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AN ECONOMIC-STATISTICAL ANALYSIS OF LUMBER REQUIREMENTS FOR CALIFORNIA HOUSING

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Residential construction normally accounts for almost half of the lumber consumed in California. A study of past trends of housing market demand, and an analysis of the factors underlying such trends, can therefore provide valuable guides toward insuring a reasonable balance between future supplies of forest products and future needs for them.

The demand for new residential structures in California during the period 1920–1941 was found to be closely correlated with the increase in population, levels of family income, the cost of new home ownership, and the available supply of housing. The quantity of lumber used per dwelling in the same period was influenced by size of dwelling, type of construction, and geographic location, and showed a decline with time which indicates the influences of substitute materials and of more economical methods of wood use. Lumber consumption for new residential construction in California averaged 1.2 billion board feet per year in the period 1920–1929, and 0.9 billion board feet per year in the period 1930–1939.

Under conditions of normal full employment, housing lumber requirements during the next two decades may be expected to range from 1.0 to 1.7 billion board feet per year. These figures correspond to minimum and maximum anticipated rates of population growth.

This paper is a summary of a dissertation under the same title submitted in partial fulfillment of the requirements of the degree of Doctor of Philosophy at the University of California, 1948. Much of the basic data on unit lumber requirements, and portions of the material on residential construction, were obtained as part of the Forest Survey in California, conducted by the California Forest and Range Experiment Station, U. S. Forest Service, maintained at Berkeley in coöperation with the California Agricultural Experiment Station.

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INTRODUCTION

LONG-RANGE PLANNING for a reasonable balance between future supplies of forest products and future needs for them requires a high degree of foresight. Continued liquidation of timber resources, unaccompanied by measures designed to provide for future timber crops, will of course lead to such eventual scarcities of wood supply that many consumers who now use wood will be forced by higher prices to turn to less expensive substitutes. The situation of high prices in the presence of unproductive timberland will mean great social losses if allowed to develop. On the other hand, if we were to attempt to exploit the full timber-growing capacity of all our forest land, we would eventually grow such large quantities of timber that the wood markets of the country could not absorb them at prices adequate to cover the real costs of production. This, too, would involve large private and public losses resulting from the investment in timber-growing enterprises of capital and labor which could have been devoted to other purposes to greater economic and social advantages.

If we are to avoid these dangers, we need carefully defined goals of timber production which will insure a reasonable degree of balance in the wood markets of the future. Such goals must be based on a detailed study of the trends of market demand for wood products, on an analysis of the factors responsible for these trends, and on a consideration of the relation to future demands of the costs at which timber supplies can then be made available.

Analyses of this kind are of particular importance to California because of the size and peculiarities of its own forest industries. About 17 per cent of the state's forest area is timber cropland, primarily suited for wood production (Wieslander and Jensen, 1946).[3] Prior to 1941, exploitation of this forest resource proceeded at a moderate rate. Recently, however, increases in demand for timber and the progressive liquidation of supplies in other areas have led to greatly expanded production (table 1). At the same time, popu-

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[3] See "Literature Cited" for citations, referred to in text by author and date.

lation growth and increasing industrialization have raised lumber consumption to higher levels than have ever been experienced before. The question of the adequacy of our future timber supply thus concerns both a major basic industry and most of the state's consumers.

Table 1

PRODUCTION AND APPARENT CONSUMPTION OF LUMBER IN CALIFORNIA: 1920–1945*

Year	Production MM bd. ft.	Apparent consumption	
		Total MM bd. ft.	Per capita bd. ft.
1920	1,418.9	2,257	649
1921	1,360.3	n.a.†	n.a.
1922	1,720.6	3,387	852
1923	2,119.1	4,481	1,068
1924	1,996.5	3,569	809
1925	2,043.0	n.a.	n.a.
1926	2,188.0	3,557	733
1927	2,070.8	n.a.	n.a.
1928	1,952.7	3,067	579
1929	2,063.2	n.a.	n.a.
1930	1,514.3	2,414	421
1931	957.7	n.a.	n.a.
1932	680.5	1,457	245
1933	784.6	n.a.	n.a.
1934	1,014.7	1,498	243
1935	1,355.7	n.a.	n.a.
1936	1,647.5	2,569	424
1937	1,775.7	n.a.	n.a.
1938	1,462.0	2,635	421
1939	1,684.7	n.a.	n.a.
1940	1,954.5	3,374	488
1941‡	2,331.0	3,836	529
1942‡	2,330.0	4,192	551
1943‡	2,352.6	3,706	458
1944	2,468.9	n.a.	n.a.
1945	2,260.8	n.a.	n.a.

* Sources: U. S. Bureau of Census, Census of Forest Products; and Division of Economics, U. S. Forest Service.
† n.a. = data not available.
‡ 1941 to 1943 figures based on domestic lumber only; import statistics not available.

The problem is complicated, and its importance emphasized, by the nature of the California lumber trade. Although we normally consume a third again as much lumber as we produce, between a fourth and a third of our own lumber output is normally marketed elsewhere (figure 1). This results from the specialty character of ponderosa pine, sugar pine, and redwood, the species which make up the bulk of California lumber production. In the past, most of our lumber imports have come from the Pacific Northwest. As virgin supplies in that area approach exhaustion, California may well be faced with the problem of meeting a larger proportion of her own needs from her own forests. This situation emphasizes the importance of a clear understanding of what those needs may be.

The present study was undertaken to provide information on one phase of the problem of future demand for lumber in California: requirements for new residential construction. Josephson (1935) has shown that housing uses have accounted for almost half of total California lumber consumption in the past. A study of this field will therefore illuminate the largest single factor involved in the problem of lumber demand.

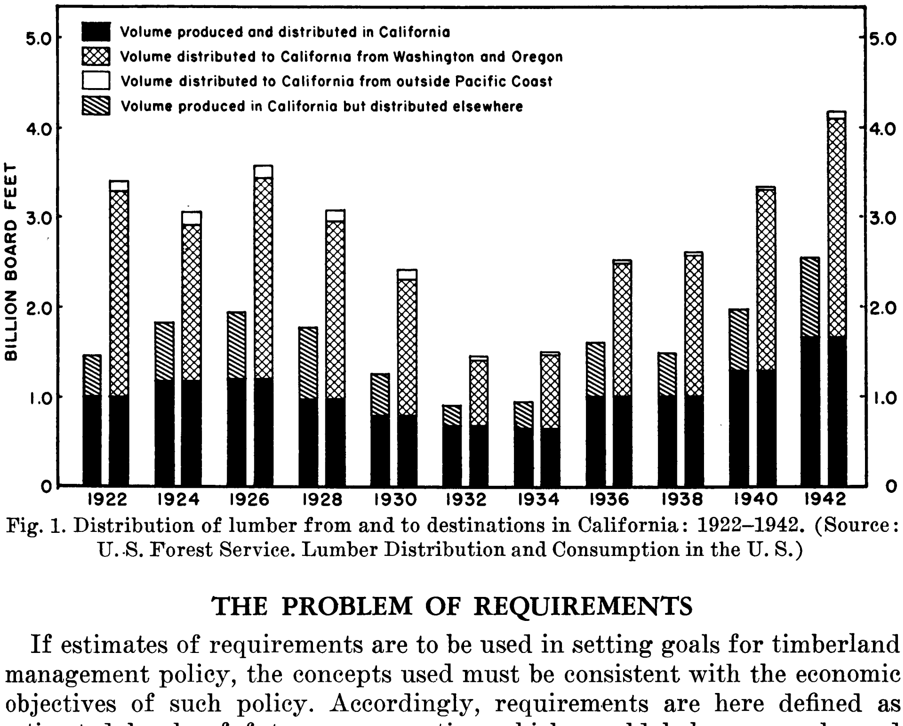

Fig. 1. Distribution of lumber from and to destinations in California: 1922–1942. (Source: U. S. Forest Service. Lumber Distribution and Consumption in the U. S.)

THE PROBLEM OF REQUIREMENTS

If estimates of requirements are to be used in setting goals for timberland management policy, the concepts used must be consistent with the economic objectives of such policy. Accordingly, requirements are here defined as estimated levels of future consumption which would balance supply and demand for timber products at prices just sufficient to cover all long-run costs of production. Such a definition assumes that timber management will be undertaken *now* on such a scale that no future timber scarcity will enable timber growers to exact royalties for their product over and above real costs of production.

The initial study of lumber consumption in California was made by Josephson (1935). His data provide a basis from which some notion can now be obtained of the long-run trend in lumber use. Josephson analyzed past new residential construction in terms of two variables: increase in population, and rate at which obsolete dwellings are replaced. These replacement figures are, in effect, a residual showing the difference between new construction and population increase. No comprehensive statistics showing past dwelling demolition in California are available to permit estimating the rate of replacement directly. Moreover, replacements usually involve a change in site, as well as a change in structure. They appear to be closely tied to changes in land use which may be largely independent of the process of new home construction (Chawner, 1939; Hallauer, 1939). This further complicates the job of identifying and measuring replacement directly.

Table 2

APPARENT ANNUAL REPLACEMENT OF DWELLINGS IN CALIFORNIA: 1920–1941

(All data in thousands)

Year	Estimated number of dwelling units in existence	Abnormal vacancy (+) or occupancy (−)*	Number of new families†	New dwelling units built‡	Apparent number of replacements made§	Replacements per million dwellings
1	*2*	*3*	*4*	*5*	*6*	*7*
1920	985	+19.1	80.8	34.0	0	0
1921	1,015	−31.1	75.8	66.5	0	0
1922	1,075	−51.2	71.1	74.8	0	0
1923	1,141	−60.0	125.2	139.7	0	0
1924	1,265	−70.3	54.3	111.2	0	0
1925	1,364	−32.1	64.8	103.0	6.1	4.5
1926	1,455	−11.1	56.9	88.3	20.3	14.0
1927	1,534	+ 3.6	58.8	84.5	29.3	19.1
1928	1,609	+16.7	56.5	94.8	55.0	34.2
1929	1,693	+27.7	76.0	88.1	39.8	23.5
1930	1,771	+36.2	37.0	93.7	92.9	52.5
1931	1,871	+79.3	44.3	29.4	29.4	15.7
1932	1,902	+57.8	32.0	29.2	29.2	15.4
1933	1,933	+56.9	35.8	19.9	19.9	10.2
1934	1,954	+16.5	49.5	29.8	0	0
1935	1,986	+16.7	52.3	44.4	8.8	4.4
1936	2,033	+ 8.9	65.6	50.4	0	0
1937	2,087	+11.3	62.9	64.2	12.6	6.0
1938	2,155	−50.8	59.1	78.5	0	0
1939	2,239	−34.9	60.8	95.6	0	0
1940	2,340	+45.4	83.4	110.8	72.8	31.1
1941	2,469	+97.3	126.4	119.1	90.0	36.4

* Product of difference between actual vacancy ratio and normal vacancy by the number of dwellings as shown in column 2. Normal vacancy assumed to be 6.7 per cent.

† From U. S. Census and California Taxpayers' Assoc. data.

‡ See table 3, p. 469.

§ Column 5 minus column 4 plus column 3, but never less than 0 nor greater than column 5.

Difficulties in using the replacement concept are further indicated by table 2, which shows the results of calculating replacement rates by indirect means. The table emphasizes the extreme variability of replacement rates from year to year. Clear analysis of rates of new construction, and hence of future requirements, therefore demands some further examination of the factors responsible for such variability.

A second study of lumber requirements for residential construction in California was made by Hallauer (1939). Using some of the data collected by Josephson but different methods of analysis, he arrived at somewhat different requirement estimates. These however are subject to qualifications on similar theoretical grounds.

