYWOD+VSYS21(J)
      GO TO 16
  106 IF(J.NE.20) GO TO 107
      HARDBD=VSYS21(J)
      GO TO 16
  107 BDFEET=BDFEET+VSYS21(J)
   16 CONTINUE
      B(1)=BDFEET
      B(2)=PLYWOD
      B(3)=HARDBD
      B(4)=COMPBD
      B(5)=XLATH
      BDFEET=PLYWOD=PARTBD=HARDBD=COMPBD=XLATH=SQRS=0.0
C
C     ROOF-CEILING SYSTEM
C
      DO 17 J=1,12
      IF(J.NE.9) GO TO 108
      PLYWOD=VSYS31(J)
      GO TO 17
  108 IF(J.NE.12) GO TO 208
      SQRS=VSYS31(J)
      GO TO 17
  208 BDFEET=BDFEET+VSYS31(J)
   17 CONTINUE
      C(1)=BDFEET
      C(2)=PLYWOD
      C(3)=SQRS
      BDFEET=PLYWOD=PARTBD=HARDBD=COMPBD=XLATH=SQRS=0.0
```

```
C
C     MILLWORK-TRIM SYSTEM
C
      DO 18 J=1,14
      IF(J.NE.2) GO TO 109
      PLYWOD=VSYS41(J)
      GO TO 18
  109 IF(J.NE.6) GO TO 110
      PLYWOD=PLYWOD+VSYS41(J)
      GO TO 18
  110 IF(J.NE.10) GO TO 210
      PLYWOD=PLYWOD+VSYS41(J)
      GO TO 18
  210 IF(J.NE.12) GO TO 111
      PLYWOD=PLYWOD+VSYS41(J)
      GO TO 18
  111 BDFEET=BDFEET+VSYS41(J)
   18 CONTINUE
      D(1)=BDFEET
      D(2)=PLYWOD
      BDFEET=PLYWOD=PARTBD=HARDBD=COMPBD=XLATH=SQRS=0.0
C
C    CALCULATING THE AMOUNT OF WOOD MATERIAL IN TWO STORY HOUSES
C
C     FLOOR SYSTEM
C
      DO 19 J=1,13
      IF(J.NE.9) GO TO 112
      PLYWOD=VSYS12(J)
      GO TO 19
  112 IF(J.NE.11) GO TO 113
      PLYWOD=PLYWOD+VSYS12(J)
      GO TO 19
  113 IF(J.NE.12) GO TO 114
      PARTBD=VSYS12(J)
```

```
      GO TO 19
  114 BDFEET=BDFEET+VSYS12(J)
   19 CONTINUE
      E(1)=BDFEET
      E(2)=PLYWOD
      E(3)=PARTBD
      BDFEET=PLYWOD=PARTBD=HARDBD=COMPBD=XLATH=SQRS=0.0
C
C     WALL SYSTEM
C
      DO 20 J=1,21
      IF(J.NE.15) GO TO 115
      XLATH=VSYS22(J)
      GO TO 20
  115 IF(J.NE.16) GO TO 116
      COMPBD=VSYS22(J)
      GO TO 20
  116 IF(J.NE.17) GO TO 117
      PLYWOD=VSYS22(J)
      GO TO 20
  117 IF(J.NE.19) GO TO 118
      PLYWOD=PLYWOD+VSYS22(J)
      GO TO 20
  118 IF(J.NE.20) GO TO 119
      HARDBD=VSYS22(J)
      GO TO 20
  119 BDFEET=BDFEET+VSYS22(J)
   20 CONTINUE
      F(1)=BDFEET
      F(2)=PLYWOD
      F(3)=HARDBD
      F(4)=COMPBD
      F(5)=XLATH
      BDFEET=PLYWOD=PARTBD=HARDBD=COMPBD=XLATH=SQRS=0.0
```

```
C     ROOF-CEILING SYSTEM
C
      DO 21 J=1,12
      IF(J.NE.9) GO TO 120
      PLYWOD=VSYS32(J)
      GO TO 21
  120 IF(J.NE.12) GO TO 220
      SQRS=VSYS32(J)
      GO TO 21
  220 BDFEET=BDFEET+VSYS32(J)
   21 CONTINUE
      G(1)=BDFEET
      G(2)=PLYWOD
      G(3)=SQRS
      BDFEET=PLYWOD=PARTBD=HARDBD=COMPBD=XLATH=SQRS=0.0
C
C     MILLWORK-TRIM SYSTEM
C
      DO 22 J=1,14
      IF(J.NE.2) GO TO 121
      PLYWOD=VSYS42(J)
      GO TO 22
  121 IF(J.NE.6) GO TO 122
      PLYWOD=PLYWOD+VSYS42(J)
      GO TO 22
  122 IF(J.NE.10) GO TO 222
      PLYWOD=PLYWOD+VSYS42(J)
      GO TO 22
  222 IF(J.NE.12) GO TO 123
      PLYWOD=PLYWOD+VSYS42(J)
      GO TO 22
  123 BDFEET=BDFEET+VSYS42(J)
   22 CONTINUE
      H(1)=BDFEET
      H(2)=PLYWOD
      BDFEET=PLYWOD=PARTBD=HARDBD=COMPBD=XLATH=SQRS=0.0
```

```
C
C   CALCULATING THE AMOUNT OF WOOD MATERIAL IN SPLIT LEVEL HOUSES
C
C     FLOOR SYSTEM
C
      DO 23 J=1,13
      IF(J.NE.9) GO TO 124
      PLYWOD=VSYS1S(J)
      GO TO 23
  124 IF(J.NE.11) GO TO 125
      PLYWOD=PLYWOD+VSYS1S(J)
      GO TO 23
  125 IF(J.NE.12) GO TO 126
      PARTBD=VSYS1S(J)
      GO TO 23
  126 BDFEET=BDFEET+VSYS1S(J)
   23 CONTINUE
      P(1)=BDFEET
      P(2)=PLYWOD
      P(3)=PARTBD
      BDFEET=PLYWOD=PARTBD=HARDBD=COMPBD=XLATH=SQRS=0.0
C
C     WALL SYSTEM
C
      DO 24 J=1,21
      IF(J.NE.15) GO TO 127
      XLATH=VSYS2S(J)
      GO TO 24
  127 IF(J.NE.16) GO TO 128
      COMPBD=VSYS2S(J)
      GO TO 24
  128 IF(J.NE.17) GO TO 129
      PLYWOD=VSYS2S(J)
      GO TO 24
  129 IF(J.NE.19) GO TO 130
```

```
      PLYWOD=PLYWOD+VSYS2S(J)
      GO TO 24
  130 IF(J.NE.20) GO TO 131
      HARDBD=VSYS2S(J)
      GO TO 24
  131 BDFEET=BDFEET+VSYS2S(J)
   24 CONTINUE
      Q(1)=BDFEET
      Q(2)=PLYWOD
      Q(3)=HARDBD
      Q(4)=COMPBD
      Q(5)=XLATH
      BDFEET=PLYWOD=PARTBD=HARDBD=COMPBD=XLATH=SQRS=0.0
C     ROOF-CEILING SYSTEM
C
      DO 25 J=1,12
      IF(J.NE.9) GO TO 132
      PLYWOD=VSYS3S(J)
      GO TO 25
  132 IF(J.NE.12) GO TO 232
      SQRS=VSYS3S(J)
      GO TO 25
  232 BDFEET=BDFEET+VSYS3S(J)
   25 CONTINUE
      R(1)=BDFEET
      R(2)=PLYWOD
      R(3)=SQRS
      BDFEET=PLYWOD=PARTBD=HARDBD=COMPBD=XLATH=SQRS=0.0
C
C     MILLWORK-TRIM SYSTEM
C
      DO 26 J=1,14
      IF(J.NE.2) GO TO 133
      PLYWOD=VSYS4S(J)
      GO TO 26
  133 IF(J.NE.6) GO TO 134
```

```
      PLYWOD=PLYWOD+VSYS4S(J)
      GO TO 26
  134 IF(J.NE.10) GO TO 234
      PLYWOD=PLYWOD+VSYS4S(J)
      GO TO 26
  234 IF(J.NE.12) GO TO 135
      PLYWOD=PLYWOD+VSYS4S(J)
      GO TO 26
  135 BDFEET=BDFEET+VSYS4S(J)
   26 CONTINUE
      S(1)=BDFEET
      S(2)=PLYWOD
      BDFEET=PLYWOD=PARTBD=HARDBD=COMPBD=XLATH=SQRS=0.0
C    CALCULATING THE WEIGHTED AMOUNT OF WOOD MATERIAL IN TYPES OF
C    HOUSES ACCORDING TO THE MARKET MIX OF HOUSES(PROP1,PROP2,PROPSL)
      DO 27 J=1,3
      A(J)=A(J)*PROP1
   27 CONTINUE
      DO 28 J=1,5
      B(J)=B(J)*PROP1
   28 CONTINUE
      DO 29 J=1,3
      C(J)=C(J)*PROP1
   29 CONTINUE
      DO 30 J=1,2
      D(J)=D(J)*PROP1
   30 CONTINUE
C
      DO 31 J=1,3
      E(J)=E(J)*PROP2
   31 CONTINUE
      DO 32 J=1,5
      F(J)=F(J)*PROP2
   32 CONTINUE
      DO 33 J=1,3
```

