DECISION AGENT MODELS OF THE RESIDENTIAL DEVELOPMENT PROCESS-- A REVIEW OF RECENT RESEARCH*

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Overview

The spatial pattern of residential urban growth is the result of the residential development process, which is seen as a complex of decisions and actions by a multiplicity of individuals and groups, each guided by his own incentives. This research presentation focuses on the decisions, decision factors, and decision agents involved in the residential development process. In particular, the decision of the predevelopment landowner to sell or to hold his land, the decision of the residential developer to locate subdivisions, and the decision of the household to move and to choose another location are examined in detail.

In our conceptual model of the residential land development process, as shown in Figure 1, the landowner, developer, and household consumer are viewed as three key decision agents, with supporting roles provided by realtors, financiers, and public officials. Local public policies serve as a "guidance system" for shaping the development decisions of the key and supporting agents. In a second paper which follows, Raymond Burby will present a complementary research investigation in which the focus switches from private sector decisions to municipal policy outputs. These policy outputs are the instruments which guide the location of new urban development.

Analytical Framework, Empirical Analyses, and Operational Models

We see local public policy as an attempt to influence the residential evolution of land by affecting the basic decision factors. The important aspects of the public policy are its content, the differentiation of the application of this content to properties over space and time, and finally the expected variation in reactions of the different decision makers to the policy content. Figure 2 illustrates the relationships between the decisions, the decision factors, and the policy factors which provide a unifying analytical framework for the various models growing out of our team research efforts.

A major portion of this presentation will be devoted to empirical analyses and proposed operational models stemming from these analyses. The analyses and the models center on the relationships between residential development decisions (dependent variable) and site characteristics, decision agent characteristics, and contextual factors (independent variables). They are based primarily on the conceptual models and on data inputs from Greensboro and Winston-Salem, North Carolina. Kendall's Tau_c and discriminant analysis are the primary statistical techniques applied. A computer program version of SYMAP is used to map the analytic results and outputs of the developer (producer) model. An initial effort is also made to tie the models together in a linked system of decision agent models designed to simulate the residential development process and produce a spatial pattern of residential subdivision potential on the urban fringe. Work on the linked models is currently underway, and the empirical findings will be published later this year. Taking the models in order of the conceptualized land development process, we move to the predevelopment landowner as the first key decision agent.

The Decisions of the Predevelopment Landowner

The first step in new residential land development on the urban fringe is generally the sale of one or more parcels of rural or estate land. Our research to date suggests that data generall available in public records can be used to estimate the probability that a landowner will sell his land during a definite period in the future. A simple modeling approach, which appears feasible even for

