The Determinants of Residential Land Values

By EUGENE F. BRIGHAM *

SINCE WORLD WAR II urban areas in the United States have experienced a gigantic expansion. A number of problems have accompanied the growth—among them are a transportation lag, urban blight, and urban sprawl. Attempts to deal with these problems continually demonstrate our need for a better understanding of the complexities of metropolitan structures. For instance, when an individual selects property in a particular residential area, what influences his choice? Certainly land prices are one of the influencing forces but what determines land values? This paper, which gives results of a study conducted at The RAND Corporation under the sponsorship of the Ford Foundation describes and tests a model of residential land values in Los Angeles County.[1]

I. An Overview

Essentially, the study is an empirical investigation of residential land values, and its structure and methodology are straightforward. First, a very simple theoretical model of land values is developed and used as a frame of reference within which to study the empirical data. The underlying model, described in more detail in the following sections, assumes that the value (V) of a particular urban area site is functionally related to its accessibility to economic activities (P), to its amenities (A), to its topography (T), to its present and future use (U—i.e., industrial, commercial, or residential), and to certain historical factors that affect its utilization (H). Provided these variables can be quantified, the basic land value model of the i^{th} site may be expressed as

$$V_i = f(P_i, A_i, T_i, U_i, H_i) \quad (1)$$

Since it is likely that accessibility, amenity, and topography will react differently on the value of land in different uses, the basic equation is restated as

$$V_{Ri} = f_1 \ (P_i, A_i, T_i, H_i) \quad (1a)$$

$$V_{Ci} = f_2 \ (P_i, A_i, T_i, H_i) \quad (1b)$$

$$V_{Ii} = f_3 \ (P_i, A_i, T_i, H_i) \quad (1c)$$

where the subscripts R, C, and I designate residential, commercial and industrial land, respectively.

The key variables are thought to be indices, with each index a function of several different variables. A site's accessibility, for example, is a joint function of its proximity to different activities and the transportation system connecting it with these possible destinations. Similarly, the social and atmospheric conditions associated with the site determine its amenity indices.

While the principal analytical tool employed in the study is multiple regression analysis, it was impossible to quantify all important land-value determinants

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[1]Eugene F. Brigham, *A Model of Residential Land Values,* Santa Monica, California: The RAND Corporation, RM-4043-RC, August 1964.

and incorporate them into the regression models. Many of the qualitative forces that shape the structure of urban land values can be considered at an intuitive level, however, especially with the aid of maps. When actual land values and the values predicted by the regression equations are plotted on topographic maps, one quickly sees points where values are high and low, and where qualitative factors cause the model to break down most severely.

The basic data for this study were obtained from tax assessment appraisal records. The sampling method, selected primarily because it was relatively inexpensive yet quite adequate, involved extending arbitrary rays, or lines, out from the Civic Center to the County boundaries. Each block a ray passed through was treated as a sample point, or observation, and the average appraised value per square foot for the block was ascertained. If a block included two or three types of land uses—for example, residential and commercial properties—this fact was noted, and subsequently individual samples of each were obtained.[2]

Three rays were selected. The first extends to the northwest through Hollywood, the Santa Monica Mountains, and up the San Fernando Valley to the Ventura County boundary. The second extends to the northeast through Alhambra, South Pasadena, San Marino, the Santa Anita racetrack, and to the base of the San Gabriel Mountains. The third extends to the southeast through the heavily industrialized East Los Angeles area to the Orange County boundary. The rays were selected with the idea of obtaining samples with diverse characteristics.[3]

II. The Value Determinants

Since land supply is fixed, land value in an urban community is determined by the demand for space. As previously mentioned, the demand function for any site in any given metropolitan area is a function of the site's accessibility, amenity level, topography, certain qualitative phenomena that may be considered "historical accidents," and the value of the land in non-urban uses. Each of these factors is discussed now in order to establish a framework within which to consider the empirical models presented.