```
      G(J)=G(J)*PROP2
   33 CONTINUE
      DO 34 J=1,2
      H(J)=H(J)*PROP2
   34 CONTINUE
C
      DO 35 J=1,3
      P(J)=P(J)*PROPSL
   35 CONTINUE
      DO 36 J=1,5
      Q(J)=Q(J)*PROPSL
   36 CONTINUE
      DO 37 J=1,3
      R(J)=R(J)*PROPSL
   37 CONTINUE
      DO 38 J=1,2
      S(J)=S(J)*PROPSL
   38 CONTINUE
C
C  CALCULATING THE AMOUNT OF WOOD MATERIAL IN EACH SYSTEM OF
C  THE AVERAGE HOUSE
C
      FBDFEET=FPLYWOD=FPARTBD=WBDFEET=WPLYWOD=WHARDBD=WCOMPBD=WLATH=0.0
      RBDFEET=RPLYWOD=TBDFEET=TPLYWOD=RSHAKS=0.0
C
C   FLOOR SYSTEM
C
      FBDFEET=A(1)+E(1)+P(1)
      FPLYWOD=A(2)+E(2)+P(2)
      FPARTBD=A(3)+E(3)+P(3)
```

```
C
C     WALL SYSTEM
C
      WBDFEET=B(1)+F(1)+Q(1)
      WPLYWOD=B(2)+F(2)+Q(2)
      WHARDBD=B(3)+F(3)+Q(3)
      WCOMPBD=B(4)+F(4)+Q(4)
      WLATH=B(5)+F(5)+Q(5)
C
C     ROOF-CEILING SYSTEM
C
      RBDFEET=C(1)+G(1)+R(1)
      RPLYWOD=C(2)+G(2)+R(2)
      RSHAKS=C(3)+G(3)+R(3)
C
C     MILLWORK-TRIM SYSTEM
C
      TBDFEET=D(1)+H(1)+S(1)
      TPLYWOD=D(2)+H(2)+S(2)
C
      PRINT 136, YEAR
  136 FORMAT(1H1,10X*AMOUNT OF WOOD MATERIAL IN EACH SYSTEM OF THE*
     1* AVERAGE HOUSE IN THE YEAR  *F5.0)
      PRINT 137, FBDFEET,FPLYWOD,FPARTBD
  137 FORMAT(1H ,///15X*FLOOR SYSTEM*/20X
     1*BOARD FEET OF LUMBER = *F15.3/20X
     2*SQUARE FEET OF PLYWOOD = *F15.3/20X
     3*SQUARE FEET OF PARTICLEBOARD = *F15.3)
      PRINT 138, WBDFEET,WPLYWOD,WHARDBD,WCOMPBD,WLATH
  138 FORMAT(1H ,//15X*WALL SYSTEM*/20X
     1*BOARD FEET OF LUMBER = *F15.3/20X
     2*SQUARE FEET OF PLYWOOD = *F15.3/20X
     3*SQUARE FEET OF HARDBOARD = *F15.3/20X
     4*SQUARE FEET OF COMPOSITION BOARD = *F15.3/20X
     5*BUNDLES OF LATH = *F15.8)
```

```
      PRINT 139,RBDFEET,RPLYWOD,RSHAKS
  139 FORMAT(1H ,//15X*ROOF-CEILING SYSTEM*/20X
     1*BOARD FEET OF LUMBER = *F15.3/20X
     2*SQUARE FEET OF PLYWOOD = *F15.3/20X
     3*SQUARES OF SHAKES AND SHINGLES = *F15.3)
      PRINT 140, TBDFEET,TPLYWOD
  140 FORMAT(1H ,//15X*MILLWORK-TRIM SYSTEM*/20X
     1*BOARD FEET OF LUMBER = *F15.3/20X
     2*SQUARE FEET OF PLYWOOD = *F15.3)
C
C   CALCULATING THE TOTAL AMOUNT OF WOOD MATERIAL IN THE AVERAGE HOUSE
C
      TTBDFT=TTPLYWD=0.0
      TTBDFT=FBDFEET+WBDFEET+RBDFEET+TBDFEET
      TTPLYWD=FPLYWOD+WPLYWOD+RPLYWOD+TPLYWOD
      PRINT 141, YEAR
  141 FORMAT(1H ,//////10X*AMOUNT OF WOOD MATERIAL IN THE*
     1* AVERAGE HOUSE IN YEAR *F5.0)
      PRINT 142, TTBDFT,TTPLYWD,FPARTBD,WHARDBD,WCOMPBD,WLATH,RSHAKS
  142 FORMAT(1H ,//20X
     1*TOTAL BOARD FEET OF LUMBER = *F15.3//20X
     2*TOTAL SQUARE FEET OF PLYWOOD = *F15.3//20X
     3*TOTAL SQUARE FEET OF PARTICLE BOARD = *F15.3//20X
     4*TOTAL SQUARE FEET OF HARDBOARD = *F15.3//20X
     5*TOTAL SQUARE FEET OF COMPOSITION BOARD = *F15.3//20X
     6*TOTAL BUNDLES OF WOOD LATH = *F10.8//20X
     7*TOTAL SQUARES OF SHAKES AND SHINGLES = *F15.3)
   14 CONTINUE
      END
```

```
      SUBROUTINE TYPE (YEAR,PROP1,PROP2,PROPSL)
      SITE=XPRP1=XMAX=0.0
      SITE=-14813.34684205+7.61631579*(YEAR)
      XPRP1=2.22279123-1.12639389*ALOG10(SITE)
      PROP2=-0.39203429+0.00374530*(SITE)
      PROP1=10.**(XPRP1)
      XMAX=1.0000-(PROP1+0.1000)
      IF(XMAX-PROP2)100,101,101
  100 PROP2=XMAX
      PROPSL=0.1000
      GO TO 102
  101 PROPSL=1.0000-(PROP1+PROP2)
  102 PRINT 1,PROP1,PROP2,PROPSL,SITE
    1 FORMAT(1H ,/////////15X*PROPORTION ONE STORY HOMES IN MARKET  =  *
     1F5.4///15X*PROPORTION TWO STORY HOMES IN MARKET  =  *F5.4///15X
     2*PROPORTION SPLIT LEVEL HOMES IN MARKET  =  *F5.4
     3///15X*INDEX OF LOT PRICE  =  *F5.1)
      RETURN
      END
```

```
      SUBROUTINE AREA (YEAR,FLAREA,FLAREA1,FLAREA2,FLAREAS,PROP1,PROP2,
     1PROPSL)
C
C     PREDICTING FORMULA....
C
C       AREA=-B(0)+B(1)*LOG(INCOME)-B(2)*(Z)-B(3)*(PLYWOOD)
C
      XINT=TERM=XLV=Z=XINCME=PLYWOD=SMEAN1=SMEAN2=SMEANSL=WEIGHT1=0.0
      WEIGHT2=WEIGHT3=WFLARA=PONE=PTWO=PSL=0.0
      XINCME=-10716.15426469+5.52691176*(YEAR)
      PLYWOD=1347.95274723-0.63791209*(YEAR)
      XINT=-488.06608476+0.25134571*(YEAR)
      TERM=-334.68914285+0.18257143*(YEAR)
      XLV=3.11285714-0.00122857*(YEAR)
      Z=(XINT)/((TERM)*(XLV))
      FLAREA=-4490.44420362+3428.14870292*ALOG10(XINCME)
     1-978.74753568*(Z)
     2-12.53264251*(PLYWOD)
C
C     CALCULATION OF THE FLOOR AREA FOR EACH ARCHITECTURAL TYPE
C
      SMEAN1=1588.57143
      SMEAN2=2513.18518
      SMEANSL=1893.00000
C
C     CALCULATION OF A WEIGHTED AVERAGE FLOOR AREA BASED ON THE
C     CURRENT VALUE OF PROP1, PROP2, AND PROPSL
C
      WEIGHT1=SMEAN1*PROP1
      WEIGHT2=SMEAN2*PROP2
      WEIGHT3=SMEANSL*PROPSL
      WFLARA=WEIGHT1+WEIGHT2+WEIGHT3
C
C     CALCULATION OF THE FLOOR AREA OF EACH ARCHITECTURAL TYPE AS A
C     PERCENTAGE OF THE AVERAGE WEIGHTED FLOOR AREA
C
```