PLAN OF THE PRESENT STUDY

The present study has estimated demands for lumber for new residential construction in California in the following manner. First, estimates of the annual rate of new dwelling construction in the state were prepared for each year from 1920 to 1945 inclusive. Next, the annual rates of new construction for the years 1920 to 1941 were correlated with independent variables such as population growth, level of family income, costs of new home ownership, and adequacy of the housing supply, in an effort to establish statistical relations between the rate of new construction and those independent economic factors primarily associated with it. (The years 1942–1945 were excluded from this phase of the study because of abnormal wartime conditions.) Third, field studies were made of the use of lumber in current new construction. These studies were designed to show both the average amount of lumber used per new dwelling, and the way in which use varied with independent factors such as size of house, type of construction, and location. Comparison of the results of this study with earlier work by Josephson (1935) gave an indication of changes in use with time. Fourth, estimates of prospective rates of new dwelling construction in California were prepared on the basis of the relations established between building, population growth, income, and costs, and estimates of the future trend of these independent variables. Finally, estimates of lumber requirements were made by applying to these forecasted construction rates estimated factors showing lumber use per dwelling. These factors were based on the experience data referred to above, and reflected probable future trends in factors shown to be related to wood use, such as size of dwelling.

VOLUME OF NEW RESIDENTIAL CONSTRUCTION: 1920–1945

The starting point for an historical analysis of demand is ordinarily found in the record of consumption. Because of the durable character of housing, lumber enters into the consumption process in two distinct phases. Initially, lumber is used in new residential construction. Later, additional lumber may be used for the maintenance and repair of the same structures. The factors that affect these two aspects of demand are not necessarily the same. The former is of much greater quantitative importance and will be considered here. Maintenance and repair requirements are not embraced by the present study.

Rate of new construction. Considerable information on the volume of new residential construction in California can be developed from annual building permit surveys conducted by the U. S. Bureau of Labor Statistics (1937–39; 1939–40) and from the Census of 1940: Housing. The building permit surveys have been made annually from 1921 to date. They give data on both the number and kinds of residential structures for which building permits were issued in each city covered by the surveys. In 1921 the survey included the 12 largest cities in the state, representing 51.1 per cent of the 1920 population. By 1940, coverage had been extended to include 178 cities representing over 70 per cent of the population in that year. By themselves, these data are inadequate as an index of new dwelling construction because coverage is not uniform throughout the period and neglects rural areas entirely. For the 11 largest cities,[4] the building permit series is both complete and consistent for the period 1921–1945. Unfortunately, comparison with Census data indicates that the number of building permits issued in a given city underestimates the number of structures actually built there. This apparently results from the erection of some unpermitted structures. To make matters worse the discrepancy was more pronounced during the depths of the depression than during the periods of active construction before and after it.

Data on housing collected by the Census of 1940 can be used to supplement the building-permit series to a considerable extent. The Census shows, by five-year age classes, the number of dwellings of each age which were standing in 1940 in each city and county, and for the state as a whole. In addition, it gives state totals for the number of dwellings remaining in 1940 which were built in each of the years 1930 to 1939. This information is superior to the building-permit data because it records structures which were actually built, and covers the entire state. However, because it enumerates buildings remaining in 1940, it underestimates new construction by the amount of intervening demolition. This is probably of no consequence for structures erected after 1930, but is an increasingly serious source of bias for periods before that date.

By pooling the available building-permit and Census data it is possible to arrive at estimates of the number of new dwelling units constructed annually during the period 1920–1945 in which the principal sources of bias have been eliminated. We may derive such estimates by the following procedures. For the period 1920–1929, the number of dwelling units for which permits were issued in the eleven largest California cities were totaled by years[5] and for five-year intervals beginning 1920. The Census data on number of dwelling units built in the eleven sample cities during the same five-year intervals, and remaining in 1940, were next adjusted to allow for demolition intervening between date of construction and 1940[6] because of the sharp changes in building activity from year to year, a further adjustment had to be applied to bring the Census figures, which reflect date of completion, into conformity with building permit figures, which indicate date of start. The lag between start and completion was assumed to be four months.[7] After adjustment, the ratio of the number of dwelling units constructed in each five-year period to the number of building permits issued in the same period was determined, and applied to the annual building permit totals to obtain an estimate of the number of dwelling units begun in each year in the eleven cities.

[4] Berkeley, Fresno, Long Beach, Los Angeles, Oakland, Pasadena, Sacramento, San Diego, San Francisco, San Jose and Stockton.

[5] The number of permits for 1920 in the 11 sample cities was estimated on the basis of data for the 5 largest cities, all that were included in the building-permit survey of that year. The number of building permits in the 5 cities was increased by 32 per cent, the excess of 11 city permits over 5 city permits in 1921, to provide the 11-city estimate for 1920.

[6] Estimated demolition of houses built in the period 1920–1924: 3 per cent; 1925–1929: 1 per cent. The Census figure for number of dwellings built 1920–1924 was therefore increased by 3 per cent; built 1925–1929, 1 per cent.

[7] Based on data reported in: U. S. Bureau of Labor Statistics. Elapsed time in building construction (Studies made by the Bureau of Labor Statistics in 1929 and 1931). Monthly Labor Rev. 36 (1):158. 1933.

Finally, the Census data indicated that 52.9 per cent of all California buildings built in the period 1920 to 1924 and remaining in 1940 were located in the eleven cities, as compared to only 49.7 per cent of those built in 1925–1929. A smooth curve was constructed showing the per cent for each year of all new dwellings located in sample cities. The eleven-city estimates of new construction were then inflated by these per cents to provide an estimate of the number of new dwelling units begun each year throughout the state.

For the period 1930–1939 the Census data on number of buildings completed each year, and remaining in 1940, were adjusted for a four-month lag between start and completion.

Table 3

ESTIMATED NUMBER OF NEW DWELLING UNITS CONSTRUCTED ANNUALLY IN CALIFORNIA: 1920–1945*

Year	Number of new dwelling units started	Year	Number of new dwelling units started	Year	Number of new dwelling units started
1920	34,000	1930	93,710	1940	110,770
1921	66,540	1931	29,370	1941	119,130
1922	74,830	1932	29,190	1942	58,660
1923	139,740	1933	19,940	1943	36,030
1924	111,230	1934	29,790	1944	50,780
1925	103,000	1935	44,380	1945	62,250
1926	88,300	1936	50,410		
1927	84,500	1937	64,210		
1928	94,810	1938	78,500		
1929	88,110	1939	95,570		

* For methods of derivation and sources of data, see text, pp. 467–469.

For the period 1940–1945, building-permit data for 128 permit-issuing places provided the basis for the estimate. The number of permitted dwellings was divided into the Census state-wide total for each of the four years 1936–1939. The resultant ratio was very nearly a constant for each of the four years and averaged 1.71. Building-permit data for the same 128 places for the years 1940–1945 were then inflated by this factor to arrive at the estimate of total number of dwelling units begun in the state in those years.

These estimates of new dwelling units begun are shown in table 3.

A comparison of the estimates with two earlier sets for decennial periods will provide a rough check on the over-all reliability of the series. One of these earlier estimates was prepared by Josephson (1935) and shows cumulated urban residential construction 1921–1930 and 1931–1940. The other, by Hallauer (1939), shows non-farm residential construction for the periods 1920–1929 and 1930–1939. In order to make valid comparisons, the annual series must first be cumulated for appropriate ten-year intervals and then reduced to the urban or non-farm basis used by the previous estimators. The latter adjustment was made by applying, to decennial sums of the annual series, the percentage of dwelling-unit increase which took place in the pertinent urban or non-farm area, as determined from the Census of 1940: Housing.

The agreement between the three sets of estimates for the period 1920–1930 is surprisingly close, considering the different methods used and the degree of reliability of available data. The annual state-wide data for the decade yield decennial estimates 4.4 per cent above Hallauer's figure for non-farm construction and 2.6 per cent below Josephson's figure for urban housing. Agreement over the decade 1930–1940 is not nearly so good, although again the annual series yields results falling midway between the older estimates. Our estimate exceeded Hallauer's by 31 per cent, but was 20 per cent less than Josephson's.

For the period 1920–1930, observed differences in the estimates are no greater than can be accounted for by the margins of error involved in the estimating procedures.

Two factors may have tended to inflate Josephson's figure for the subsequent decade. Working in 1934, he overestimated growth in the number of urban families by about 17,000 units, giving rise to an equal increase in his estimate of dwelling construction. Moreover, his estimate involved an allowance for replacements based on "normal" rates of demolition. It appears probable that actual replacement during the period 1931–1940 was only about two-thirds of the "normal" rate. These two factors appear to be sufficient to account for the observed 63,000-unit difference between the two estimates.

Hallauer's estimate for California was derived from nation-wide figures. He has not described his method of allocating these national totals among individual states, so it is impossible to determine the reasons for the observed difference with any assurance. His procedure apparently involved an assumption of uniform rates of new construction per 10,000 in the nation's non-farm population as of 1930. During the period 1930–1939, California population growth was considerably more rapid than that for the nation as a whole. Consequently the above assumption would have brought the estimate for California too low. A second possible factor may lie in the fact that Hallauer attempted to adjust his estimates to the swings of the national construction cycle. There is some evidence that the trough of the general depression of the 1930's was less prolonged and relatively shallower in California than elsewhere. If Hallauer's estimate reflects the nationwide rather than the California cycle, this too would have resulted in some underestimation.

The California Reconstruction and Reemployment Commission (1947) has estimated total non-farm dwelling unit completion in the period 1940–1944 at 375,673 units. This is 3.9 per cent below the figure given by the annual series for the same period. In view of the small amount of new dwelling construction undertaken on farms during the war period, the two estimates appear to be in close agreement.

EFFECTS OF INCOME, POPULATION GROWTH, AND COSTS OF OWNERSHIP ON HOUSING DEMANDS

Theoretically, the number of consuming units, consumer incomes, and market price might be expected to have a major effect on demand. Do the data on rates of new housing construction reflect these influences?

In order to test such a hypothesis certain characteristics of the market must be recognized. First, most consumers will not be in the market for new houses at all. If we assume for the moment that demolitions are negligible and that vacancy ratios remain constant,[8] the potential size of the market for new houses is dependent on the number of new family units appearing in the area during the market period. The many new families who do not wish to occupy new houses will be exactly compensated for, under such assumptions, by old families who wish to transfer from an old to a new house. Thus the number of consuming units pertinent to this problem is equal to the number of new families appearing in the area during the period.

It should also be noted that the "price" which is appropriate to the new housing market is not simply the purchase price of a new house. Rather it is the entire cost of new home ownership and reflects annual carrying charges for mortgage interest, taxes, insurance, and maintenance costs.[9]

During periods as short as the 22-year interval under discussion, the extent to which existing dwellings are occupied is subject to significant fluctuations. These are due to speculative building booms, doubling-up of families during periods of low income, waves of population increase, and similar factors of a short-run character. Tinbergen (1939, p. 92) points out that

> the number of unoccupied houses . . . may directly discourage building, even if rents, building costs, and interest rates are in a favorable relation to each other. In a perfect market for housing services, such a situation would not occur: rents would fall. The stickiness of rents, closely connected with the long duration of letting contracts and further imperfections in this market, prevents such a rapid adaptation. Consequently, the number of unoccupied houses is a largely independent factor which also influences building activity.

Allowance for this source of variation must be made in the present analysis.

With these conditions in mind, the author correlated estimated number of new dwelling units constructed annually, with income, number of new families, ownership costs, and the vacancy ratio.

Primary data on vacancy ratios for the state as a whole are not available. Consequently such rates had to be calculated from the number of families in the state and estimated number of dwelling units as determined from Census data, the series on new construction, and assumed demolition rates. The average rate of vacancy for the 22-year period, as displayed by this calculated series, was 6.7 per cent. This is considerably above the nation-wide "normal" vacancy, which is estimated by Terborgh (1937) as 4.2 per cent during a comparable period. Because of more rapid population growth, higher levels of family income, and the significance of resort and recreational areas in the state, a somewhat above-average normal vacancy appears reasonable.