FIGURE 1

THE RESIDENTIAL LAND DEVELOPMENT PROCESS: SEQUENCE OF STATES, KEY DECISIONS, DECISION FACTORS, AND LOCAL PUBLIC POLICIES

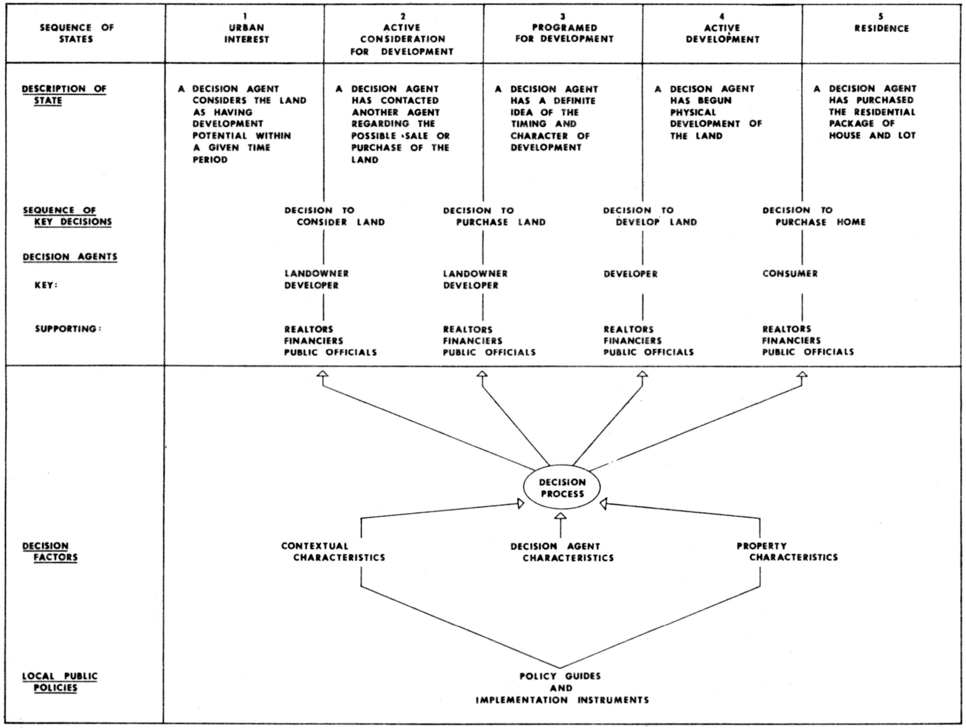


FIGURE 2

ELEMENTS IN THE RESIDENTIAL DEVELOPMENT PROCESS: AN ANALYTICAL FRAMEWORK

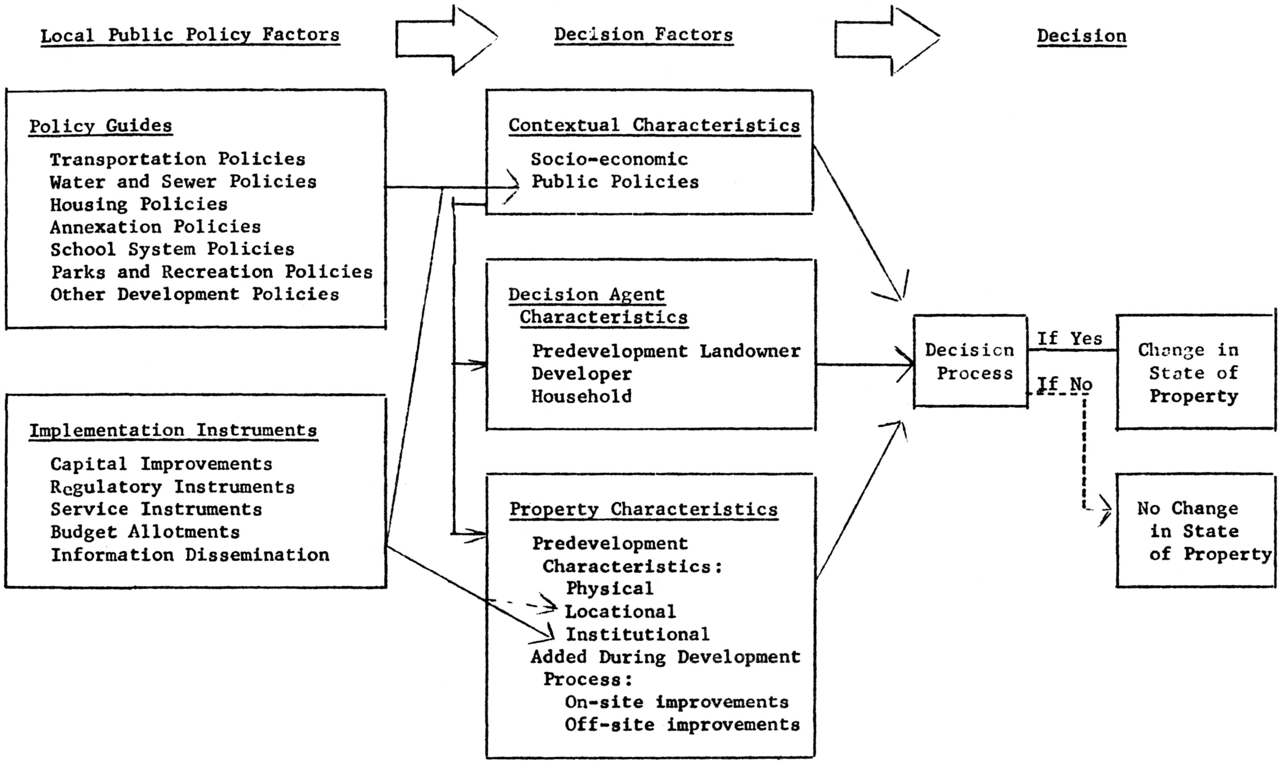
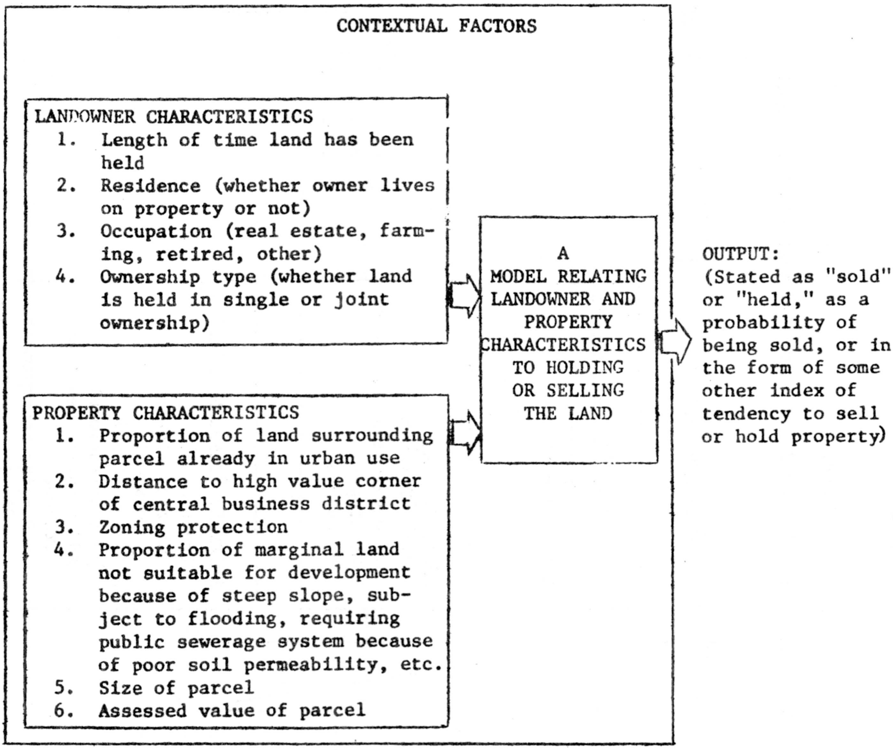