```
      PONE=SMEAN1/WFLARA
      PTWO=SMEAN2/WFLARA
      PSL=SMEANSL/WFLARA
C
C     CALCULATION OF THE FLOOR AREA OF EACH ARCHITECTURAL TYPE
C
      FLAREA1=FLAREA*PONE
      FLAREA2=FLAREA*PTWO
      FLAREAS=FLAREA*PSL
      PRINT 1,FLAREA,FLAREA1,FLAREA2,FLAREAS,XINCME,PLYWOD,Z,XINT,
     1TERM,XLV
    1 FORMAT(1H ,////16X*MEDIAN  SQUARE FEET OF FLOOR AREA FOR ALL*
     1* ARCHITECTURAL TYPES  =  *F7,2///20X
     2*FLOOR AREA ONE STORY  =  *F7,2///20X
     3*FLOOR AREA TWO STORY  =  *F7.2///20X
     4*FLOOR AREA SPLIT LEVEL  =  *F7,2////
     516X*MEDIAN FAMILY INCOME INDEX  =  *F6.2///
     616X*PLYWOOD  PRICE INDEX  =  *F6.2///
     716X*INTEREST FACTOR  =  *F8.5////
     816X*INTEREST RATE  =  *F5.2//
     916X*LENGTH OF LOAN  =  *F6.2//16X*LOAN TO VALUE RATIO  =  *F6.2)
      RETURN
      END
```

```
      SUBROUTINE SYS1(FLAREA1,FLAREA2,FLAREAS,PSYS11,PSYS12,PSYS1S,
     1VSYS11,VSYS12,VSYS1S)
      DIMENSION PSYS11(13),PSYS12(13),PSYS1S(13),
     1VSYS11(13),VSYS12(13),VSYS1S(13)
C
C                       ONE STORY FLOOR SYSTEM
C
      XMUDSIL=FLRJIST=FLRSKRT=BRIDGNG=BLOCK=CLEAT=POST=BDS=PLY=0.0
      FFLR=UPLY=UPART=BLKM=0.0
C     MUD SILL
      XMUDSIL=-11.24477+0.13675*(FLAREA1)
      VSYS11(1)=XMUDSIL*PSYS11(1)
C     FLOOR JOIST
      FLRJIST=-545.41678+2.01458*(FLAREA1)
      VSYS11(2)=FLRJIST*PSYS11(2)
C     FLOOR SKIRT
      FLRSKRT=35.00510+0.10579*(FLAREA1)
      VSYS11(3)=FLRSKRT*PSYS11(3)
C     BRIDGING
      BRIDGNG=-8.67206+0.06156*(FLAREA1)
      VSYS11(4)=BRIDGNG*PSYS11(4)
C     I-BEAM BLOCKING
      BLOCK=9.89906+0.02262*(FLAREA1)
      VSYS11(5)=BLOCK*PSYS11(5)
C     TILE CLEATING
      CLEAT=-39.60628+0.03992*(FLAREA1)
      VSYS11(6)=CLEAT*PSYS11(6)
C     BASEMENT POSTS
      POST=-112.32491+0.10882*(FLAREA1)
      VSYS11(7)=POST*PSYS11(7)
C     SUB-FLOOR SHEATHING BOARDS
      BDS=18.44209+1.17813*(FLAREA1)
      VSYS11(8)=BDS*PSYS11(8)
C     SUBFLOOR SHEATHING PLYWOOD
      PLY=-177.78506+1.20752*(FLAREA1)
      VSYS11(9)=PLY*PSYS11(9)
```

```
C     FINISH FLOORING
      FFLR=866.35283-0.06547*(FLAREA1)
      VSYS11(10)=FFLR*PSYS11(10)
C     UNDERLAYMENT PLYWOOD
      UPLY=-31.97170+0.62836*(FLAREA1)
      VSYS11(11)=UPLY*PSYS11(11)
C     UNDERLAYMENT PARTICLE BOARD
      UPART=-518.61887+0.86659*(FLAREA1)
      VSYS11(12)=UPART*PSYS11(12)
C     MISCELLANEOUS BLOCKING
      BLKM=399.39582-0.08113*(FLAREA1)
      VSYS11(13)=BLKM*PSYS11(13)
C
C                    TWO STORY FLOOR SYSTEM
C
      XMUDSIL=FLRJIST=FLRSKRT=BRIDGNG=BLOCK=CLEAT=PCST=PDS=PLY=0.0
      FFLR=UPLY=UPART=BLKM=0.0
C     MUD SILL
      XMUDSIL=148.29441+0.00919*(FLAREA2)
      VSYS12(1)=XMUDSIL*PSYS12(1)
C     FLOOR JOIST
      FLRJIST=195.57507+1.77699*(FLAREA2)
      VSYS12(2)=FLRJIST*PSYS12(2)
C     FLOOR SKIRT
      FLRSKRT=99.32146+0.09217*(FLAREA2)
      VSYS12(3)=FLRSKRT*PSYS12(3)
C     BRIDGING
      BRIDGNG=-71.97851+0.11294*(FLAREA2)
      VSYS12(4)=BRIDGNG*PSYS12(4)
C     I-BEAM BLOCKING
      BLOCK=-18.80592+0.02301*(FLAREA2)
      VSYS12(5)=BLOCK*PSYS12(5)
C     TILE CLEATING
      CLEAT=-128.81752+0.06966*(FLAREA2)
      VSYS12(6)=CLEAT*PSYS12(6)
```

```
C     BASEMENT POSTS
      POST=12.99016+0.00445*(FLAREA2)
      VSYS12(7)=POST*PSYS12(7)
C     SUBFLOOR SHEATHING BOARDS
      BDS=-30.27464+1.15928*(FLAREA2)
      VSYS12(8)=BDS*PSYS12(8)
C     SUBFLOOR SHEATHING PLYWOOD
      PLY=602.19260+0.89640*(FLAREA2)
      VSYS12(9)=PLY*PSYS12(9)
C     FINISH FLOORING
      FFLR=1163.66437+0.16694*(FLAREA2)
      VSYS12(10)=FFLR*PSYS12(10)
C     UNDERLAYMENT PLYWOOD
      UPLY=945.70436+0.22494*(FLAREA2)
      VSYS12(11)=UPLY*PSYS12(11)
C     UNDERLAYMENT PARTICLE BOARD
      UPART=1021.76246+0.20939*(FLAREA2)
      VSYS12(12)=UPART*PSYS12(12)
C     MISCELLANEOUS BLOCKING
      BLKM=296.12246-0.05496*(FLAREA2)
      VSYS12(13)=BLKM*PSYS12(13)
C
C                      SPLIT LEVEL FLOOR SYSTEM
C
      XMUDSIL=FLRJIST=FLRSKRT=BRIDGNG=BLOCK=CLEAT=POST=BDS=PLY=0.0
      FFLR=UPLY=UPART=BLKM=0.0
C     MUD SILL
      XMUDSIL=161.62053-0.00354*(FLAREAS)
      VSYS1S(1)=XMUDSIL*PSYS1S(1)
C     FLOOR JOIST
      FLRJIST=602.31453+1.05261*(FLAREAS)
      VSYS1S(2)=FLRJIST*PSYS1S(2)
C     FLOOR SKIRT
      FLRSKRT=242.45033-0.02242*(FLAREAS)
      VSYS1S(3)=FLRSKRT*PSYS1S(3)
```

```
C     BRIDGING
      BRIDGNG=196.78274-0.05158*(FLAREAS)
      VSYS1S(4)=BRIDGNG*PSYS1S(4)
C     I-BEAM BLOCKING
      BLOCK=284.07138-0.08650*(FLAREAS)
      VSYS1S(5)=BLOCK*PSYS1S(5)
C     TILE CLEATING  (COMBINED WITH I-BEAM BLOCKING)
      CLEAT=0.0
      VSYS1S(6)=CLEAT*PSYS1S(6)
C     BASEMENT POSTS (NO BASEMENT POSTS IN SAMPLE)
      POST=0.0
      VSYS1S(7)=0.0*PSYS1S(7)
C     SUBFLOOR SHEATHING BOARDS
      BDS=1454.18460+0.08213*(FLAREAS)
      VSYS1S(8)=BDS*PSYS1S(8)
C     SUBFLOOR SHEATHING PLYWOOD
      PLY=1356.46417+0.05216*(FLAREAS)
      VSYS1S(9)=PLY*PSYS1S(9)
C     FINISH FLOORING
      FFLR=1025.70566-0.14101*(FLAREAS)
      VSYS1S(10)=FFLR*PSYS1S(10)
C     UNDERLAYMENT PLYWOOD
      UPLY=813.72007+0.07491*(FLAREAS)
      VSYS1S(11)=UPLY*PSYS1S(11)
C     UNDERLAYMENT PARTICLEBOARD  (NO PARTICLE BOARD IN SAMPLE)
      UPART=832.0
      VSYS1S(12)=UPART*PSYS1S(12)
C     MISCELLANEOUS BLOCKING  (COMBINED WITH I-BEAM BLOCKING)
      BLKM=0.0
      VSYS1S(13)=BLKM*PSYS1S(13)
      RETURN
      END
```