[8] The vacancy ratio is the per cent of total dwelling units unoccupied at a given time.

[9] 75 per cent of the dwelling units in California were either rented or mortgaged in 1940 according to the *Census of Housing*. It seems probable that the percentage for new houses is even higher.

A further explanation of the discrepancy may lie in overstimulated building in California during the 1920's followed by several depression years which saw an unusual amount of doubling up.

An index of the costs of new home ownership also had to be compiled, using the following method. Variations in costs of new dwellings were represented by an index of new frame dwelling construction costs in San Francisco.[10] For the second element (the interest rate on funds required for investment in a new home) no applicable building and loan interest rate was found to be

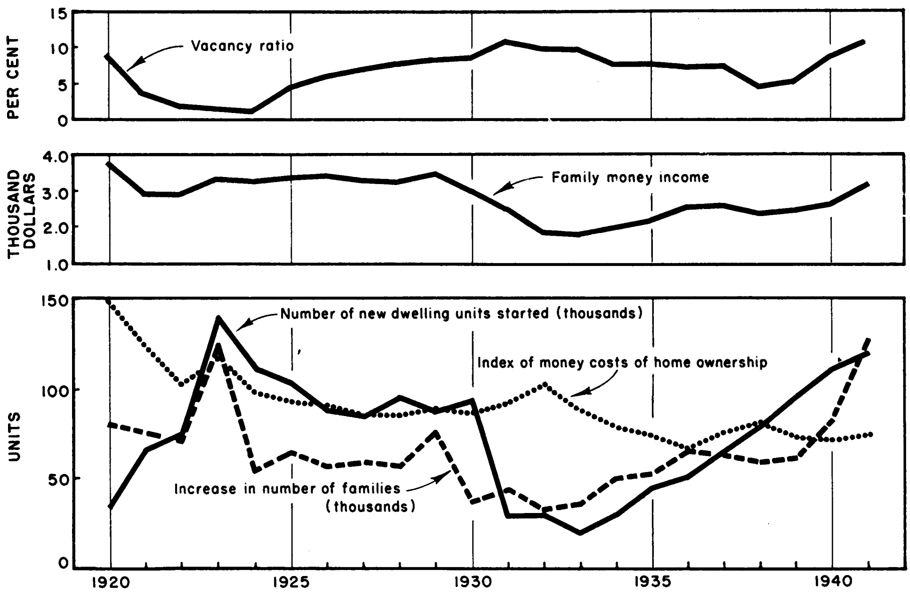

Fig. 2. Rate of new dwelling construction in California and certain factors affecting it: 1920–1941.

available. An index of the average annual yield on domestic corporate bonds was used instead.[11] The product of this index and that of construction costs was taken as an index of the money costs of home ownership.

Some new homes are, of course, built for rent. This fact, however, is unlikely to modify relations significantly, as an index of rents was found to correlate fairly highly with the index of ownership costs ($r = 0.78$). Thus, little is gained by trying to isolate the effects of ownership costs and rents separately. At the same time, the ownership cost index can be taken as reasonably representative of variations in rents as well.

Despite major upward movements in 1923, 1930 to 1932, and 1937 to 1938, the index of real costs of new home ownership displayed a marked downward trend during the 1920–1941 period, primarily as a result of decreases in long-run interest rates.

[10] Boeckh, E. H., and Associates, Inc. Index of residential construction costs. Survey Cur. Business **1942** (Supplement) :27.

[11] Moody's average yield of domestic corporate bonds. Survey Cur. Business **1942** (Supplement) :84.

The five series of data used in the correlation analysis are recapitulated in table 4 and figure 2.

The statistical study supports the hypothesis of significant relations between new house construction and income, cost of ownership, increase in number of families, and vacancy ratio. The following regression equation was obtained:

Table 4

RATE OF NEW DWELLING CONSTRUCTION AND CERTAIN FACTORS AFFECTING IT: 1920–1941

Year	Number of new dwellings started, in thousands	Family money income, in thousand dollars	Increase in number of families, in thousands	Vacancy ratio	Index of money costs of home ownership
(1)	*(2)**	*(3)†*	*(4)‡*	*(5)§*	*(6)‖*
1920	34.0	3.75	80.8	8.6	149.7
1921	66.5	2.92	75.8	3.6	124.0
1922	74.8	2.91	71.1	1.9	103.4
1923	139.7	3.35	125.2	1.4	117.5
1924	111.2	3.29	54.3	1.1	98.9
1925	103.0	3.38	64.8	4.3	93.1
1926	88.3	3.42	56.9	5.9	90.8
1927	84.5	3.29	58.8	6.9	85.3
1928	94.8	3.25	56.5	7.7	85.6
1929	88.1	3.45	76.0	8.3	89.1
1930	93.7	2.99	37.0	8.7	86.9
1931	29.4	2.46	44.3	10.9	92.1
1932	29.2	1.85	32.0	9.7	102.1
1933	19.9	1.79	35.8	9.6	88.9
1934	29.8	1.99	49.5	7.5	79.2
1935	44.4	2.16	52.3	7.5	74.2
1936	50.4	2.52	65.6	7.1	66.4
1937	64.2	2.55	62.9	7.2	75.3
1938	78.5	2.34	59.1	4.3	80.1
1939	95.6	2.42	60.8	5.1	73.7
1940	110.8	2.61	83.4	8.6	70.6
1941	119.1	3.14	126.4	10.6	74.2

* 1940 Census of Housing, and building permit data. See text for method of derivation.
† Bureau of Foreign and Domestic Commerce and Census data.
‡ U. S. Census and California Taxpayers' Assn. data.
§ Calculated from 1940 Census of Housing, and col. 2. See text for method.
‖ Calculated from indices of construction costs and interest rates. See text for details.

$$\underset{}{\text{Log } X_1 = 1.77} + \underset{(4.80)}{0.267\,X_2} - \underset{(3.65)}{0.033\,X_3} - \underset{(4.94)}{.0070\,X_4} + \underset{(2.12)}{.0025\,X_5}$$

where X_1 = new dwelling units constructed per year, in thousands
X_2 = annual money family income, in thousands of dollars
X_3 = vacancy ratio
X_4 = index of money ownership costs
X_5 = annual increase in number of families, in thousands.

The figures in parentheses are the values of t obtained for each of the several regression coefficients. With 17 degrees of freedom available, the first three t

values are significant at the 1 per cent level of probability. The value for increase in families is significant at the 5 per cent level. The adjusted coefficient of multiple correlation was 0.88.

Semi-logarithmic functions with the dependent variable expressed in logarithmic form were found to fit the data somewhat better than linear functions. Thus, a unit change in family income was associated with a bigger change in new housing construction at high income levels than at low income levels. When family income was $2,000 yearly, a $100 income change corresponded to a change of about 2,700 dwelling units. At the $3,500 income level the related figure was about 7,000 dwelling units.

Most studies of housing requirements assume that new dwelling unit construction will, after certain adjustments for replacement, etc., tend to equal the number of new family units added during a given period.[12] However, the current analysis indicates that such an assumption may not be valid for periods of less than two decades. On a year to year basis, other factors remaining equal, the net effect of a thousand-unit change in the number of new families entering the state was associated with a change of only 400 units in the rate of new house construction (at the mean level of family income). In other words, in the short run, factors of income, extent of vacancy, and ownership cost are as important as population increase in determining demand for new housing.

As in the case of other relations, a semi-logarithmic function provided the best fit between construction data and the vacancy ratio. A change in vacancies from 1 per cent to 2 per cent was associated with a decrease of about 8,000 units of new construction, while a change from 10 per cent to 11 per cent was accompanied by a reduction of only about 4,500 units.

New house construction varied with the cost of new home ownership much as might be expected on orthodox theoretical grounds. Figure 3, which displays the net relation between the index of ownership costs and the rate of new construction, is closely akin to a statistical demand curve for new housing. A change of 10 per cent in the index of costs of ownership was associated with a change of about 16,000 units in the rate of new construction when the index was at 65. At index 105, the associated change was only 8,500 units.

Demand during the period 1920–1941 appears to have been generally elastic. The elasticity of demand for new construction with respect to price varied from approximately –1.2 to –2.0 throughout the observed range of the data. This implies that the building industry could probably have increased its gross revenues during much of the period by some price reduction. Figure 3 indicates that, with the possible exception of 1920, gross returns to the building industry would have been increased by undertaking the larger volume of business which a somewhat lower level of prices would have permitted.

From the foregoing analysis we conclude that changes in income, changes in vacancy ratios, increases in the number of families, and changes in ownership costs are important variables to be considered in analysis of prospective rates of new dwelling construction. An indication of the reliability of estimates of new construction based on a synthesis of these four variables may

[12] For example, see Hallauer, *op. cit.*, and Josephson, *op. cit.*

be obtained from figure 4. It displays observed rates of construction and rates computed from the regression equation given above, both plotted over time. The general "fit" between the two curves appears to be reasonably good when due consideration is given to the limitations in accuracy of the basic data. Major discrepancies appear only in 1930, 1932–1933 and 1936–1938. Although no precise analysis can be made it seems probable that the discrepancies in 1930 and 1932–1933 are associated with inaccuracies in reports

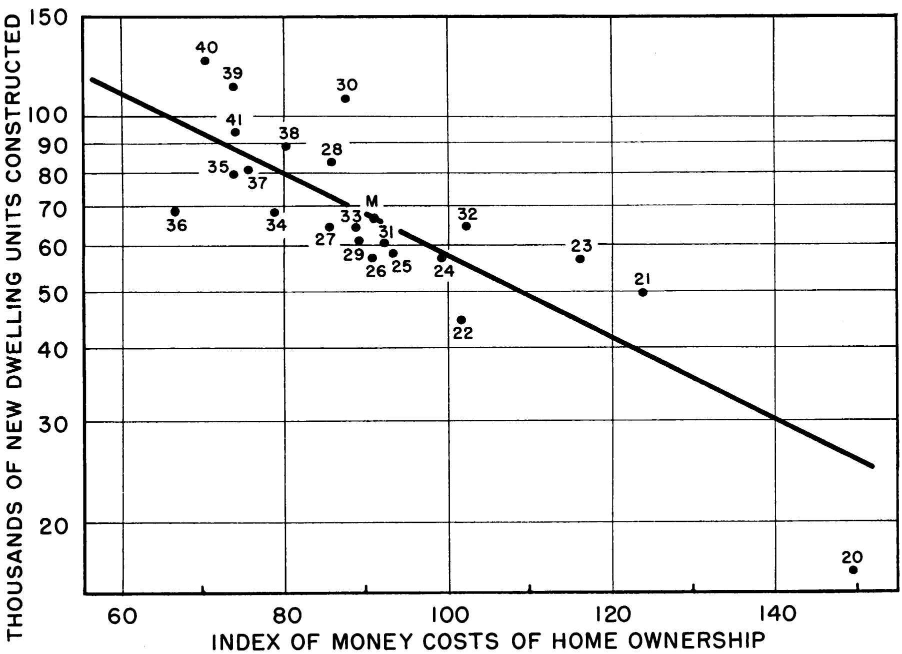

Fig. 3. Net relationship between money cost of home ownership and volume of new residential construction in California: 1920–1941. Plotted points show deviations of individual years.

to the Census on building age, coupled with probable shifts in the normal lag between start and completion of structures at turning points in the building cycle. The discrepancies observed in the 1936–1938 period appear to be of a more fundamental character. The 1937–1938 recession shows up markedly in the computed series, but is not reflected at all in the construction estimates. A possible explanation appears to lie in the timing of activities of the Federal Housing Authority. In the regression analysis, no account was taken of the conditions of mortgage credit other than the interest rate. It is conceivable that, entirely apart from changes in interest costs, the ease with which credit can be obtained has an important effect on the rate of new construction.[13] This factor was not included in the present analysis because no adequate statistical measure could be determined for it.[14] The Federal Housing Authority's pro-

[13] In St. Louis, it was found that "the really important financial factor is the availability of funds. This is not measured by interest rates." See Roos (1934).