Accessibility Value. Urban land has a value over and above its value in rural uses because it affords relatively easy access to various necessary or desirable activities. If transportation were instantaneous and costless, then the urban population could spread out over all usable space and all land prices would be reduced to their approximate value in the best alternative use. But transportation is not instantaneous and costless and, since modern life requires the concentration of people in cities, urban land takes on a special accessibility value. The theoretical relationship between accessibility and land values has been discussed at length by Wingo and others.[4]

Under very restrictive assumptions it is possible to specify a precise relation-

[2] The theoretical model is for residential land only and most of the analysis is concentrated on this sample. The same general relationships, however, were found in each of the samples when they were used in the regression models.

[3] The southeast ray did not meet the assumptions of the model, so it was not studied in detail and is not discussed in this paper. See Brigham, *op. cit.*, pp. 51–52.

[4] Lowden Wingo, *Transportation and Urban Land* (Washington, D. C.: Resources for the Future, inc., 1961); W. B. Hansen, "An Approach to the Analysis of Metropolitan Residential Extension," *Journal of Regional Science*, Summer 1961, pp. 37–55; Herbern Mohring, "Land Values and the Measurement of Highway Benefits," *Journal of Political Economy*, June 1961, pp. 236–249; and William Alonzo, "A Theory of the Urban Land Market," *Papers and Proceedings of the Regional Science Association*, 1960, pp. 149–157.

ship between a site's accessibility and its value relative to other sites in the metropolitan area. Once the simplifying assumptions are dropped, it is no longer possible to specify the accessibility value function. The direction of impact of certain factors can be specified, however, and a number of relationships postulated. Diffusion of trip destinations, especially employment centers, leads to lower travel times and costs and tends to reduce land values in the aggregate. Higher incomes lead to more intensive bids for space, hence to higher land prices. Family characteristics that stimulate greater space preferences also lead to higher land prices. Transportation services vary widely among sites located the same distance from the Central Business District or other major trip destinations. Areas that offer easier access to bus lines, arterial boulevards, or freeways than other equidistant areas may have an accessibility value that influences land value. Finally, cost is not a linear function of distance but increases at an increasing rate as one travels into a congested area.

These relations cannot all be expressed in precise mathematical notation but some can be illustrated with graphs. Suppose a line is drawn from a point near the center of a city to the rural fringe at the edge of the metropolitan area. The ray could be expected to cut across freeways and other arterial roads (where increased accessibility brings relatively high values) and through areas close to satellite employment centers that again cause accessibility value peaks. The land value per square foot at each point along the ray could be ascertained and plotted against distance from the city's center, and a graph like Fig. 1 would result. A larger city, or one with a wealthier population, might have the dashed rent gradient curve. The dashed line would also represent a city with a population having high space-consumption preferences. A city with decentralized employment might have the lower accessibility value curve but its curve would have some important "blips" and would cross that of the centralized city out on the right tail. A city expected to grow quite rapidly might have the same accessibility *rent* curve as an identical city that expects slower growth, but it expects higher future rents, hence its accessibility *value* curve (measured land prices) will be higher.[5] And a city with topographic or other effective constraints on expansion in certain directions will tend to have longer commutes, higher travel-cost savings from living close to the center, and higher values than a city of similar size with no such barriers.

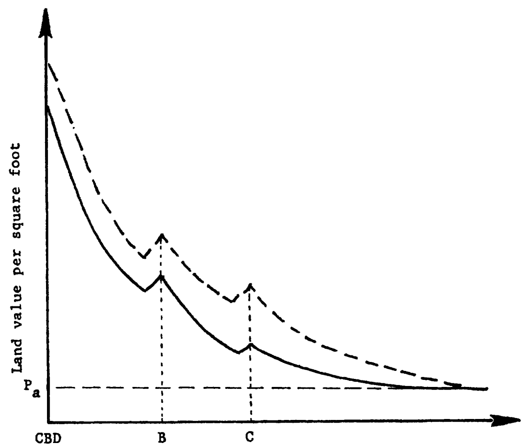

FIG. 1—HYPOTHETICAL CROSS-SECTIONAL VIEW OF LAND-VALUE SURFACE

In conclusion, we have an idea about the shape of the accessibility function, but can only specify it under highly

[5] Higher land prices would probably force rents up also but this is not entirely clear. Speculators are often willing to rent land at nominal rates while waiting for the land to "ripen" for a higher and better use.

simplified conditions far removed from the real world. Many of these simplifying conditions are reassumed in the following subsection where an accessibility variable suitable for empirical testing is formulated and when it is used in a regression model.