```
      SUBROUTINE SYS2 (FLAREA1,FLAREA2,FLAREAS,PSYS21,PSYS22,PSYS2S,
     1VSYS21,VSYS22,VSYS2S)
      DIMENSION PSYS21(21),PSYS22(21),PSYS2S(21),
     1VSYS21(21),VSYS22(21),VSYS2S(21)
C
C                    ONE STORY WALL SYSTEM
C
       PSTUD=SSTUD=GSTUD=GRSTUD=BSTUD=XMSTUD=WPLT=BPLT=XMPLT=POST=0.0
       PBACK=BLKFUR=BRACE=HEAD=XLATH=COMP=WPLY=WS=PS=HS=WBEAM=0.0
C     PRE CUT WALL STUDS
       PSTUD=137.78762+1.35394*(FLAREA1)
       VSYS21(1)=PSTUD*PSYS21(1)
C     SHOULDER STUDS
       SSTUD=87.64745+0.13924*(FLAREA1)
       VSYS21(2)=SSTUD*PSYS21(2)
C     GABLE STUDS
       GSTUD=-39.73512+0.15946*(FLAREA1)
       VSYS21(3)=GSTUD*PSYS21(3)
C     GARAGE STUDS
       GRSTUD=321.06638-0.02386*(FLAREA1)
       VSYS21(4)=GRSTUD*PSYS21(4)
C     BATH WALL STUDS
       BSTUD=29.84345+0.02773*(FLAREA1)
       VSYS21(5)=BSTUD*PSYS21(5)
C     MISCELLANEOUS STUDS
       XMSTUD=-96.93364+0.09494*(FLAREA1)
       VSYS21(6)=XMSTUD*PSYS21(6)
C     WALL PLATES
       WPLT=194.94294+0.43989*(FLAREA1)
       VSYS21(7)=WPLT*PSYS21(7)
C     BATH WALL PLATES
       BPLT=18.57899+0.01133*(FLAREA1)
       VSYS21(8)=BPLT*PSYS21(8)
C     MISCELLANEOUS PLATES
       XMPLT=-9.42115+0.01974*(FLAREA1)
       VSYS21(9)=XMPLT*PSYS21(9)
```

```
C     POSTS
       POST=-44.01365+0.06793*(FLAREA1)
       VSYS21(10)=POST*PSYS21(10)
C     PARTITION PACKING
       PPACK=-15.40183+0.04585*(FLAREA1)
       VSYS21(11)=PBACK*PSYS21(11)
C     MISCELLANEOUS BLOCKING AND FURRING
       BLKFUR=-156.35182+0.24703*(FLAREA1)
       VSYS21(12)=BLKFUR*PSYS21(12)
C     CORNER BRACES
       BRACE=39.97845+0.00742*(FLAREA1)
       VSYS21(13)=BRACE*PSYS21(13)
C     HEADERS
       HEAD=-106.62722+0.43533*(FLAREA1)
       VSYS21(14)=HEAD*PSYS21(14)
C     LATH AND PLASTER GROUNDS
       XLATH=1.1
       VSYS21(15)=XLATH*PSYS21(15)
C     WALL SHEATHING COMPOSITION BOARD
       COMP=765.31319+0.58352*(FLAREA1)
       VSYS21(16)=COMP*PSYS21(16)
C     WALL SHEATHING PLYWOOD
       WPLY=3428.15013-1.28414*(FLAREA1)
       VSYS21(17)=WPLY*PSYS21(17)
C     SIDING WOOD
       WS=476.72685+0.21718*(FLAREA1)
       VSYS21(18)=WS*PSYS21(18)
C     SIDING PLYWOOD
       PS=-810.71888+1.29752*(FLAREA1)
       VSYS21(19)=PS*PSYS21(19)
C     SIDING HARDBOARD
       HS=-715.86940+1.38695*(FLAREA1)
       VSYS21(20)=HS*PSYS21(20)
C     WALL BEAMS
       WBEAM=-139.34480+0.19685*(FLAREA1)
       VSYS21(21)=WBEAM*PSYS21(21)
```

```
C
C                    TWO STORY WALL SYSTEM
C
      PSTUD=SSTUD=GSTUD=GRSTUD=BSTUD=XMSTUD=WPLT=BPLT=XMPLT=POST=0.0
      PBACK=BLKFUR=BRACE=HEAD=XLATH=COMP=WPLY=WS=PS=HS=WBEAM=0.0
C    PRE CUT WALL STUDS
      PSTUD=447.67810+1.21793*(FLAREA2)
      VSYS22(1)=PSTUD*PSYS22(1)
C    SHOULDER STUDS
      SSTUD=31.62974+0.15597*(FLAREA2)
      VSYS22(2)=SSTUD*PSYS22(2)
C    GABLE STUDS
      GSTUD=297.18529+0.01330*(FLAREA2)
      VSYS22(3)=GSTUD*PSYS22(3)
C    GARAGE STUDS
      GRSTUD=239.37767+0.01854*(FLAREA2)
      VSYS22(4)=GRSTUD*PSYS22(4)
C    BATH WALL STUDS
      BSTUD=-46.51017+0.06578*(FLAREA2)
      VSYS22(5)=BSTUD*PSYS22(5)
C    MISCELLANEOUS STUDS
      XMSTUD=-166.17228+0.10390*(FLAREA2)
      VSYS22(6)=XMSTUD*PSYS22(6)
C    WALL PLATES
      WPLT=146.38252+0.40058*(FLAREA2)
      VSYS22(7)=WPLT*PSYS22(7)
C    BATH WALL PLATES
      BPLT=-19.27354+0.02827*(FLAREA2)
      VSYS22(8)=BPLT*PSYS22(8)
C    MISCELLANEOUS PLATES
      XMPLT=34.12580+0.00446*(FLAREA2)
      VSYS22(9)=XMPLT*PSYS22(9)
C    POSTS
      POST=-222.19695+0.13779*(FLAREA2)
```

```
      VSYS22(10)=POST*PSYS22(10)
C     PARTITION BACKING
      PBACK=1.27135+0.03403*(FLAREA2)
      VSYS22(11)=PBACK*PSYS22(11)
C     MISCELLANEOUS BLOCKING AND FURRING
      BLKFUR=-518.92119+0.38476*(FLAREA2)
      VSYS22(12)=BLKFUR*PSYS22(12)
C     CORNER BRACES
      BRACE=81.97867+0.00229*(FLAREA2)
      VSYS22(13)=BRACE*PSYS22(13)
C     HEADERS
      HEAD=-69.62474+0.34479*(FLAREA2)
      VSYS22(14)=HEAD*PSYS22(14)
C     LATH AND PLASTER GROUNDS
      XLATH=2.0
      VSYS22(15)=XLATH*PSYS22(15)
C     WALL SHEATHING COMPOSITION BOARD
      COMP=1317.21282+0.50960*(FLAREA2)
      VSYS22(16)=COMP*PSYS22(16)
C     WALL SHEATHING PLYWOOD
      WPLY=-212.39128+0.42668*(FLAREA2)
      VSYS22(17)=WPLY*PSYS22(17)
C     SIDING WOOD
      WS=1776.34229+0.12327*(FLAREA2)
      VSYS22(18)=WS*PSYS22(18)
C     SIDING PLYWOOD
      PS=-1114.38402+0.59190*(FLAREA2)
      VSYS22(19)=PS*PSYS22(19)
C     SIDING HARDBOARD
      HS=81.46054+1.14245*(FLAREA2)
      VSYS22(20)=HS*PSYS22(20)
C     WALL BEAMS
      WBEAM=323.29764+0.12367*(FLAREA2)
      VSYS22(21)=WBEAM*PSYS22(21)
```