[14] The rate of new construction shows very high negative correlation with an index of mortgage foreclosures published by the Federal Home Owners Loan Corporation, covering

gram of guaranteeing mortgages got under way late in 1935 and in 1936. It undoubtedly had a strong influence in the direction of making mortgage financing more readily available. Thus, this influence may have offset the unfavorable factors reflected in the computed index of new construction. It may have provided the necessary "shot in the arm" to carry the California construction industry over the recession period without a major break in its upward course.

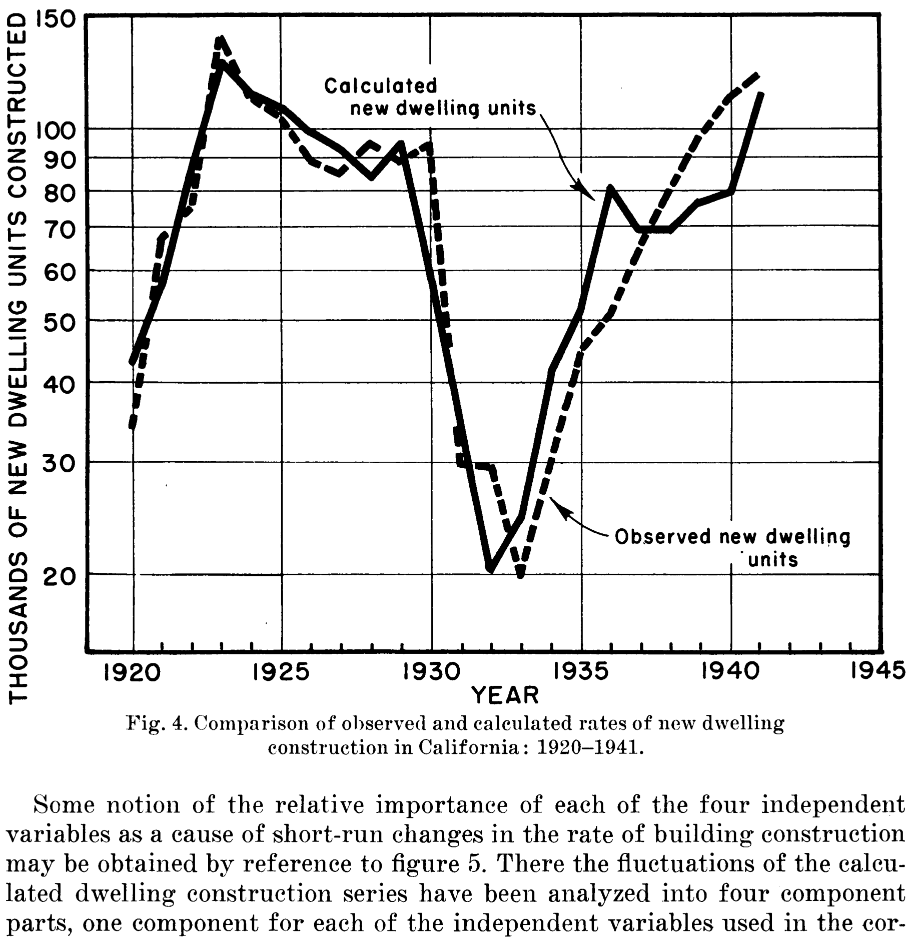

Fig. 4. Comparison of observed and calculated rates of new dwelling construction in California: 1920–1941.

Some notion of the relative importance of each of the four independent variables as a cause of short-run changes in the rate of building construction may be obtained by reference to figure 5. There the fluctuations of the calculated dwelling construction series have been analyzed into four component parts, one component for each of the independent variables used in the correlation study. Each series has been plotted over time in terms of deviations from its own mean. (Observed variation not associated with changes in the four stipulated factors is shown by the spread between the solid and broken lines in the upper part of figure 4.) A study of the chart indicates that no one of the four factors has exerted a predominant influence on the rate of dwelling construction throughout the period 1920–1941.

the period 1926–1941. Insofar as terms of credit (other than interest) are influenced by foreclosure rates, this is evidence of an association between such terms and the rate of new construction.

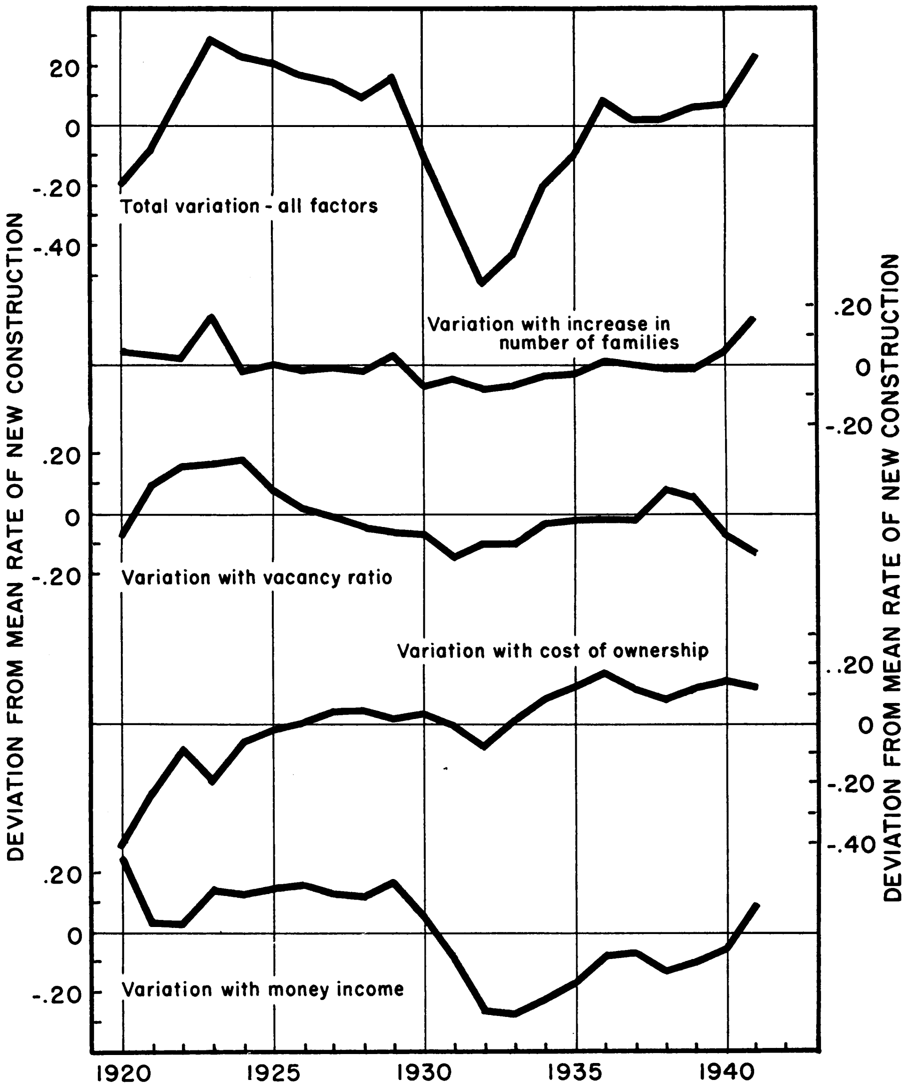

Fig. 5. Analysis of variations in the calculated rate of new dwelling construction in California: 1920–1941.

From 1920 through 1923, falling ownership costs and vacancy ratios, supplemented by a large increase in the number of families in the latter year, accounted for the rapid growth in the rate of dwelling construction. Thereafter, until 1929, generally increasing vacancies appeared as the only factor subject to significant change. Beginning with the crisis of 1929, income became the dominant determinant of building activity, although it was usually reinforced by harmonious changes in the other three factors. After 1935, construction costs exerted little influence because of their stability, but the pre-war influx of new families developed as an important stimulating force.

Comparison of estimated with observed 1946 construction. Preliminary data for construction, income, building costs, and population increase were available for 1946. An estimated rate of 1946 construction could therefore be compared with the observed rate. Per capita income in California in 1946 has been estimated at $1,531 (California State Chamber of Commerce, 1947). Family size averaged about 3.10 persons, giving an estimated family income of $4,750 (1946 dollars). Adjusted to 1920–1941 purchasing power this equals $3,490 per family. The index of ownership costs, similarly adjusted, is estimated at 93.0. Vacancies are known to have been very low and may be assumed as at the practicable minimum of 1 per cent. Population increase has been estimated at 200,000 persons, or 64.5 thousand families (California State Chamber of Commerce, 1947).

Insertion of these values in our equation yields an estimate of 151,000 new dwelling units for 1946 construction. The standard error of this "forecast" is about 9,000 units. Actual new construction in 1946 has been given as 107,000 units, some 44,000 units less than the forecasted amount.

A discrepancy of this magnitude between actual and "forecasted" values could be expected to result from sampling variation in less than one case out of a hundred. But in view of the conditions which prevailed in 1946 this discrepancy is certainly not unexpected and should hardly be interpreted as casting doubt on our statistical conclusions. During 1946, all new residential construction was subject to both administrative controls and shortages of supply. Rent ceilings inhibited building for certain types of investment. Other potential builders could not qualify for the necessary priorities. The difficulty of obtaining materials and labor discouraged many people from undertaking new construction and slowed down the progress of many others. An extensive black market existed in certain building materials and probably resulted in actual levels of cost significantly above those reflected in the index of ownership costs, based as it was on the "white" market.

All things considered, the situation was so "abnormal" that an equation applying to normal conditions would almost certainly yield a substantial overestimate, perhaps by fully as much as we have actually obtained.

USE OF LUMBER IN HOUSING

The preceding analysis has furnished measures of consumer demand for the service of housing. The extent to which this demand is reflected in demand for lumber for residential construction purposes remains to be determined. This involves analysis of the factors which affect the amount of wood used per house.

Up to this point we have considered housing as an undifferentiated commodity and emphasis has been on quantitative variations in the rate of new dwelling construction and the factors associated with it. But certain qualitative differences in housing are also of great importance in determining lumber requirements. Among such differences the type of dwelling, its size, location, and type of construction may all be related to lumber used per house.

Survey of lumber used in new residential construction: 1946. In order to appraise the effects on wood use of variations in such factors as the above, a detailed study of the use of lumber in new residential construction was made in 20 California communities.[15]

California communities were first stratified geographically into three areas: (1) six San Francisco Bay counties (Alameda, Contra Costa, Marin, San Francisco, San Mateo, Santa Clara); (2) ten southern California counties (Imperial, Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara, Ventura); and (3) the remainder of the state. Within each of these strata, communities were segregated on the basis of number of dwelling units in 1940 (as shown by the Sixteenth Census of the U. S.: 1940—Housing) into (1) large cities, with more than 20,000 dwelling units, (2) medium cities, with 4,000 to 20,000 dwelling units, and (3) all other communities, with less than 4,000 dwelling units. Sample communities were drawn at random from within these strata and are listed in table 5. Preliminary analysis showed that San Francisco differed from other San Francisco Bay area communities in the relative importance of single and multi-family dwellings and in the frequency of occurrence of different types of construction. Dwellings there were also of significantly smaller size. Therefore San Francisco was ultimately handled as an independent sampling segment. No sampling was done in the "Other areas–large cities" segment. Sacramento is the only such community in this segment, and its housing characteristics are believed to be substantially comparable to those of large southern California cities.