The Accessibility Potential Variable. If the CBD is the only work-place, if the journey to work is the only significant trip any household member takes, and if travel to and from the CBD is equally easy in any direction, then the distance from any site R_i to the CBD provides an index of the site's accessibility. If these conditions are not met, then this distance variable is an imperfect proxy for accessibility. It is quite obvious that the necessary conditions are violated in all metropolitan areas and especially in Los Angeles. The following potential model variable makes allowances for many workplaces and is suggested as a possible improvement to distance alone.

$$P_i = \sum_{j=i}^{N} \frac{E_j}{a + bD_{ij}^{\,c}} ,$$

where P_i is the accessibility potential of the i^{th} site, E_j is the total employment in the j^{th} workplace, D_{ij} is the distance between sites i and j; a, b, and c are parameters; and the summation is over all of the N workplaces in the community. Under this formulation, the employment accessibility potential of site i varies directly with the employment opportunities surrounding it and inversely with the distance between it and these employment opportunities. The workplace and residence zones may, of course, be aggregates of sites rather than individual lots; in fact, census tracts were used in this study. It is obvious that the model could be improved by providing a weighting system in the numerator for different types of jobs—possibly by weighting different types of employment by the mean income in each job category —and by putting a time factor in the denominator to account for differences in the transportation systems connecting different pairs of points. These desirable modifications were not made in the model because the necessary data were not available.

Amenity Value. If, for example, a particular site generally has less smog than an otherwise identical site, then it will be a more pleasant place to live in and will have a higher amenity level. Naturally, a site having a higher amenity level is more desirable and more valuable than one with fewer amenities, if all else is equal.

The amenity level is clearly a qualitative factor determined subjectively by different individuals. Its level at a particular site cannot be measured directly as can elevation or temperature but one could measure its value. Suppose a sample of the city's population was selected and allowed to become completely familiar with all the residential neighborhoods in the area. These people could then be asked to rank the residential sites in the order of their relative amenity levels, designating points of indifference by the same rank, and an ordinal set of site amenity rankings could be compiled. Amenity rankings would differ somewhat from person to person—bohemians might find a certain area highly desirable while more conventional types might consider it a slum—but in general these rankings would tend to be very similar.

The ordinal rankings of each individual person participating in the experiment could be scaled from 1 to 100 by assigning his rank percentile to each site

—the most desirable 1 per cent of the sites would be given a value of 100, and so on. The percentile rankings of each participant could be aggregated; the final product would be a numerical index of amenity levels in the community.

This composite amenity index would probably be highly correlated with a number of quantitative variables such as the nonwhite proportion of the population, median family incomes, and the extent of dwelling-unit crowding, all of which are readily available on a census-tract basis. Other quantitative factors that are important determinants of amenity, especially in Los Angeles, include the mean and extreme temperatures, and the smog levels in different sections of the metropolitan area.

Since there can be dramatic changes in amenities from one block to the next, it is desirable to have an amenity proxy that is somewhat more sensitive than the census tract-wide variables.[6] Such a variable is the average value of the dwelling-unit structures in a given block. If the average value of the improvements (holding constant the value of the land itself) of each dwelling unit is high, this probably indicates a number of things. First, the buildings are probably more pleasing to the eye. Second, because it will be expensive to live in them their occupants will have relatively high incomes, and high incomes are associated with high levels of education and high social and economic positions. This leads to the feeling that a certain amount of "prestige" is attached to living in the neighborhood, and it is "a good place in which to bring up one's children." It is argued, then, that the value of dwelling-unit improvements has an influence on and can be used as a rather fine-grained measure of the amenity level in a given neighborhood.