```
C
C                    SPLIT LEVEL WALL SYSTEM
C
      PSTUD=SSTUD=GSTUD=GRSTUD=BSTUD=XMSTUD=WPLT=BPLT=XMPLT=POST=0.0
      PRACK=BLKFUR=BRACE=HEAD=XLATH=COMP=WPLY=WS=PS=HS=WBEAM=0.0
C     PRE CUT WALL STUDS
      PSTUD=1938.88031+0.24976*(FLAREAS)
      VSYS2S(1)=PSTUD*PSYS2S(1)
C     SHOULDER STUDS
      SSTUD=67.05326+0.11650*(FLAREAS)
      VSYS2S(2)=SSTUD*PSYS2S(2)
C     GABLE STUDS
      GSTUD=285.81068-0.05942*(FLAREAS)
      VSYS2S(3)=GSTUD*PSYS2S(3)
C     GARAGE STUDS
      GRSTUD=162.35688+0.06320*(FLAREAS)
      VSYS2S(4)=GRSTUD*PSYS2S(4)
C     BATH WALL STUDS
      BSTUD=190.42758-0.06142*(FLAREAS)
      VSYS2S(5)=BSTUD*PSYS2S(5)
C     MISCELLANEOUS STUDS
      XMSTUD=-506.54169+0.43578*(FLAREAS)
      VSYS2S(6)=XMSTUD*PSYS2S(6)
C     WALL PLATES
      WPLT=571.75226+0.18951*(FLAREAS)
      VSYS2S(7)=WPLT*PSYS2S(7)
C     BATH WALL PLATES
      BPLT=92.53297-0.02936*(FLAREAS)
      VSYS2S(8)=BPLT*PSYS2S(8)
C     MISCELLANEOUS PLATES
      XMPLT=115.69847-0.04590*(FLAREAS)
      VSYS2S(9)=XMPLT*PSYS2S(9)
C     POSTS
      POST=245.99592-0.08093*(FLAREAS)
      VSYS2S(10)=POST*PSYS2S(10)
```

```
C     PARTITION BACKING
       PBACK=1.79659+0.03402*(FLAREAS)
       VSYS2S(11)=PBACK*PSYS2S(11)
C     MISCELLANEOUS BLOCKING AND FURRING
       BLKFUR=-365.08540+0.33459*(FLAREAS)
       VSYS2S(12)=BLKFUR*PSYS2S(12)
C     CORNER BRACES
       BRACE=122.14459-0.02852*(FLAREAS)
       VSYS2S(13)=BRACE*PSYS2S(13)
C     HEADERS
       HEAD=197.55205+0.15549*(FLAREAS)
       VSYS2S(14)=HEAD*PSYS2S(14)
C     LATH AND PLASTER GROUNDS
       XLATH=1.4
       VSYS2S(15)=XLATH*PSYS2S(15)
C     WALL SHEATHING COMPOSITION BOARD
       COMP=1443.63304+0.16524*(FLAREAS)
       VSYS2S(16)=COMP*PSYS2S(16)
C     WALL SHEATHING PLYWOOD
       WPLY=1968.0
       VSYS2S(17)=WPLY*PSYS2S(17)
C     SIDING WOOD
       WS=169.29904+0.65973*(FLAREAS)
       VSYS2S(18)=WS*PSYS2S(18)
C     SIDING PLYWOOD    (NO SIDING PLYWOOD IN SAMPLE)
       PS=0.0
       VSYS2S(19)=PS*PSYS2S(19)
C     SIDING HARDBOARD
       HS=1596.00
       VSYS2S(20)=HS*PSYS2S(20)
C     WALL BEAMS
       WBEAM=-424.29116+0.33539*(FLAREAS)
       VSYS2S(21)=WBEAM*PSYS2S(21)
       RETURN
       END
```

```
      SUBROUTINE SYS3 (FLAREA1,FLAREA2,FLAREAS,PSYS31,PSYS32,PSYS3S,
     1VSYS31,VSYS32,VSYS3S)
      DIMENSION PSYS31(12),PSYS32(12),PSYS3S(12),
     1VSYS31(12),VSYS32(12),VSYS3S(12)
C
C                     ONE STORY ROOF-CEILING SYSTEM
C
C     CEILING JOIST
      CJOIST=-39.40505+0.92078*(FLAREA1)
      VSYS31(1)=CJOIST*PSYS31(1)
C     RAFTERS
      RAFTER=-603.89437+1.98682*(FLAREA1)
      VSYS31(2)=RAFTER*PSYS31(2)
C     COLLAR TIES
      CTIE=-36.72466+0.13363*(FLAREA1)
      VSYS31(3)=CTIE*PSYS31(3)
C     RIDGE BOARDS
      RBD=-38.50704+0.07745*(FLAREA1)
      VSYS31(4)=RBD*PSYS31(4)
C     ROOF JOISTS
      RJOIST=756.0
      VSYS31(5)=RJOIST*PSYS31(5)
C     GARAGE COLLAR TIES AND TRUSSES
      GRTIE=-57.94249+0.22537*(FLAREA1)
      VSYS31(6)=GRTIE*PSYS31(6)
C     MOCK BEAM BLOCKING
      BEAM=80.0
      VSYS31(7)=BEAM*PSYS31(7)
C     ROUGH CORNICE MATERIAL
      CORNICE=-71.16845+0.19594*(FLAREA1)
      VSYS31(8)=CORNICE*PSYS31(8)
C     ROOF SHEATHING PLYWOOD
      RSPLY=151.81053+1.76489*(FLAREA1)
      VSYS31(9)=RSPLY*PSYS31(9)
```

```
C     ROOF SHEATHING BOARDS
       RSBDS=366.25338+1.80577*(FLAREA1)
       VSYS31(10)=RSBDS*PSYS31(10)
C     KNEE WALL STUDS
       WKSTUD=-240.39072+0.29449*(FLAREA1)
       VSYS31(11)=WKSTUD*PSYS31(11)
C     SHAKES AND SHINGLES
       SS=1.25
       VSYS31(12)=SS*PSYS31(12)
C
C                     TWO STORY ROOF-CEILING SYSTEM
C
C     CEILING JOIST
       CJOIST=304.41714+0.37853*(FLAREA2)
       VSYS32(1)=CJOIST*PSYS32(1)
C     RAFTERS
       RAFTER=-2075.59262+1.86181*(FLAREA2)
       VSYS32(2)=RAFTER*PSYS32(2)
C     COLLAR TIES
       CTIE=-120.19112+0.12152*(FLAREA2)
       VSYS32(3)=CTIE*PSYS32(3)
C     RIDGE BOARDS
       RBD=-46.95843+0.04575*(FLAREA2)
       VSYS32(4)=RBD*PSYS32(4)
C     ROOF JOISTS    (NO ROOF JOISTS IN SAMPLE)
       RJOIST=0.0
       VSYS32(5)=RJOIST*PSYS32(5)
C     GARAGE COLLAR TIES AND TRUSSES
       GRTIE=-346.71012+0.26991*(FLAREA2)
       VSYS32(6)=GRTIE*PSYS32(6)
C     MOCK BEAM BLOCKING
       BEAM=-619.41500+0.23960*(FLAREA2)
       VSYS32(7)=BEAM*PSYS32(7)
C     ROUGH CORNICE MATERIAL
       CORNICE=-645.47970+0.37736*(FLAREA2)
       VSYS32(8)=CORNICE*PSYS32(8)
```

```
C     ROOF SHEATHING PLYWOOD
        RSPLY=-970.80017+1.59058*(FLAREA2)
        VSYS32(9)=RSPLY*PSYS32(9)
C     ROOF SHEATHING BOARDS
        RSBDS=-421.63701+1.47501*(FLAREA2)
        VSYS32(10)=RSBDS*PSYS32(10)
C     KNEE WALL STUDS
        WKSTUD=204.63619+0.00724*(FLAREA2)
        VSYS32(11)=WKSTUD*PSYS32(11)
C     SHAKES AND SHINGLES
        SS=36.75
        VSYS32(12)=SS*PSYS32(12)
C
C                     SPLIT LEVEL ROOF-CEILING
C
C     CEILING JOIST
        CJOIST=144.55914+0.53545*(FLAREAS)
        VSYS3S(1)=CJOIST*PSYS3S(1)
C     RAFTERS
        RAFTER=2954.78414-0.53855*(FLAREAS)
        VSYS3S(2)=RAFTER*PSYS3S(2)
C     COLLAR TIES
        CTIE=56.71752+0.03782*(FLAREAS)
        VSYS3S(3)=CTIE*PSYS3S(3)
C     RIDGE BOARDS
        RBD=69.66221-0.00765*(FLAREAS)
        VSYS3S(4)=RBD*PSYS3S(4)
C     ROOF JOISTS  (NO ROOF JOISTS IN SAMPLE)
        RJOIST=0.0
        VSYS3S(5)=RJOIST*PSYS3S(5)
C     GARAGE COLLAR TIES AND TRUSSES
        GRTIE=245.25911+0.00681*(FLAREAS)
        VSYS3S(6)=GRTIE*PSYS3S(6)
C     MOCK BEAM BLOCKING     (NO MOCK BEAM BLOCKING IN SAMPLE)
        BEAM=0.0
        VSYS3S(7)=BEAM*PSYS3S(7)
```