In each sample community, building permits were examined in the office of the local building inspector. Data were tabulated from a number of 1946 new residential permits showing, for each dwelling, the type of construction, the number of family dwelling units in the structure, the gross permitted dimensions (or gross area), the number of stories, and the number of rooms. The number of permits sampled at each locality varied with the total 1946 residential construction activity in the community, but proportionately larger

[15] This phase of the study was carried out as an official project of the California Forest and Range Experiment Station, U. S. Forest Service. Most of the field work was done by Richard H. May, Associate Forester, U. S. Forest Service, and Alex Simontacchi, Assistant Forester, U. S. Forest Service. These men, with the assistance of Miss Blanche Fadie, also participated extensively in office analysis of the field data.

Table 5

COMMUNITIES SAMPLED IN STUDY OF LUMBER USED IN NEW RESIDENTIAL CONSTRUCTION: 1946

Geographic area			Community size class								
			Large			Medium			Small		
Name	Permits	Plans	Name	Permits	Plans	Name	Permits	Plans	Name	Permits	Plans
San Francisco Bay area	1,425	25	Berkeley	132	4	Palo Alto	64	2	Los Gatos	50	3
			Oakland	273	9	San Leandro	54	2	San Rafael	58	2
			San Francisco	745	0				Santa Clara	49	3
Southern California	1,991	57	Los Angeles	1,219	29	Ontario	135	5	Anaheim	70	3
			Pasadena	111	4	Pomona	132	4	Chino	53	2
						Riverside	133	4	Montebello	67	3
									Oxnard	71	3
Other areas	187	9	None	0	0	Santa Rosa	68	4	Healdsburg	34	2
									Pacific Grove	85	3
Total	3,603	91		2,480	46		586	21		537	24

samples were taken in the smaller towns so that reliable averages could be obtained for each individual sample community. The number of permits in the sample from each locality is shown in table 5. The 3,603 permitted structures in the sample included 3,991 dwelling units, about 3.7 per cent of all the new dwellings built in California in 1946.

Approximately 2½ per cent of the sample structures in each community were selected at random for further study. Detailed builder's plans for each of these subsample structures were carefully examined and, working from data shown on the plans, the volume of lumber used in each structure was computed.[16]

Variations in lumber use with type of construction. Two basic types of construction, calling for radically different amounts of wood, can be recognized in new California dwellings. These are (1) dwellings with a frame made primarily of wood, and (2) dwellings without a wood frame. Conventional frame and stucco dwellings are examples of the first class; and concrete block, adobe, reinforced concrete, and structural steel frame structures illustrate the second.

The amount of structural lumber used in a frame dwelling is very largely a function of dwelling size. Although net cubic volume is the most precise measure of dwelling size, it is less useful for present purposes than total permit area, because net cubic volume can only be measured for the relatively small number of structures included in the sample of building plans. Total permit area is defined as the gross plan area of the structure as shown by the building permit, multiplied by the number of stories in the structure. It can be quickly determined for any dwelling covered by a building permit. Consequently the relation of volume of lumber used to total permit area per structure will be employed in further analysis.

Sample single-family dwellings were classified into three groups: (1) wood frame dwellings with exterior principally of wood, (2) wood frame dwellings with exterior material principally other than wood, and (3) dwellings without a wood frame.[17]

The regression relations obtained from the various class-of-construction and geographic sorts of the data are shown in figure 6. The significance of each of the observed differences was tested in the following way. Differences in regression coefficients were subjected to the t test. Wherever these differences were found to be insignificant, a pooled regression coefficient was calculated on the basis of the variation of each set of sample data from its own mean. The variance of each of the samples about a regression line, passed through the sample mean and of slope equal to that of the pooled regression coefficient, was then compared with the variance around a single regression

[16] Methods of computing volume of lumber used from plan data were developed for this study by Richard H. May. By careful analysis of building methods and of the relationships between various major wood components, May was able to devise techniques which permitted accurate estimation of wood use from a relatively small number of measurements on the original plans. He has described these methods in detail in an office report in the files of the Division of Economics, California Forest and Range Experiment Station, Berkeley, California.

[17] Provision was originally made for segregating dwellings without a wood frame into fireproof and nonfireproof types. However, no fireproof structures were included in the building permit sample; so the distinction was abandoned in the analysis phase.

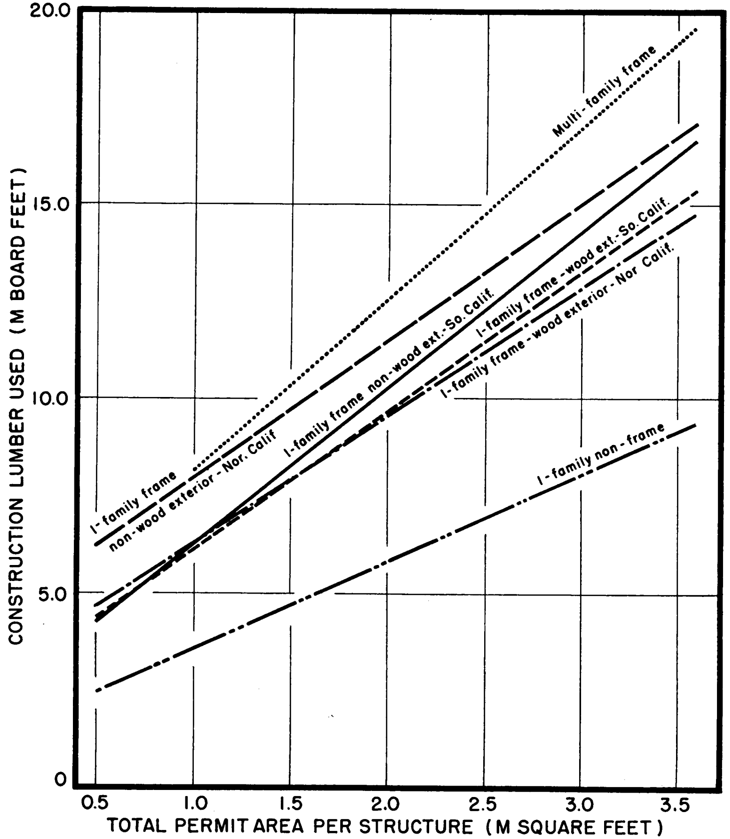

Fig. 6. Gross variation in volume of construction lumber used with size of dwelling, by types of dwelling in northern and southern California: 1946.

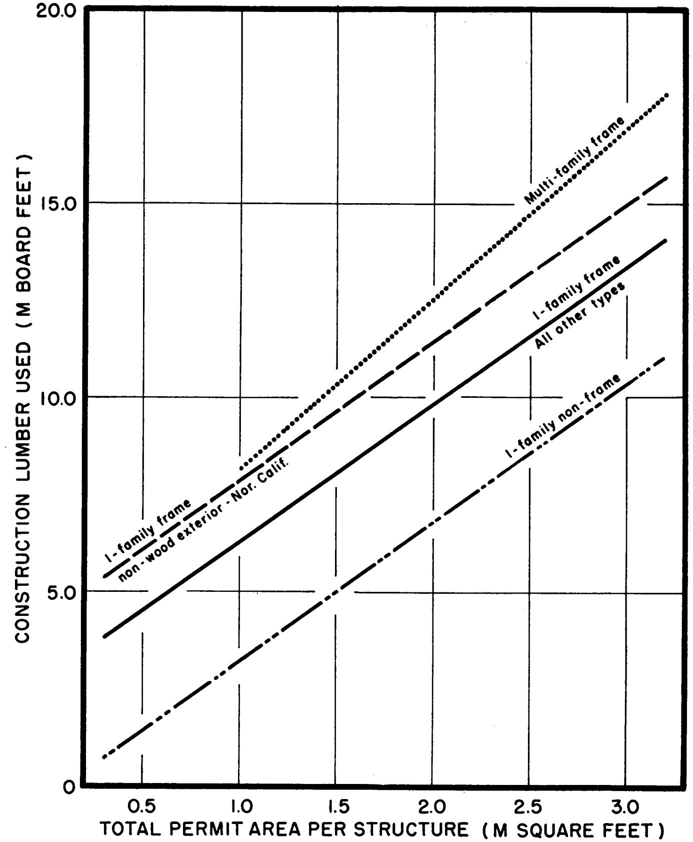

Fig. 7. Net variation in volume of construction lumber used with size of dwelling, by types of dwelling in California: 1946.

line computed from pooled data of all the samples in question. Standard analysis of variance procedure then indicated whether or not the observed differences in the means of the several samples were statistically significant.[18] Where this test yielded negative indications of significance, data from all appropriate samples were pooled and the common regression line used.

The analysis described in the above paragraph led to the identification of four regression equations showing significantly different relations between volume of construction lumber used and size of structure. These four regressions corresponded to differences in type of construction, and differences in geographic location. They are graphed in figure 7, and the various statistics appear in table 6. The following important relations developed:

Table 6

REGRESSION STATISTICS* SHOWING RELATION OF CONSTRUCTION LUMBER REQUIREMENTS TO SIZE, LOCATION, AND CLASS OF CONSTRUCTION OF DWELLINGS IN CALIFORNIA: 1946

Location and type	Constant term	Regression coefficient	Correlation coefficient	Standard error of estimate	Standard error of regression coefficient	Number of observations
	a	b_{yx}	r_{yx}	$\bar{S}_{yx}$	σ_b	n
Single family:						
Wood frame dwellings						
Northern Calif.—exterior other than wood	4.29					16
All other	2.74	3.55	0.902	1.16	0.193	59
Non-wood-frame dwellings	0.32					6
Multi-family	3.80	4.37	0.980	4.31	0.310	10

* All expressions are of the type: M bd. ft. of construction lumber = $a + b_{yx}$ (M sq. ft. total permit area).

a) The increase in volume of lumber used per unit increase in dwelling size is the same for single-family dwellings, regardless of location or type of construction.

b) Structures without a wood frame require only 50 to 60 per cent as much structural lumber as wood frame dwellings.

c) Structural lumber requirements for wood frame dwellings with exterior principally of wood are the same in northern and southern parts of California.

d) Wood frame structures with exterior material principally other than wood in northern California require more structural lumber than do comparable structures in southern California. Most of the difference is due to the use of wood wall sheeting underneath stucco finishes in northern California, a practice not generally followed in southern California.

Multi-family dwellings required more lumber per unit of size, probably because they are often two stories high and therefore require heavier construction.

The type of construction not only affects the amount of construction lumber used but also the amount of wood siding. Frame dwellings with siding principally of wood require the largest volume of siding lumber. Relations ob-

[18] The procedure used has been described in detail by Tippett (1937).

tained from sample plans showing these wood siding requirements were as follows:

M bd. ft. of wood siding per structure = .304 + 0.623 (M sq. ft. total permit area).
$r = 0.810$; $\bar{S}_{y.x} = 0.241$; $\sigma_b = 0.0921$

Other types of dwelling frequently require incidental use of wood siding in combination with stucco or other external material. The volume used, however, does not appear to be a function of dwelling size. An average of 0.095 ± 0.064 M bd. ft. of siding lumber was used for 55 sample dwellings in this class.

Lumber used for interior finish and trim. The amount of wood used for interior finish purposes and for exterior trim is not closely correlated with type of construction. Major interior lumber requirements are for flooring, sash, doors, cupboard and closet shelves, baseboards, and moldings. Exterior trim may include shutters, porch lumber, and a variety of decorative features. All of these items are likely to be found in houses of any type of construction. Substitution of other materials for wood in sash, flooring, or other interior uses is as likely to occur in a frame house as in a concrete block house. The principal exception to this interchangeability of materials is in fireproof construction, where every effort is made to eliminate wood from interiors as well as from structural components. However, a negligible proportion of residential construction in California is of the fireproof type.