Topography. As used in this paper, the term "topography" means the natural, physical characteristics of a particular site. Foremost among these features are slope, elevation, and soil condition. Topography has two separate impacts on measured land values. First, a site's terrain has an effect on its amenity index. For example, a site situated high up on a steep hill might be above the smog level and might have a commanding view of the city; both factors would tend to increase its amenity level. But, on the other hand, this steep, hilly site might be excessively windy and dangerous for smaller children—factors that create negative amenities for people who dislike wind or who have small children. Thus topography's effect on a site's amenity ranking would vary from family to family depending on their composition and preferences.

Besides its amenity impact, topography also has a bearing on land values through its effect on development cost. Consider a tract of *un-developed* acreage, half of which is quite hilly and half of which is relatively flat. The flat land can be subdivided into residential lots rather easily; while putting in access roads, grading for construction, providing utilities, and so forth, will be quite expensive in the hilly section, whose value will be reduced *vis-a-vis* that of the flat land by these added costs. Similarly, if half the acreage had been on well-drained land and half in a swamp,

[6] Census tracts consist of relatively homogeneous neighborhoods and contain, on the average, about 4,000 people. Depending on the population density in the area, tracts in Los Angeles generally contain from 20 to 80 square blocks. In the built-up single-family areas of the San Fernando Valley, for example, the average tract in 1960 had about 60 square blocks, while in the densely-populated multiple-dwelling unit area close to the Civic Center, tracts averaged around 25 square blocks.

the value of the swampy half would be reduced by the costs of providing drainage.

Differential values resulting from topography might not be expected with already developed land. In the examples above, if the aggregate accessibility and amenity indices of the hilly sites, after development, are identical to those of the flat sites, then buyers in general will be willing to pay the same price for a developed lot on either the favored or unfavored land, and measured land values will be identical. This is not necessarily true, however, when land values are computed on a square foot basis. The reason for this can best be illustrated by Fig. 2, which shows a cross-section view of a given area under two alternative development plans. In Plan A only the ridges and valleys, which are relatively flat and easy to prepare for construction, are developed. These lots are quite large, but a buyer acquires much unusable space, and most of the purchase price is actually paid for that part of the lot on which a house may be built. Under Plan B (presumably put into effect only if the area's accessibility to employment centers is extremely high) the developer cuts roads into the hillsides and uses the entire area. Plan B lots are much smaller than those of Plan A, and are probably about the same price, so the measured value per square foot of lots in the area will be much higher if Plan B is adopted.

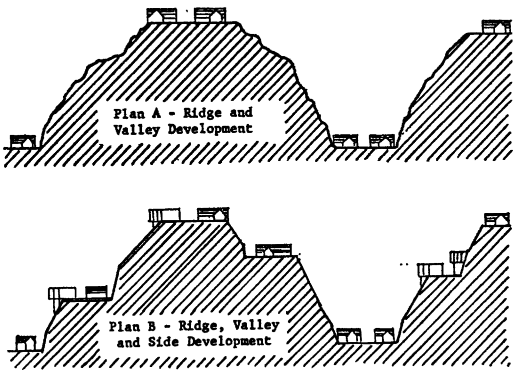

FIG. 2—HYPOTHETICAL DEVELOPMENTS OF HILLY TERRAIN

Historical Factors. In a sense, all factors affecting land values are either historical or physical. An historical accident may have determined the position of a major arterial, hence land values in the area. The lower class residential district of a city may have been located by an historical accident and thus have had a permanent impact on amenity levels and land prices of sites in the city. In this paper, however, a different type of historical factor is considered. As used here, *an historical factor is the employment of land in a way that is no longer suitable.* For example, consider the alternative development Plans A and B in Fig. 3. Plan A might be adopted and carried