```
C     ROUGH CORNICE MATERIAL
      CORNICE=-55.30369+0.13670*(FLAREAS)
      VSYS3S(8)=CORNICE*PSYS3S(8)
C     ROOF SHEATHING PLYWOOD
      RSPLY=1081.36610+0.73884*(FLAREAS)
      VSYS3S(9)=RSPLY*PSYS3S(9)
C     ROOF SHEATHING BOARDS
      RSBDS=1382.65397+0.70272*(FLAREAS)
      VSYS3S(10)=RSBDS*PSYS3S(10)
C     KNEE WALL STUDS
      WKSTUD=-695.49902+0.43832*(FLAREAS)
      VSYS3S(11)=WKSTUD*PSYS3S(11)
C     SHAKES AND SHINGLES  (NO SHAKES OR SHINGLES IN SAMPLE)
      SS=0.0
      VSYS3S(12)=SS*PSYS3S(12)
      RETURN
      END
```

```
      SUBROUTINE SYS4 (FLAREA1,FLAREA2,FLAREAS,PSYS41,PSYS42,PSYS4S,
     1VSYS41,VSYS42,VSYS4S)
      DIMENSION PSYS41(14),PSYS42(14),PSYS4S(14),
     1VSYS41(14),VSYS42(14),VSYS4S(14)
C
C                      ONE STORY MILLWORK-TRIM SYSTEM
C
      XCL=XCP=WINDOW=DOOR=SFTL=SFTP=FASCIA=BASE=PNLLBR=PNLPLY=0.0
      TRIMLBR=TRIMPLY=STAIR=FREIZE=0.0
C     KITCHEN CABINET LUMBER
      XCL=190.85089+0.00460*(FLAREA1)
      VSYS41(1)=XCL*PSYS41(1)
C     KITCHEN CABINET PLYWOOD
      XCP=283.27919+0.02281*(FLAREA1)
      VSYS41(2)=XCP*PSYS41(2)
C     WINDOWS
      WINDOW=16.94059+0.13480*(FLAREA1)
      VSYS41(3)=WINDOW*PSYS41(3)
C     DOORS
      DOOR=211.39134+0.55263*(FLAREA1)
      VSYS41(4)=DOOR*PSYS41(4)
C     SOFFIT LUMBER
      SFTL=69.05189+0.00543*(FLAREA1)
      VSYS41(5)=SFTL*PSYS41(5)
C     SOFFIT PLYWOOD
      SFTP=52.36913+0.18378*(FLAREA1)
      VSYS41(6)=SFTP*PSYS41(6)
C     FASCIA
      FASCIA=38.62677+0.05577*(FLAREA1)
      VSYS41(7)=FASCIA*PSYS41(7)
C     INTERIOR BASE MOULDING
      BASE=1.78005+0.02067*(FLAREA1)
      VSYS41(8)=BASE*PSYS41(8)
C     WALL PANELING LUMBER
      PNLLBR=117.82458-0.00231*(FLAREA1)
      VSYS41(9)=PNLLBR*PSYS41(9)
```

```
C     WALL PANELING PLYWOOD AND OTHER SHEAT MATERIAL
      PNLPLY=80.0
      VSYS41(10)=PNLPLY*PSYS41(10)
C     MISCELLANEOUS EXTERIOR TRIM LUMBER
      TRIMLBR=-7.10025+0.09487*(FLAREA1)
      VSYS41(11)=TRIMLBR*PSYS41(11)
C     MISCELLANEOUS EXTERIOR TRIM PLYWOOD
      TRIMPLY=160.82265+0.10892*(FLAREA1)
      VSYS41(12)=TRIMPLY*PSYS41(12)
C     STAIRS
      STAIR=149.15063-0.00556*(FLAREA1)
      VSYS41(13)=STAIR*PSYS41(13)
C     FREIZE BOARD
      FRIEZE=128.55705-0.02141*(FLAREA1)
      VSYS41(14)=FRIEZE*PSYS41(14)
C
C                    TWO STORY MILLWORK-TRIM SYSTEM
C
      XCL=XCP=WINDOW=DOOR=SFTL=SFTP=FASCIA=BASE=PNLLBR=PNLPLY=0.0
      TRIMLBR=TRIMPLY=STAIR=FREIZE=0.0
C     KITCHEN CABINET LUMBER
      XCL=200.82
      VSYS42(1)=XCL*PSYS42(1)
C     KITCHEN CABINET PLYWOOD
      XCP=324.44
      VSYS42(2)=XCP*PSYS42(2)
C     WINDOWS
      WINDOW=143.78337+0.09972*(FLAREA2)
      VSYS42(3)=WINDOW*PSYS42(3)
C     DOORS
      DOOR=67.42817+0.52839*(FLAREA2)
      VSYS42(4)=DOOR*PSYS42(4)
C     SOFFIT LUMBER
      SFTL=-2240.12266+0.87796*(FLAREA2)
      VSYS42(5)=SFTL*PSYS42(5)
```

```
C     SOFFIT PLYWOOD
      SFTP=-311.21370+0.25990*(FLAREA2)
      VSYS42(6)=SFTP*PSYS42(6)
C     FASCIA
      FASCIA=35.97918+0.04479*(FLAREA2)
      VSYS42(7)=FASCIA*PSYS42(7)
C     INTERIOR BASE MOULDING
      BASE=-2.28784+0.02145*(FLAREA2)
      VSYS42(8)=BASE*PSYS42(8)
C     WALL PANELING LUMBER
      PNLLBR=-123.78283+0.08558*(FLAREA2)
      VSYS42(9)=PNLLBR*PSYS42(9)
C     WALL PANELING PLYWOOD AND OTHER SHEAT MATERIAL
      PNLPLY=865.0
      VSYS42(10)=PNLPLY*PSYS42(10)
C     MISCELLANEOUS EXTERIOR TRIM LUMBER
      TRIMLBR=-522.90784+0.31976*(FLAREA2)
      VSYS42(11)=TRIMLBR*PSYS42(11)
C     MISCELLANEOUS EXTERIOR TRIM PLYWOOD
      TRIMPLY=-131.99599+0.19908*(FLAREA2)
      VSYS42(12)=TRIMPLY*PSYS42(12)
C     STAIRS
      STAIR=222.23838-0.03556*(FLAREA2)
      VSYS42(13)=STAIR*PSYS42(13)
C     FREIZE BOARD
      FREIZE=-198.39099+0.12568*(FLAREA2)
      VSYS42(14)=FREIZE*PSYS42(14)
C
C                    SPLIT LEVEL MILLWORK-TRIM
C
      XCL=XCP=WINDOW=DOOR=SFTL=SFTP=FASCIA=BASE=PNLLBR=PNLPLY=0.0
      TRIMLBR=TRIMPLY=STAIR=FREIZE=0.0
C     KITCHEN CABINET LUMBER
      XCL=200.0
      VSYS4S(1)=XCL*PSYS4S(1)
```

```
C     KITCHEN CABINET PLYWOOD
      XCP=329.0
      VSYS4S(2)=XCP*PSYS4S(2)
C     WINDOWS
      WINDOW=293.87478-0.00934*(FLAREAS)
      VSYS4S(3)=WINDOW*PSYS4S(3)
C     DOORS
      DOOR=456.35028+0.31941*(FLAREAS)
      VSYS4S(4)=DOOR*PSYS4S(4)
C     SOFFIT LUMBER
      SFTL=208.0
      VSYS4S(5)=SFTL*PSYS4S(5)
C     SOFFIT PLYWOOD
      SFTP=-356.23416+0.33568*(FLAREAS)
      VSYS4S(6)=SFTP*PSYS4S(6)
C     FASCIA
      FASCIA=43.57947+0.04137*(FLAREAS)
      VSYS4S(7)=FASCIA*PSYS4S(7)
C     INTERIOR BASE MOULDING
      BASE=19.94319+0.01181*(FLAREAS)
      VSYS4S(8)=BASE*PSYS4S(8)
C     WALL PANELING LUMBER
      PNLLBR=110.0
      VSYS4S(9)=PNLLBR*VSYS4S(9)
C     WALL PANELING PLYWOOD AND OTHER SHEAT MATERIAL  (NON IN SAMPLE)
      PNLPLY=0.0
      VSYS4S(10)=PNLPLY*PSYS4S(10)
C     MISCELLANEOUS EXTERIOR TRIM LUMBER
      TRIMLBR=-12.42010+0.10249*(FLAREAS)
      VSYS4S(11)=TRIMLBR*PSYS4S(11)
C     MISCELLANEOUS EXTERIOR TRIM PLYWOOD
      TRIMPLY=155.92363+0.05746*(FLAREAS)
      VSYS4S(12)=TRIMPLY*PSYS4S(12)
C     STAIRS
      STAIR=47.0
      VSYS4S(13)=STAIR*PSYS4S(13)
```