All classes of construction may therefore be considered together in estimating lumber required for interior finish. No significant differences were observed in amount used as between different geographic locations. The regression equations obtained for finish lumber are:

Single-family structures:

M bd. ft. of finish lumber = 0.581 + 1.29 (M sq. ft. total permit area).
$r_{y.x} = 0.812$; $\bar{S}_{y.x} = .575$; $n = 79$; $\sigma_b = 0.105$

Multi-family structures:

M bd. ft. of finish lumber = −0.472 + 1.74 (M sq. ft. total permit area).
$r_{y.x} = 0.975$; $\bar{S}_{y.x} = 2.11$; $n = 10$; $\sigma_b = 0.152$

Variations in dwelling size. It is apparent from the relations just described that dwelling size is a major determinant of housing lumber requirements. The sample building permit data provide a basis for analysis of the factors associated with variation in dwelling size, and for estimating dwelling size in California.

In studying size, attention was given to variations associated with degree of urbanization, geographic location, and type of construction. Average total permit area was computed, by types of structure, for each of the 20 communities included in 3,603 sample permits. Observed mean differences between communities and between classes of structure were then tested by the analysis of variance to determine whether or not such differences could be attributed to sampling variation. Wherever differences were thus shown to be statistically insignificant, dwelling-size data were pooled, and means calculated for the pooled samples.

The average single-family dwelling was larger in the San Francisco Bay area (exclusive of San Francisco itself) than elsewhere. Bay area cities showed no significant size differences as between types of construction and, save for San Francisco, all sampled communities in the area had very similar average sizes. The smaller dwellings found in San Francisco can be accounted for by the highly urbanized character of the city and small size of available lots.

Elsewhere, considerable variations in dwelling size were apparent. There were significant differences in the average size of dwellings in sample communities which were not associated with size of community, geographical location, or other measurable variable. In addition, medium and small communities had smaller average-size dwellings than large cities, and dwellings with exteriors principally other than wood were larger than those of other classes of construction. No satisfactory basis for explaining these variations has been found. Some correlation was observed between size of dwelling and average rental value in 1940. This suggests that some communities may be typically "small home" communities built for the low rental market. The observed relations were not sufficiently close, however, to permit detailed analysis or confirmation of this hypothesis.

Table 7

AVERAGE TOTAL PERMIT AREA OF NEWLY CONSTRUCTED DWELLINGS IN CALIFORNIA, BY LOCATION, SIZE OF COMMUNITY, AND TYPE OF STRUCTURE: 1946

Location and type of structure	Mean total permit area	Standard error of mean
	M sq. ft.	*M sq. ft.*
Single-family dwellings:		
San Francisco—all types	1.078	0.011
Other Bay area communities—all types	1.527	.031
All other large cities:		
Wood siding	0.903	.035
Exterior other than wood	1.332	.037
Non-wood-frame	0.988	.092
All other medium and small communities:		
Wood siding	0.899	.063
Exterior other than wood	1.071	.050
Non-wood-frame	0.952	.174
Multi-family dwelling structures:		
San Francisco—all types	2.417	.072
Los Angeles—all types	4.697	.430
All other communities—all types	2.645	0.147

Sampling was thus inadequate to stratify the medium and small communities outside the San Francisco Bay area into segments homogeneous with respect to size. To arrive at estimates of average size for these areas, field data were regarded as a random sample from the entire population of communities involved. The resultant mean sizes for each segment showing significant differentiation as to size are summarized in table 7, with appropriate standard errors.

Except in San Francisco and Los Angeles, sample data were not sufficiently numerous to permit analysis of size variations in two- and multi-family units. A simple average of available figures was therefore taken as an estimate of size for such dwellings outside the two metropolises.

Lumber requirements for the average California dwelling unit in 1946. The average dwelling sizes shown in table 7 can now be substituted in the several wood requirement equations previously described to arrive at the

Table 8

LUMBER REQUIREMENTS PER NEW DWELLING STRUCTURE, BY LOCATION, SIZE OF COMMUNITY, AND TYPE OF STRUCTURE

	Type of structure		
	Wood frame		Other
	Wood siding	Siding other than wood	
	Lumber required per structure in M bd. ft.		
Single-family dwellings			
Large cities			
San Francisco	12.60	.....	.....
Other Bay area	11.96	12.36	7.75
All other	8.55	9.86	5.14
Medium and small communities			
Bay Area	11.96	12.36	7.75
All other	8.53	8.59	4.33
Two- and multi-family dwellings			
Large cities			
San Francisco	24.39	.....	.....
Los Angeles	36.20	33.07	25.09
All other	21.44	19.58	13.29
Other communities	21.44	19.58	13.29

average lumber requirements per structure in the various sampling segments. The results of such a calculation are shown in table 8, which gives for each sampling unit the total volume of lumber required for different types of structure. The volumes range from 12.60 M bd. ft., for an average dwelling in San Francisco, to 4.33 M bd. ft. for a dwelling with frame other than wood in medium and small southern California communities.

From inspection of table 8 it is apparent that lumber requirements for the "average" California dwelling will depend greatly on the distribution of actual construction among different types of structure and among different geographical areas. Geographical distribution of 1946 dwelling construction was approximated from National Housing Agency data showing the number of dwelling units covered by building permits in all permit-issuing localities in the state during the first eight months of that year (U. S. National Housing Agency, 1947). This procedure involved the assumptions that nonpermitted dwelling units (about 20 per cent of all construction) were distributed geographically in the same way as permitted units, and that permits issued during the first eight months represented an unbiased sample of the full year's issue.

Type of dwelling construction within each geographical segment was obtained on the basis of sample building-permit data. These revealed a positive correlation between size of community and proportion of two- and multi-family dwellings, and showed a higher proportion of stucco and non-

Table 9

ESTIMATED NUMBER OF DWELLING UNITS ERECTED IN CALIFORNIA, BY LOCATION, SIZE OF COMMUNITY, AND TYPE OF STRUCTURE: 1946

Location and size of community	Type of structure			Total
	Wood frame		Other	
	Wood siding	Siding other than wood		
	Thousands of dwelling units erected			
Single-family dwellings				
Large cities				
San Francisco	2.28	0	0	2.28
Other Bay area	0.46	1.06	0.01	1.53
All other	6.02	14.43	1.38	21.83
Medium and small communities				
Bay area	3.22	7.03	0.50	10.75
All other	12.26	30.71	6.55	49.52
Two- and multi-family dwellings				
Large cities				
San Francisco	1.37	0	0	1.37
Los Angeles	0.45	8.74	0.23	9.42
All other	0.32	4.61	0.08	5.01
Other communities	0.65	3.37	1.27	5.29
Total	27.03	69.95	10.02	107.00

wood-frame construction outside the San Francisco Bay area. Table 9 displays the results of this analysis, and shows the estimated number of all 1946 new dwelling units in each of the geographic and type-of-construction segments.

Application of the weights in table 9 to the lumber requirements of table 8 yielded the weighted average requirement per dwelling unit for the entire state. As table 9 shows proportion of all dwelling units, and table 8 shows lumber requirements per structure, it was necessary to divide requirements per structure for two- and multi-family structures by the average number of dwelling units per structure. This was estimated from the building-permit data.

The average lumber requirement per dwelling unit, thus obtained, was 8.70 M bd. ft. For all single-family dwellings total requirements were 9.03 M bd. ft. per unit. In each case, about three fourths of the lumber used was of rough, construction grade; about one fifth was finish lumber; and the remainder was wood siding.

Trends in unit lumber requirements. No other data comparable to those just given are available to permit complete analysis of trends in the use of lumber per dwelling structure. However, a partial analysis can be made with information compiled by the U. S. Bureau of Labor Statistics (1937–39; 1939–40), and by Josephson (1935).

In 1934 a survey of nine California cities indicated that only 7 per cent of the houses built between 1927 and 1933 had wood siding exteriors. According to the 1946 survey, 27.3 per cent of new dwelling structures built in that year had siding primarily of wood. This implies a rise in popularity of this type of design since 1934.

On the other hand, almost one tenth of all dwelling structures permitted in 1946 were of non-wood-frame construction. No data are available showing the extent of this type of building at earlier dates, but it seems likely to have been negligible prior to 1935. Over 90 per cent of the non-wood-frame structures sampled in the 1946 survey were concrete block or Quonset structures, types which were not on the market in appreciable volume prior to the war.

It is sometimes assumed that, because of increasing urbanization, there is a trend toward two-family and apartment-type structures, at the expense of the conventional single-family dwelling. As California has for many decades exhibited a relatively high degree of urbanization we might expect to find a larger and larger proportion of new dwellings consisting of multifamily units accompanying the rapid population growth of the state. But this does not appear to be the case. Analysis of data published in the 1940 Census of Housing shows that, after allowing for the effect of size of city on type of dwelling, the newer California communities have a smaller proportion of multi-family dwellings than do the older ones. Further confirmation of the trend away from multi-family dwellings is found as late as 1947 when data for the first four months of the year showed that 82.8 per cent of all new dwellings authorized for both rural and urban areas were in one-family structures (U. S. National Housing Agency, 1947).

From Josephson's study (1935) data are available on permit areas for Los Angeles, Berkeley, Oakland, and Riverside. When the average sizes observed by him are compared with those obtained in the same cities in 1946, a trend toward smaller dwellings is indicated in the case of three of the four cities. Statistical data are not sufficient to permit testing the significance of the observed differences.

More positive evidence of some decline in size can be obtained from the surveys of building permits conducted by the U. S. Bureau of Labor Statistics (1937–39, 1939–40). A summary of 49,364 single-family dwelling permits issued in 19 major cities between 1929 and 1935 showed an average of 5.35 rooms per dwelling. In 1946 the average number of rooms per dwelling was only 4.64.

The 1940 Census shows, for all dwelling units in California, an average of 4.32 rooms per unit. As this figure includes apartments which are characteristically smaller than single-family dwelling units, it is not directly comparable with those of the preceding paragraph. The relations suggest, however, that dwellings erected in the period 1929–1935 may have had an abnormally large number of rooms. A possible explanation is that, during depression years, home building tends to be restricted to a more limited, and relatively more prosperous, segment of the community which indulges in larger than average homes.

Evidence on trends in ceiling height is clear-cut. In 1935 Josephson stated that "ceiling heights have decreased from 9 or 10 feet to about 8.5 feet" during the two preceding decades. By 1946 average heights were 8.1 feet, a decline of about 5 per cent.[19]

Little reliable quantitative evidence is available to indicate the extent to which economies or substitution have affected lumber used in dwelling construction. Numerous specific examples of these effects can be cited. Cement has replaced wood flooring to some extent. Wood lath has given way largely to metal, and more recently to various types of composition material. The use of wood for decorative or "gingerbread" effects has largely disappeared. Interior moldings, wainscoting, and wood paneling, at one time standard features in the average house, are now used sparingly, if at all. But what has been the quantitative effect of these and other changes?

An indication is provided by lumber requirements data for 27 single-family dwellings in Berkeley, Oakland, and Fresno collected by Josephson (1935 data). Only one of these structures had a full wood exterior. The sample may be considered fairly comparable, therefore, with the 16 northern California structures in the 1946 survey which were wood frame dwellings with exteriors other than wood. The average dwelling in the 1933 sample was considerably larger than that in 1946. Therefore, it is necessary to compute regressions of lumber use on size of dwelling. As permit area is not available for the 1933 houses, net floor area must be used instead. Comparisons for both construction and finish lumber are shown in figure 8. Construction lumber requirements appear to have declined somewhat, but finish lumber needs are little changed.[20]

For the average size of house in the two samples, 1946 construction lumber requirements were about 25 per cent below those of 1933. However, the average house in the 1933 group contained 1.94 M sq. ft. while that in 1946 had but 1.29 M sq. ft. It seems entirely possible that the true relation between net floor area and construction lumber used is curvilinear in character. The range of neither sample is adequate to test this hypothesis effectively for the pertinent range. The two sets of samples have been plotted together in figure 9. From inspection of the plotted points some decrease in wood use seems quite probable, but the statistical data are inconclusive.