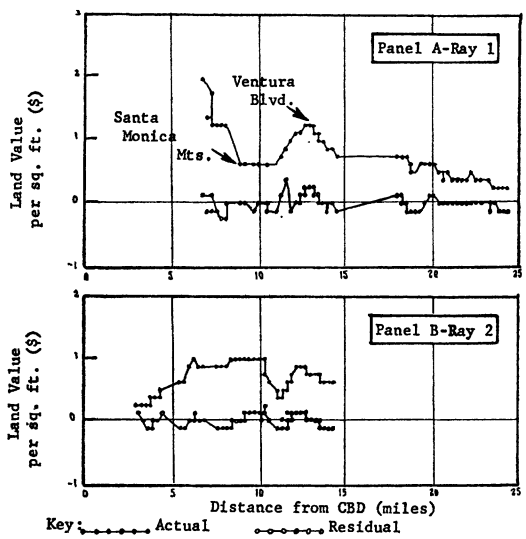

FIG. 3—ACTUAL LAND VALUES AND RESIDUALS ABOUT REGRESSION EQUATION BASED ON DATA FROM THE INDIVIDUAL RAY ONLY; SINGLE-FAMILY PROPERTIES. (THE EQUATIONS WITH CBD THE DISTANCE VARIABLE WERE USED TO DERIVE THE RESIDUALS FOR PANELS A AND B RESPECTIVELY.)

TABLE I—THE REGRESSION EQUATIONS FOR SINGLE-FAMILY PROPERTIES

Sample	Constant Term	Distance to CBD	Accessibility Potential	Neighborhood Variable[a]	Building Value	Topography Dummy[b]	R^2
A. Ray 1							
Regression Coef.	1.73	–.051	—	–.15	1.06	–.51	.87
(Std. Error)		(.003)	—	(.13)	(.23)	(.07)	
Partial Corr. Coef.		–.89	—	–.12	.44	–.64	
Regression Coef.	–.29	—	8.80	–.01	.97	–.48	.79
(Std. Error)			(.66)	(.16)	(.30)	(.08)	
Partial Corr. Coef.			.53	–.01	.33	–.53	
B. Ray 2							
Regression Coef.	1.35	–.041		–4.28	.28	–.70	
(Std. Error)		(.004)		(.31)	(.18)	(.08)	.87
Partial Corr. Coef.		–.68		–.83	.17	–.69	
Regression Coef.	.21		14.90	–5.57	.32	–.91	
(Std. Error)			(1.58)	(.35)	(.17)	(.08)	.89
Partial Corr. Coef.			.73	–.87	.20	–.76	

[a] Median family income is used for Ray 1, and the percentage of dwelling units with more than 1.01 persons per room is used for Ray 2.

[b] A dummy variable set equal to 1 for sites located in the Santa Monica Mountains, through which Ray 1 passes, and the hills about one-third of the way out Ray 2.

out because, at a particular time, the marginal revenue from the sale of the hillside lots is lower than the marginal cost entailed in this expensive development. If the acreage had been developed later, after the growth of the city had increased the accessibility of the tract, Plan B might be feasible. Now in a given area some tracts are developed early (like Plan A), others later (according to Plan B); we say that an historical factor—the point in time at which development took place—influences measured land prices. In the long run, redevelopment may occur to equate these land prices but the long run can involve many years in the case of real property.

III. *The Regression Equations*

Regression equations were fitted to five-block moving averages of the land value per square foot for single-family properties on each ray. The data were smoothed by moving averages in order to remove as much spurious variation as possible; the purpose of the study was to investigate general, not local, variations in land values and the smoothing process helped make these primary influences more apparent.[7]

Since there are several different proxies for the accessibility and amenity indices and since these proxies are frequently too highly intercorrelated[8] to be

[7] The data were also fitted in a sample which pooled rays 1, 2, and 3 together. This sample was constructed in order to see the differences between a single-ray and the entire metropolitan area, so the inclusion of Ray 3 is necessary there. The combined ray sample exhibited the same characteristics as those for the single rays. Brigham, *op. cit.*, pp. 50 and 60.