```
C     FREIZE
      FREIZE=506.08238-0.26576*(FLAREAS)
      VSYS48(14)=FREIZE*PSYS48(14)
      RETURN
      END
```

```
      SUBROUTINE SUBA1 (YEAR,PSYS11,PSYS12,PSYS13)
      DIMENSION PSYS11(13),PSYS12(13),PSYS13(13)
C
C  SUBROUTINE WHICH SIMULATES THE REMOVAL OF FLOOR FRAMING MATERIAL
C
C  REDUCING THE PROPORTION OF ONE STORY HOMES HAVING A WOOD
C  WOOD FRAME SYSTEM BY 25 PERCENT
C
C  MUD SILL
      PSYS11(1)=PSYS11(1)-0.00839
C  FLOOR JOIST
      PSYS11(2)=PSYS11(2)-0.01471
C  FLOOR SKIRT
      PSYS11(3)=PSYS11(3)-0.01332
C  BRIDGING
      PSYS11(4)=PSYS11(4)-0.01447
C  I-BEAM BLOCKING
      PSYS11(5)=PSYS11(5)-0.01447
C  TILE CLEATING
      PSYS11(6)=PSYS11(6)-0.00537
C  BASEMENT POSTS
      PSYS11(7)=PSYS11(7)-0.00210
C  MISC BLOCKING
      PSYS11(13)=PSYS11(13)-0.00374
C
C  REDUCING THE PROPORTION OF TWO STORY HOMES HAVING A WOOD
C  WOOD FRAME SYSTEM BY 25 PERCENT
C
C  MUD SILL
      PSYS12(1)=PSYS12(1)-0.00545
C  FLOOR JOIST
      PSYS12(2)=PSYS12(2)-0.01705
C  FLOOR SKIRT
      PSYS12(3)=PSYS12(3)-0.01705
```

```
C  BRIDGING
      PSYS12(4)=PSYS12(4)-0.01253
C  I-BEAM BLOCKING
      PSYS12(5)=PSYS12(5)-0.01416
C  TILE CLEATING
      PSYS12(6)=PSYS12(6)-0.00818
C  BASEMENT POSTS
      PSYS12(7)=PSYS12(7)-0.00490
C  MISC BLOCKING
      PSYS12(13)=PSYS12(13)-0.00164
C
C  REDUCING THE PROPORTION OF SPLIT LEVEL HOMES HAVING A WOOD
C  WOOD FRAME SYSTEM BY 25 PERCENT
C
C  MUD SILL
      PSYS1S(1)=PSYS1S(1)-0.00735
C  FLOOR JOIST
      PSYS1S(2)=PSYS1S(2)-0.01470
C  FLOOR SKIRT
      PSYS1S(3)=PSYS1S(3)-0.01470
C  BRIDGING
      PSYS1S(4)=PSYS1S(4)-0.01470
C  I-BEAM BLOCKING,TILE CLEATING, AND MISC BLOCKING
      PSYS1S(5)=PSYS1S(5)-0.01470
C  NO BASEMENT POSTS IN SPLIT LEVEL SAMPLE
      RETURN
      END
```

```
      SUBROUTINE SUBA2 (YEAR,PSYS11,PSYS12,PSYS1S)
      DIMENSION PSYS11(13),PSYS12(13),PSYS1S(13)
C
C  SUBROUTINE WHICH SIMULATES THE REMOVAL OF FLOOR FRAMING MATERIAL
C
C  REDUCING THE PROPORTION OF ONE STORY HOMES HAVING A WOOD
C  WOOD FRAME SYSTEM BY 50 PERCENT
C
C  MUD SILL
      PSYS11(1)=PSYS11(1)-0.01680
C  FLOOR JOIST
      PSYS11(2)=PSYS11(2)-0.02941
C  FLOOR SKIRT
      PSYS11(3)=PSYS11(3)-0.02848
C  BRIDGING
      PSYS11(4)=PSYS11(4)-0.02894
C  I-BEAM BLOCKING
      PSYS11(5)=PSYS11(5)-0.02894
C  TILE CLEATING
      PSYS11(6)=PSYS11(6)-0.01074
C  BASEMENT POSTS
      PSYS11(7)=PSYS11(7)-0.00420
C  MISC BLOCKING
      PSYS11(13)=PSYS11(13)-0.00746
C
C  REDUCING THE PROPORTION OF TWO STORY HOMES HAVING A WOOD
C  WOOD FRAME SYSTEM BY 50 PERCENT
C
C  MUD SILL
      PSYS12(1)=PSYS12(1)-0.01089
C  FLOOR JOIST
      PSYS12(2)=PSYS12(2)-0.02941
C  FLOOR SKIRT
      PSYS12(3)=PSYS12(3)-0.02941
C  BRIDGING
      PSYS12(4)=PSYS12(4)-0.02505
```

```
C  I-BEAM BLOCKING
      PSYS12(5)=PSYS12(5)-0.02832
C  TILE CLEATING
      PSYS12(6)=PSYS12(6)-0.01634
C  BASEMENT POSTS
      PSYS12(7)=PSYS12(7)-0.00980
C  MISC BLOCKING
      PSYS12(13)=PSYS12(13)-0.00327
C
C  REDUCING THE PROPORTION OF SPLIT LEVEL HOMES HAVING A WOOD
C  WOOD FRAME SYSTEM BY 50 PERCENT
C
C  MUD SILL
      PSYS1S(1)=PSYS1S(1)-0.01470
C  FLOOR JOIST
      PSYS1S(2)=PSYS1S(2)-0.02941
C  FLOOR SKIRT
      PSYS1S(3)=PSYS1S(3)-0.02941
C  BRIDGING
      PSYS1S(4)=PSYS1S(4)-0.02647
C  I-BEAM BLOCKING,TILE CLEATING, AND MISC BLOCKING
      PSYS1S(5)=PSYS1S(5)-0.02647
C  NO BASEMENT POSTS IN SPLIT LEVEL SAMPLE
      RETURN
      END
```

```
      SUBROUTINE SUBA3 (YEAR,PSYS11,PSYS12,PSYS1S)
      DIMENSION PSYS11(13),PSYS12(13),PSYS1S(13)
C
C  SUBROUTINE WHICH SIMULATES THE REMOVAL OF FLOOR FRAMING MATERIAL
C
C  REDUCING THE PROPORTION OF ONE STORY HOMES HAVING A WOOD
C  WOOD FRAME SYSTEM BY 100 PERCENT
C
C  MUD SILL
      PSYS11(1)=PSYS11(1)-0.03360
C  FLOOR JOIST
      PSYS11(2)=PSYS11(2)-0.05882
C  FLOOR SKIRT
      PSYS11(3)=PSYS11(3)-0.05695
C  BRIDGING
      PSYS11(4)=PSYS11(4)-0.05789
C  I-BEAM BLOCKING
      PSYS11(5)=PSYS11(5)-0.05789
C  TILE CLEATING
      PSYS11(6)=PSYS11(6)-0.02148
C  BASEMENT POSTS
      PSYS11(7)=PSYS11(7)-0.00840
C  MISC BLOCKING
      PSYS11(13)=PSYS11(13)-0.01494
C
C  REDUCING THE PROPORTION OF TWO STORY HOMES HAVING A WOOD
C  WOOD FRAME SYSTEM BY 100 PERCENT
C
C  MUD SILL
      PSYS12(1)=PSYS12(1)-0.02179
C  FLOOR JOIST
      PSYS12(2)=PSYS12(2)-0.05882
C  FLOOR SKIRT
      PSYS12(3)=PSYS12(3)-0.05882
C  BRIDGING
      PSYS12(4)=PSYS12(4)-0.05010
```

```
C  I-BEAM BLOCKING
      PSYS12(5)=PSYS12(5)-0.03665
C  TILE CLEATING
      PSYS12(6)=PSYS12(6)-0.03268
C  BASEMENT POSTS
      PSYS12(7)=PSYS12(7)-0.01960
C  MISC BLOCKING
      PSYS12(13)=PSYS12(13)-0.00654
C
C  REDUCING THE PROPORTION OF SPLIT LEVEL HOMES HAVING A WOOD
C  WOOD FRAME SYSTEM BY 100 PERCENT
C
C  MUD SILL
      PSYS1S(1)=PSYS1S(1)-0.02941
C  FLOOR JOIST
      PSYS1S(2)=PSYS1S(2)-0.05882
C  FLOOR SKIRT
      PSYS1S(3)=PSYS1S(3)-0.05882
C  BRIDGING
      PSYS1S(4)=PSYS1S(4)-0.05294
C  I-BEAM BLOCKING,TILE CLEATING, AND MISC BLOCKING
      PSYS1S(5)=PSYS1S(5)-0.05294
C  NO BASEMENT POSTS IN SPLIT LEVEL SAMPLE
      RETURN
      END
```