In the case of finish lumber, there is no evidence of a decline in its use in houses of similar size and general type. The spread between the two finish lumber regressions in figure 8 is no greater than might be expected on the basis of sampling variation alone.

[19] Although the decline has been only about 0.4 feet, the data attest to the significance of the change. In 1934 a very large proportion of all houses observed by Josephson had 8.5 foot ceiling heights; a few were somewhat higher, and practically none was lower. In 1946, 62 per cent of all ceiling heights were 8.0 feet, and only 25 per cent were over 8.2 feet.

[20] Analysis of the variance about the two construction regression lines shows that differences in slope are not significant, but the vertical displacement is highly significant.

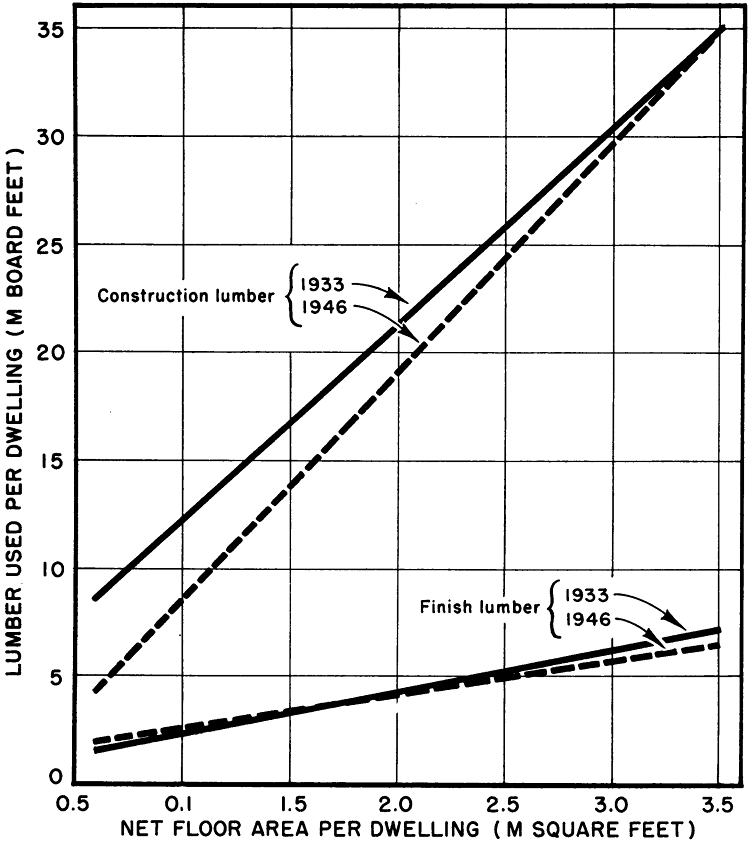

Fig. 8. Net relationship of lumber used in single-family dwellings in northern California to size of dwelling: 1933 and 1946.

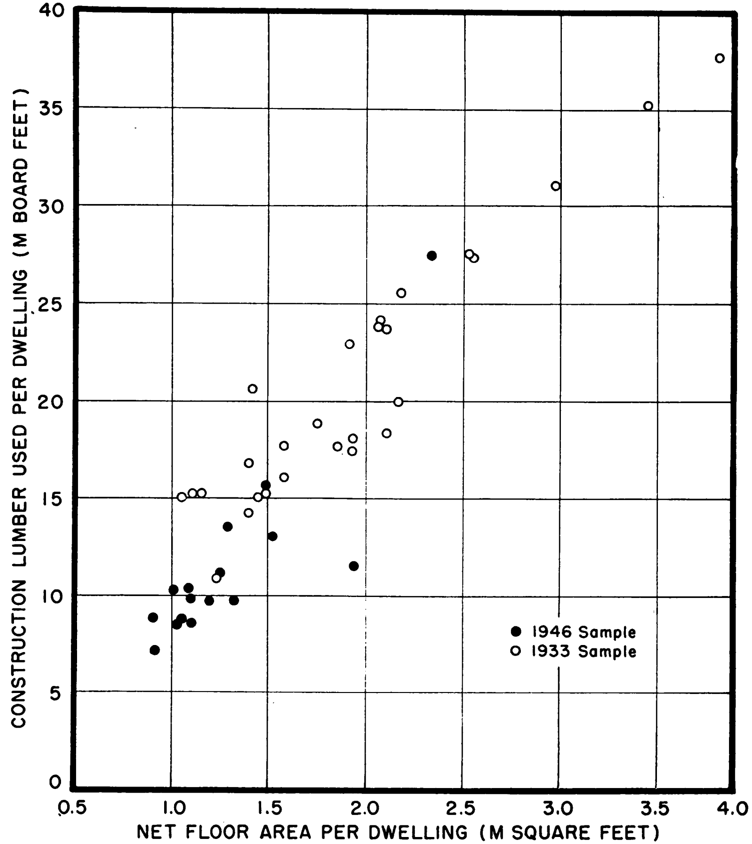

Fig. 9. Construction lumber used in sample single-family dwellings in northern California: 1933 and 1946.

CONCLUSION

Aggregate demand for housing lumber in California. The findings of the two preceding sections provide bases for estimating aggregate demand for lumber for residential construction purposes in California, as of different periods of time. Because of the broad nature of the estimates of lumber requirements per dwelling unit, changes in demand will be considered by ten-year intervals rather than on a year-to-year basis.

1920–1941: During the decade 1920–1929, residential building activity in California was stimulated by relatively high levels of income, by rapid population growth, and by high occupancy ratios. New construction averaged 88,500 dwelling units per year over the period. Lumber requirements per unit were apparently sustained well above the levels which now prevail. Although an abnormally large proportion of duplex and apartment-type structures were erected, the average dwelling appears to have been larger than that typical in current construction. Aside from a relatively small number of fireproof apartments and adobe dwellings, construction was of conventional wood-frame type. Lumber requirements for the average house were thus about 14 M bd. ft. per dwelling unit. Average total housing lumber consumption is therefore estimated at about 1.2 billion bd. ft. per year.

During the succeeding period 1930–1934 construction fell to very low levels in response to drastic curtailment of income, slower population growth, and the emergence of a large number of vacancies. Some recovery began in 1935 and by the beginning of World War II construction rates had been restored to the boom levels of the preceding decade. During the twelve-year period 1930–1941 new construction averaged 62,700 units per year. Apartment building was halted for much of the period, and this along with other cyclical factors affecting lumber use probably led to a slight increase in wood required per dwelling unit, as compared with the previous decade. Average total residential construction lumber consumption for the period appears to have been only about 0.9 billion bd. ft. per year—25 per cent below that of a decade earlier.

1942–1946: Because of abnormal building conditions, the war years do not provide a reliable guide to "normal" lumber requirements. All wartime residential construction was subject to rigid controls affecting both volume and type of construction and proceeded at a relatively slow rate. Consequently no estimates have been prepared for the period 1942–1945.

During 1946 an estimated 105,000 new dwelling units were started in nonfarm areas. Farm residential construction was of minor importance and does not appear to have exceeded 2,000 units. Average lumber requirements per unit are estimated to have been only 8.7 M bd. ft. The decline in unit requirements reflects primarily decreases in average dwelling size, the adoption of concrete block and other non-wood-frame types of construction on a significant scale, and certain economies in lumber use in conventional frame structures. Lumber consumption for new residential construction in 1946 is estimated at 0.93 billion bd. ft., or somewhat above the average for the period 1930–1939.

The outlook for housing demand. Attempts to forecast demand for a given year or period of years for any commodity are obviously colored by implicit assumptions and personal judgments. Moreover it is almost impossible to specify all the limitations and qualifications which are necessary to prevent misinterpretation. But forecasting *can* fulfill a useful function by exploring the range within which future demands will most probably lie. The forecaster thus makes explicit the major alternative possibilities in the demand outlook; he provides some quantitative indication of the relative importance of changes in the different variables which affect demand; he provides benchmarks from which others can formulate their own forecasts on the basis of their own judgments as to critical variables—and from the same benchmarks revised forecasts can readily be prepared as the need arises. The ranges of prospective housing-lumber demand described below are presented with these objectives in view.

What levels of future income, population increase, ownership costs, and vacancy ratios can reasonably be assumed as a basis for estimating new residential construction requirements during the next twenty years?

Vacancy ratio. If high levels of income are maintained, it is quite probable that the basic factors which explain past vacancy relations in California will continue in effect with only moderate, if any, lessening of force. On this ground the main reason for anticipating subnormal vacancies in the future is the fact of current abnormal overcrowding, which seems unlikely to be entirely eliminated for some time.

Under these circumstances we may expect a rising trend of vacancies during the next twenty years, which will carry the vacancy ratio from its 1946 level of about 1 per cent to close to the prewar normal—say 6.5 per cent—by 1965.

Prospective ownership costs. Costs of home ownership displayed a steady downward trend from 1920 to 1936, interrupted only by sharp upward breaks in 1923 and 1932. Since 1936 an upward movement has been in effect, reaching explosive proportions during 1946 and 1947. It appears possible that current levels of cost may not be long maintained. Prices for most grades of lumber have already turned downward and the advent of a buyer's market has recently been noted by most lumber trade analysts. Building materials other than lumber have experienced no general skyrocketing of prices. The B. L. S. combined index of building materials prices rose only 14.6 per cent between 1941 and 1945, as compared with a 32.6 per cent rise in lumber. Some of the wartime labor cost increases will probably be offset by increases in productivity as the shortage of construction labor eases.

In sum, the costs of new construction during the period 1946–1965 may be expected to recede from current peaks, but with full employment are unlikely to sink to the levels of the mid-1930's. At the same time, the wide interest in public effort to stimulate residential construction is likely to insure continuance of the relatively low rates of mortgage interest prevalent since 1934. The net result of these forces seems likely to produce costs of home ownership in the period 1946–1965 comparable to the average 1920–1941.

Outlook for population change. The problems of future rates of population increase and future levels of family income are closely related. Under conditions of relatively high national and state income, with good opportunities for employment, migration into California is likely to be sustained at high levels, giving rise to a large increase in the number of families in the state. Indeed a recent study has concluded that "internal migration is a necessary, if not sufficient, condition to the attainment of full employment in the postwar period. . . . Migration of population is a much more likely prospect than a geographic shift in opportunity—at least during the decade or two following the war." (Jaffe and Wolfbein, 1945.) If we accept this view, a high rate of migration (and rapid increase in the number of families) becomes a necessary corollary of a full-employment assumption. But if income should sag

Table 10

SELECTED ESTIMATES OF EXCESS OF BIRTHS OVER DEATHS AND OF MIGRATION IN CALIFORNIA

Period and estimate	Excess of births over deaths	Birth rate	Apparent net immigration
CRRC high estimate			
1946–1950 av. annual	105,000	21.1	185,000
1950–1960 av. annual	73,000	17.5	250,000
Comparative observations			
1920–1930 av. annual	23,135	17.6	201,904
1940–1946 av. annual	67,085	19.3	282,539
CRRC low estimate			
1946–1950 av. annual	87.500	19.6	62.500
1950–1960 av. annual	50,000	16.2	100,000
Comparative observations			
1930–1940 av. annual	14,251	13.9	108,762

Source: California Reconstruction and Reemployment Commission (1946).

significantly between now and 1965, smaller population increases in California are likely to materialize as a result of smaller migration rates.