[8] See Brigham, *op. cit.*, Appendix C, for a complete breakdown of the simple correlation matrix.

used together, a number of different equations are calculated for each of the samples. Table I presents the most interesting and useful of these models.

Accessibility. The accessibility variables behave as expected—land values are negatively related to distance from the CBD and the nearest freeway, and positively related to the employment accessibility potential variable. There are differences in the parameters of the accessibility proxies of the several samples but these variations seem reasonable in view of the diverse characteristics of the rays.[9] Ray 1's coefficient for distance to the CBD is slightly larger than that of Ray 2, indicating more distance-sensitivity, but this conclusion should not be pushed too far, considering the differences between the rays. Single-family properties start much closer to the CBD on Ray 2 than on Ray 1. Ray 2 terminates abruptly some 14 miles from the CBD, while Ray 1 continues 25 miles out from the CBD, extending to the point where urban activity has faded away.

The coefficients of the distance variables, all of which exceed their standard errors by 10 times, suggest that land values fall by about four or five cents per square foot for every one-mile increase in distance from the CBD after amenity levels and other value-influencing factors are taken into account. Put another way, the distance elasticities computed at the point of means, values of −1.13 for Ray 1 and −.96 for Ray 2, indicate that a 10-per cent increase in distance from the CBD is associated with a decrease of about ten percent in land values.

In conclusion, we can state that there is clearly a relationship between land values and accessibility to urban activity but that this relationship, even after holding certain other effects relatively constant by the use of multiple regression analysis, is far from stable when different samples are examined.

Amenity. The census tract amenity variables—income for Ray 1, crowding for Ray 2—behave as expected.[10] Neighborhood variables are quite important on Ray 2, relatively less significant on Ray 1. These variations appear to be caused by important differences in ray characteristics. Once the single-family areas have been reached, Ray 1 goes through a series of fairly homogeneous upper-middle class neighborhoods; the mean income is $8,800 and the standard deviation is $1,858. Ray 2, on the other hand, has a mean income of $10,330 in the single-family sections; however, the standard deviation is $4,100, indicating pronounced variations in socio-economic conditions along the ray. A comparison of means and standard deviations of the other two amenity proxies, crowding and single-family building values, revealed similar tendencies. Naturally, with so much more amenity variation to be explained, the amenity proxies would appear more important in Ray 2.

Topographic Dummy. The coefficient of the topographic dummy is negative and highly significant, indicating that single-family land values are relatively low in very hilly areas. Since all properties included in the sample are devel-

[9] The exponent in the accessibility potential equation was determined by experimentation; the value 1.0 was used for Ray 1 and 0.8 for Ray 2. This means that the potential will be higher for Ray 1, *ceteris paribus,* than for Ray 2, hence the accessibility potential regression coefficient should be lower for Ray 1.

[10] Income has the wrong sign but is less than its standard error in the Ray 1 model when used together with building values. This is because of the high correlation between incomes and the values of single-family homes. Land values are positively related to incomes when building values are removed from the equation.

oped sites, it is likely that the negative relationship is caused by the inclusion of undevelopable land in hill area lots.

IV. Plots of Land Values and Residuals

Actual land values and residuals about the regression equations were plotted on a large-scale, detailed topographic map of the Los Angeles area. The major peaks and valleys in both actual land values and residuals about the regression lines were then compared with the features shown on the map—the points where the residuals differ greatly from zero are especially significant since they show where the regression model breaks down most seriously. Land values and residuals, plotted against distance to the CBD, are shown separately in Fig. 3.

Panel A of Fig. 3, which gives the plots for Ray 1, shows very clear peaks and valleys for the actual land values but fewer pronounced patterns for the residuals. The actual values are quite high initially—these sites are on the south slope of the Santa Monica Mountains very close to Hollywood—then fall markedly in the mountainous area, rise in the vicinity of Ventura Boulevard, and tail off rather gradually to the end of the County. The dummy variable adequately accounts for the land value dip in the Santa Monica Mountains but the Ventura Boulevard peak appears on the residual plot. Actual values rise initially on Ray 2 as the very low amenity area is traversed, then follow an irregular pattern to the terminus. The residuals are all fairly close to zero, but there is a tendency, especially toward the tail-end, for the deviations to follow the actual land values rather closely.