```
      SUBROUTINE SUBB1 (YEAR,PSYS21,PSYS22,PSYS2S)
      DIMENSION  PSYS21(21),PSYS22(21),PSYS2S(21)
C
C  SUBROUTINE WHICH SIMULATES THE REMOVAL OF PRE-CUT WALL STUDS
C
C  REDUCING THE PROPORTION OF ONE STORY HOMES HAVING PRECUT WALL STUDS
C  BY 25 PERCENT
      PSYS21(1)=PSYS21(1)-0.01476
C  REDUCING THE PROPORTION OF TWO STORY HOMES HAVING PRECUT WALL STUDS
C  BY 25 PERCENT
      PSYS22(1)=PSYS22(1)-0.01476
C  REDUCING THE PROPORTION OF SPLIT LEVEL HOMES HAVING PRECUT WALL STUDS
C  BY 25 PERCENT
      PSYS2S(1)=PSYS2S(1)-0.01476
      RETURN
      END

      SUBROUTINE SUBB2 (YEAR,PSYS21,PSYS22,PSYS2S)
      DIMENSION  PSYS21(21),PSYS22(21),PSYS2S(21)
C
C  SUBROUTINE WHICH SIMULATES THE REMOVAL OF PRE-CUT WALL STUDS
C
C  REDUCING THE PROPORTION OF ONE STORY HOMES HAVING PRECUT WALL STUDS
C  BY 50 PERCENT
      PSYS21(1)=PSYS21(1)-0.02941
C  REDUCING THE PROPORTION OF TWO STORY HOMES HAVING PRECUT WALL STUDS
C  BY 50 PERCENT
      PSYS22(1)=PSYS22(1)-0.02941
C  REDUCING THE PROPORTION OF SPLIT LEVEL HOMES HAVING PRECUT WALL STUDS
C  BY 50 PERCENT
      PSYS2S(1)=PSYS2S(1)-0.02941
      RETURN
      END
```

```
      SUBROUTINE SUBB3 (YEAR,PSYS21,PSYS22,PSYS2S)
      DIMENSION  PSYS21(21),PSYS22(21),PSYS2S(21)
C
C  SUBROUTINE WHICH SIMULATES THE REMOVAL OF PRE-CUT WALL STUDS
C
C  REDUCING THE PROPORTION OF ONE STORY HOMES HAVING PRECUT WALL STUDS
C  BY 100 PERCENT
      PSYS21(1)=PSYS21(1)-0.05882
C  REDUCING THE PROPORTION OF TWO STORY HOMES HAVING PRECUT WALL STUDS
C  BY 100 PERCENT
      PSYS22(1)=PSYS22(1)-0.05882
C  REDUCING THE PROPORTION OF SPLIT LEVEL HOMES HAVING PRECUT WALL STUDS
C  BY 100 PERCENT
      PSYS2S(1)=PSYS2S(1)-0.05882
      RETURN
      END

      SUBROUTINE SUBC1 (YEAR,PSYS11,PSYS12,PSYS1S)
      DIMENSION PSYS11(13),PSYS12(13),PSYS1S(13)
C
C  SUBSTITUTION OF STEEL FOR WOOD FLOOR JOISTS RESULTING IN COMPLETE ELMINIATION
C  OF WOOD FLOOR JOISTS IN 1973 AND SUBSEQUENT YEARS
C
      IF(YEAR.LE.1972.) GO TO 100
      PSYS11(2)=0.0
      PSYS12(2)=0.0
      PSYS1S(2)=0.0
  100 RETURN
      END
```

```
      SUBROUTINE SUBC2 (YEAR,PSYS11,PSYS12,PSYS1S)
      DIMENSION PSYS11(13),PSYS12(13),PSYS1S(13)
C
C  SUBSTITUTION OF STEEL FOR WOOD FLOOR JOISTS WITH A 50 PERCENT
C  DECLINE IN WOOD FLOOR JOIST USE AFTER 1973
C
      IF(YEAR.LE.1972.) GO TO 100
      PSYS11(2)=PSYS11(2)-0.03846
      PSYS12(2)=PSYS12(2)-0.03846
      PSYS1S(2)=PSYS1S(2)-0.03846
  100 RETURN
      END


      SUBROUTINE SUBD1 (YEAR,PSYS21,PSYS22,PSYS2S)
      DIMENSION PSYS21(21),PSYS22(21),PSYS2S(21)
C
C  SUBSTITUTION OF STEEL FOR WOOD PRE-CUT WALL STUDS RESULTING IN
C  COMPLETE ELIMINATION OF WOOD PRE-CUT WALL STUDS IN 1975 AND
C  IN ALL SUBSEQUENT YEARS
C
      IF(YEAR.LE.1974.) GO TO 100
      PSYS21(1)=0.0
      PSYS22(1)=0.0
      PSYS2S(1)=0.0
  100 RETURN
      END
```

```
      SUBROUTINE SUBD2 (YEAR,PSYS21,PSYS22,PSYS2S)
      DIMENSION PSYS21(21),PSYS22(21),PSYS2S(21)
C
C SUBSTITUTION OF STEEL FOR WOOD PRE-CUT WALL STUDS WITH A 50 PERCENT
C  DECLINE IN WOOD PRE-CUT WALL STUDS BEGINNING IN 1975 AND AFTER
C
      IF(YEAR.LE.1974.) GO TO 100
      PSYS21(1)=PSYS21(1)-0.04545
      PSYS22(1)=PSYS22(1)-0.04545
      PSYS2S(1)=PSYS2S(1)-0.04545
  100 RETURN
      END
```

```
      SUBROUTINE TECH1 (YEAR,C,G,R)
      DIMENSION C(3),G(3),R(3)
C
C  CHANGE IN TECHNICAL DESIGN. ASSUME 100 PERCENT OF HOUSES WILL
C  USE A TRUSS ROOF SYSTEM BY THE YEAR 1985
C
      IF(YEAR.NE.1969.) GO TO 100
      PCONVT=0.95000-0.0558823
      PTRUSS=0.05000+0.0558823
      VTRUSS=0.0
      GO TO 101
C
C  ANNUAL INCREASE IN USE OF TRUSS SYSTEMS(OR DECREASE IN CONVENTIONAL
C  SYSTEMS) IS DETERMINED BY DIVIDING THE TOTAL PERCENT CHANGE BETWEEN
C  1969 AND 1985 BY 17 YEARS
C
  100 PCONVT=PCONVT-0.0558823
      PTRUSS=PTRUSS+0.0558823
C  CONVENTIONAL ROOF FRAME SYSTEM = 4039.0  BOARD FEET
  101 WCVOL=(PCONVT)*(4039.0)
C  TRUSS ROOF FRAME SYSTEM=2293.0 BOARD FEET
      WTVOL=(PTRUSS)*(2293.0)
C  VOLUME LOSS DUE TO DECLINE IN HOMES USING CONVENTIONAL SYSTEM
      CLOSS=4039.0-WCVOL
C  VOLUME GAIN DUE TO INCREASE IN HOMES USING TRUSS SYSTEM
      TGAIN=VTRUSS+WTVOL
C
C  SUBTRACTING THE VOLUME FROM EACH ARCHITECTURAL TYPE
C
      C(1)=C(1)-CLOSS+TGAIN
      G(1)=G(1)-CLOSS+TGAIN
      R(1)=R(1)-CLOSS+TGAIN
      RETURN
      END
```

```
      SUBROUTINE TECH2 (YEAR,C,G,R)
      DIMENSION C(3),G(3),R(3)
C
C  CHANGE IN TECHNICAL DESIGN. ASSUME 100 PERCENT OF HOUSES WILL
C  USE A TRUSS ROOF SYSTEM BY THE YEAR 1975
C
      IF(YEAR.NE.1969.) GO TO 100
      PCONVT=0.95000-0.13571
      PTRUSS=0.05000+0.13571
      VTRUSS=0.0
      GO TO 101
C
C  ANNUAL INCREASE IN USE OF TRUSS SYSTEMS(OR DECREASE IN CONVENTIONAL
C  SYSTEMS) IS DETERMINED BY DIVIDING THE TOTAL PERCENT CHANGE BETWEEN
C  1969 AND 1975 BY  7 YEARS
C
  100 IF(YEAR.GE.1976.) GO TO 102
      PCONVT=PCONVT-0.13571
      PTRUSS=PTRUSS+0.13571
C  CONVENTIONAL ROOF FRAME SYSTEM = 4039.0  BOARD FEET
  101 WCVOL=(PCONVT)*(4039.0)
C  TRUSS ROOF FRAME SYSTEM=2293.0 BOARD FEET
      WTVOL=(PTRUSS)*(2293.0)
      CLOSS=4039.0-WCVOL
      TGAIN=VTRUSS+WTVOL
      GO TO 103
  102 CLOSS=4039.0
      TGAIN=2293.0
C
C  SUBTRACTING THE VOLUME FROM EACH ARCHITECTURAL TYPE
C
  103 C(1)=C(1)-CLOSS+TGAIN
      G(1)=G(1)-CLOSS+TGAIN
      R(1)=R(1)-CLOSS+TGAIN
      RETURN
      END
```