In view of the dominance of the migration factor, population forecasts for California cannot be made with the same assurance as can those for areas where natural increase is the predominant variable. However, past history provides examples of considerable variations in migration rates. With these as a guide, ranges of prospective population may be established which will define within reasonable limits the probable future situation.

One such estimate has been recently prepared by the California Reconstruction and Reemployment Commission (1946). This was based on revised estimates of the probable number of births and net migration between now and 1960. The Commission made two alternative assumptions. The first was that national employment and national income would continue at high levels from now until 1960 with consequent high birth rates and relatively large net migration into California. The minimum assumption envisages a major depression during the next decade. The estimates of excess of births over deaths and net migration developed by the Commission on these assumptions are shown in table 10. Maximum and minimum values observed for these statistics in the past are also shown for comparative purposes. The relatively high birth rate assumed by the high estimate for 1946–1950 reflects the postwar increases in marriages and births. For 1950–1960 it reflects birth rates somewhat below past peaks. In the light of comparison with the prosperous 1920s, the estimate of 250,000 immigrants per year from 1950 to 1960 appears high even under an assumption of general prosperity. The low estimates for migration are below those of the relatively static 1930's.

On the basis of these data California Reconstruction and Reemployment Commission has estimated the range of future population in California as follows:

Date	*High Estimate*	*Low Estimate*
Sept. 1, 1946	9,375,000	9,125,000
Jan. 1, 1950	10,270,000	9,600,000
Jan. 1, 1960	13,500,000	11,100,000

An older, but extremely detailed set of population forecasts prepared by Weeks (1930) has already proved to be too optimistic so far as estimates for 1940 and 1950 are concerned. However, the deviations in these forecasts can be shown to rest entirely on an assumption of higher immigration and birth rates for the period 1930–1940 than were actually realized. It has been noted that both factors were at a very low level during this period, a situation which could not have been foreseen in 1930. If, therefore, we revise Weeks's estimates in the light of fifteen years additional history of births and migration, we will have a useful comparison with forecasts discussed above.[21]

In 1940 the population under 10 years of age represented 13 per cent of all Californians, compared with 15.7 per cent forecasted by Weeks. This difference reflects the decreased birth rate during the 1930's. The postwar upswing in number of births will tend to stabilize the ratio at approximately its present level. Starting from a 1940 population estimate of 6,912,900 persons, assuming maximum and minimum limits of migration during the remainder of the decade as in table 10, and assuming maximum and minimum migration thereafter as 2 million and 1 million persons per decade, the following projections result:

Year	*Maximum estimate*	*Minimum estimate*
1950	9,800,000	9,240,000
1960	12,295,000	10,540,000
1970	14,710,000	11,800,000

These estimates fall somewhat below those of the California Reconstruction and Reemployment Commission, particularly in the case of the maximum figures. This is to be expected in view of the somewhat lower levels of migration which have been assumed. Because of their closer correspondence with past experience and because the projections extend through the entire period 1946–1965, the forecasts derived from survival and age-class ratios will be used hereafter in preference to those of the California Reconstruction and Reemployment Commission.

[21] The method involved applying crude survival rates based on California life tables to population at the beginning of a decade, adding estimated migration during the decade, and adjusting for percentage of population under 10 years of age at the end of the decade. See Weeks (1930), Chapter 3.

In converting population increase to increase in number of families, account must also be taken of the change in the average number of persons per family. From 1880 to 1940 family size in California declined with great regularity from about 5 to about 3.25 persons per family. Although this long-run trend was sharply disrupted by wartime disturbances, there is no reason to think that it will not be resumed in the future. Reduction of average family size to about 2.7 persons by 1965 appears reasonably probable: When this family size trend is applied to the estimates of population increase previously given, the following estimates result:

	Average annual increase in families (thousands)	
Decade	*Maximum*	*Minimum*
1946 to 1955	90.0	47.0
1956 to 1965	103.0	66.0

Outlook for family incomes. Future family incomes in California will, of course, be strongly affected by national conditions. The Twentieth Century Fund (Dewhurst, 1947) has prepared estimates of national income under conditions of normal demand at sustained high levels of economic activity which seem appropriate for the present purpose. The Fund estimates national income in 1950 at $106 billion and in 1960 at $134 billion, both in terms of 1940 prices. These may be converted to a per capita basis by use of available national population forecasts published by Thompson and Whelpton (1943). The pertinent estimates are $733 per capita in 1950 and $864 in 1960.

The ratio of California per capita income to national per capita income during the prewar period has been observed to be reasonably stable (Clawson and Calhoun, 1946). Wartime and postwar conditions have resulted in some decline in the ratio (Shapiro, 1947). It seems probable that a ratio of at least 1.35 is essential for consistency with the conditions assumed for the maximum levels of population growth presented above. A 1.20 ratio appears to be a reasonable concomitant for the minimum population forecast.

If these premises are accepted we may estimate California per capita income as follows (in terms of 1940 prices):

	1950	*1960*
Maximum estimate	$990	$1165
Minimum estimate	880	1035

The preceding estimates of prospective trends in California incomes, population, housing costs, and residential vacancies may now be used in conjunction with the relations already established to estimate prospective new residential construction. When the estimated values of these independent variables are substituted in the regression equation relating them to rates of new construction, the following results are obtained:

At maximum prospective income and population increase

1946 to 1955 : 170,000 new units per year, ± 21,000 units
1956 to 1965 : 180,000 new units per year, ± 23,000 units

At minimum prospective income and population increase

1946 to 1955 : 100,000 new units per year, ± 10,000 units
1956 to 1965 : 110,000 new units per year, ± 12,000 units

Comparison of the forecasted rates with those of recent experience is given in figure 10.

The outlook for unit lumber requirements. The drastic curtailment in lumber requirements per dwelling unit previously noted gives rise to speculation as to whether such trends may be expected to continue in the future. Data which give only a sketchy picture of past developments provide, of

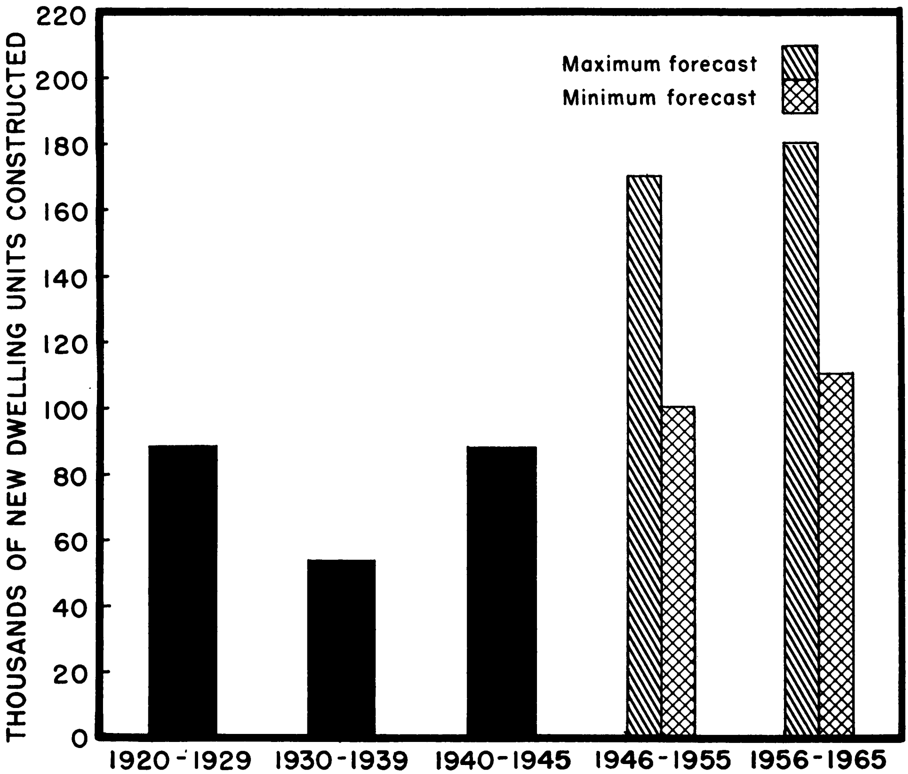

Fig. 10. Estimated and forecasted average annual rates of dwelling construction in California: 1920–1965.

course, a shaky vantage point from which to view the future, particularly in such a complex field. Yet, keeping these limitations in mind, we may advance tentative estimates of the lumber requirement outlook.

The most important single factor affecting reduction in unit lumber requirements between 1933 and 1946 appears to have been reduction in the average size of single-family houses. Lowering of ceiling heights is largely a matter of custom or taste. Ceiling heights of 8 feet, or slightly above, seem now to be standard. There is no reason to expect a return to the more ample head room of twenty years ago. On the other hand, there are definite physical limitations to further reductions in this dimension of housing. A stabilization of ceiling heights at about present levels seems likely.

Further reductions in average dwelling area are, of course, entirely feasible. Previous analysis, however, has suggested that much of the reduction of areas noted between 1933 and 1946 may have been of cyclical origin. The current pressure for increased housing lays extra emphasis on volume production, and it may well be that 1946 conditions produced abnormally small dwellings. The average single-family dwelling built in that year contained only 4.64 rooms, significantly below the 5-room unit regarded as standard housing for a large majority of American families. For the long pull, a modest increase of perhaps 5 per cent above 1946 size levels seems probable.

There is no present indication of significant future changes in the relative importance of single- and multi-family dwelling units, nor in the proportion of wood siding to other forms of exterior material.

The future of concrete block and other non-wood-frame types of construction is not yet clear. Quonset types, which comprised a significant proportion of 1946 building of this class, are definitely emergency adaptations, and are unlikely to survive the current housing crisis. Adobe structures have always been used in parts of California and undoubtedly will retain their relative popularity. Concrete block houses are an important new development. To what extent they will continue to make inroads on all-wood construction, or to what extent their present popularity results from scarcities and high prices of lumber, remains to be seen. The 10 per cent of the market which they possess now will probably be retained.

Although the data on substitution for and economies in the use of wood in standard construction gave no clear-cut trend indications, some future decreases in lumber use due to this sort of thing are possible. During the past seven years lumber prices have risen much more rapidly than have those of competing building materials. Some recession from peak levels is now in sight but, barring a major depression, full restoration of prewar building material price relations is highly improbable. Decreased supplies of available stumpage would probably prevent such a restoration, even if other costs of lumber production were to revert to 1939 levels. In the long run this decrease will undoubtedly have some effect on wood use. However, experience of the last two years, when lumber was both very scarce and relatively very high priced, indicates that such substitution may not proceed very far.

In sum, the analysis suggests that during the next ten or twenty years, lumber requirements for California dwelling units may be slightly above those which prevailed in 1946, but are very unlikely to return to the level experienced in the early 1930's. A future requirement of 9.0 to 10.0 M bd. ft. per average unit seems reasonable.

Prospective demand for housing lumber. When the above requirement is applied to the estimates of prospective new home construction, the following estimates of prospective demand for housing lumber are obtained:

Maximum population and income increase

1946 to 1955 : 1.6 billion bd. ft.
1956 to 1965 : 1.7 billion bd. ft.

Minimum population and income increase

1946 to 1955 : 0.95 billion bd. ft.
1956 to 1965 : 1.05 billion bd. ft.

In the light of these estimates it seems improbable that California's average needs for new residential lumber during the next two decades will fall below the 1946 level of consumption. Indeed, there is a reasonable possibility that they may exceed previous consumption peaks attained during the 1920's.

These estimates are, of course, no better than the various assumptions as to future conditions which have been made in preparing them. Many things may happen to cause future events to follow a different pattern than the one here assumed. But, if this qualification is borne in mind, the estimates can serve a useful purpose as benchmarks in analyzing our wood needs. As events develop, they may require further qualification or revision.

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