One feature of the Ray 2 plots, the pronounced dip in both actual and residual values that occurs about 12 miles out, is partly explained by the map analysis. At this point an "historical accident" occurs—the ray goes through a very fine old neighborhood with large, well-kept-up single-family homes that, over the four blocks responsible for the valley, are situated on lots with an average dimension of 200 x 200. These homes will eventually be removed and the land converted to a more efficient use as the buildings deteriorate and accessibility increases. Assuming a free market exists, single-family homes will be removed to make room for apartments (or other more intensive uses) when the value of the land alone, in the new use, exceeds the value of both land and buildings in the old use. If the old buildings are in very good shape and are therefore valuable in the old use, it is relatively difficult for conversion to occur. The high building values, then, seem to be holding land values down in this instance.[11]

One thing should be made clear—though the *plots* do not reveal clear land value gradients, *these gradients are nonetheless present in the Los Angeles market*. The plots are two-dimensional and do not include the very important amenity factor. When amenities are brought in, as they are in the regression equations, then a very strong negative relation is seen to exist between value and distance from the CBD. This illustrates the inadvisability of looking at simple cor-

[11] A question that has been raised is why the expectation of eventual conversion has not been capitalized into present land values in this particular area. The answer is, probably, that speculative builders who would be the likely candidates for the redevelopment of the area have very high discount rates; hence, expected returns discounted back over a fairly long period have a relatively low present value. The properties simply have a higher present value as residences to the present owners than in alternative uses to speculative builders.

relations between value and distance, and probably explain why Frieden found no rent gradients in Los Angeles.[12]

Conclusions

This paper was designed to present the findings of an empirical study dealing with the determinants of residential land values in an urban area. The value of any particular site is assumed to be related to its accessibility index, its amenity level, its topography, and certain historical factors including the way the land is being used. Serious measurement problems are encountered in dealing with these value determinants but they can be approximated by certain quantitative proxy variables. These surrogates are used to fit multiple regression equations to a sample of land values in Los Angeles County.

Accessibility to employment opportunities is positively related to residential land values. This relationship is sometimes swamped by the presence of low amenity levels near the primary work centers and is disturbed by the existence of satellite employment and shopping centers (e.g., Hollywood) located outside the CBD. Amenities are particularly difficult to measure and the most useful proxies vary from section to section depending on the characteristics of the area in question.

The fact that most of the independent variables are correlated with one another, in different degrees, makes it difficult to appraise the significance of the regression models. When the highest inter-correlations are removed, the regression coefficients are consistent with *a priori* expectations and exceed their standard errors by fairly wide margins. The coefficients are not stable from ray to ray and this suggests factors not included in the models are at work.

Several ways of improving the empirical results have been suggested by the analysis. First, it is fairly clear that the potential variable is a better proxy for the accessibility index than is distance to the CBD but the model generating the potential factor must take into consideration travel time between different points. In addition, the analysis area must be defined in sufficient breadth to prevent such problems as the accessibility understatement on Ray 3. Third, considerably more effort could be spent on the construction of a better proxy to the amenity index. The conceptual scheme for ranking areas by their relative amenity levels might be implemented by using real estate brokers who specialize in residential properties; these rankings might be used as the dependent variable and regressed against the quantitative factors thought to influence amenities. Fourth, the number or rays might be increased and cross-town rays sampled in order to increase the representativeness of the study. Finally, the study could be extended to other cities in order to gain insights about the way parameters change in cities of different sizes, with different rates of growth, and so on.

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[12] Bernard J. Frieden, "Locational Preferences in the Urban Housing Market," *Journal of the American Institute of Planners,* November 1961.