FIGURE 3

ELEMENTS IN THE LANDOWNER MODEL TO SELL OR HOLD LAND



users with limited resources, has been applied in the tests presented here.

The analytical framework for the landowner is delineated in Figure 3. It shows the main factors and relationships hypothesized to affect the landowner's decision to hold or to sell his property on the urban periphery. Within the macroenvironment of contextual factors there are three main elements in modeling the landowner's tendency to hold or to sell his property: (1) the characteristics describing the landowner that determine his reaction to pressures for sale; (2) property characteristics that affect not only the kind and degree of pressure to sell but also the ability of the land to supply monetary or psychic income to the landowner; and (3) the form of the model itself which consists of the relationships of the landowner and property characteristics as inputs and the "sold" or "held" classification of land as the output.

Using this initial conceptualization along with preliminary research to suggest the variables, an empirical analysis was performed on a random sample of 400 land parcels in two North Carolina cities: 200 cases in Greensboro (a city of approximately 133,000 population) and 200 in Winston-Salem (a city of approximately 140,000 population). The sample was restricted to parcels of land of at least five acres, within a 35,000-foot radius of the downtown high value corner, and not in urban use in 1956. The parcel was classified in the "sold" category if it was sold in the ten-year period, 1956-1966; otherwise it was placed in the "held" category. All data on the landowner characteristics were taken from public records in the county deed and tax offices. Other property data on zoning, accessibility, surrounding urban development, topography, and soil conditions are very similar to information commonly collected by planning agencies even though they may not be in public records.

The analyses indicate that, of the variables related to the landowner, the length of time he has held the land and whether or not he lives on the land are the more strongly associated with the tendency to sell. Occupation (retired vs. not retired) and ownership type (single or joint) are also significantly related to the tendency to sell. Least likely to sell are those living on the land, those who are not retired, those who own the land by themselves, and those who at the start of the study period had held the land longer than 10 years but less than 40 years. Most likely to sell are those who are absentee owners, those who are retired, those who own the land jointly, and those who have had their land either for a very short time or for a very long time.

Of the property characteristics, the amount of contiguous urban development is the only one strongly related to selling -- a parcel is more likely to be sold in a ten-year period if there is a substantial nearby urban development. The other property characteristics tested do not substantially affect sales activity. These statistical results are summarized in Table 1.

The multivariate analysis confirmed the relative importance of the list of landowner and property characteristics when they are considered as a group, as opposed to considering each one separately in the simple bivariate analysis. In addition, it showed that assessed value of the land made a relatively strong contribution to the ability to discriminate between "sold" and "held" parcels when used in combination with the other five independent variables even though it was not statistically significant in the bivariate analysis. The multivariate discriminant analysis has another important characteristic. Results can be expressed as a classification of each observation into either the "sold" or the "held" category based on the landowner and property characteristics used on the prediction side of the equation. This predicted classification can then be compared with the actual classification of each observation to obtain the number correctly classified (that is, predicted classification agreed with observation). In some programs the probability of misclassification can also be obtained.

Using the following six predictor variables:

1. Residence (on the land or not)
2. Occupation (retired vs. not retired)

TABLE 1

STATISTICAL ASSOCIATIONS BETWEEN "SOLD" VERSUS "HELD" BEHAVIOR AND LANDOWNER AND PROPERTY CHARACTERISTICS

Predictor Variables	Chi-square Level of Significance	Kendall's Tau_c Index of Association	Kendall's Tau_c Level of Significance
Landowner Characteristics			
Length of time land has been held	.001	.18	.001
Residence	.001	.19	.001
Occupation	.01	.17	.001
Ownership type	.05	.13	.001
Property Characteristics			
Proportion of land around the parcel which is already in urban development	.01	.13	.001
Distance to high value corner	NS	--	NS
Zoning protection	NS	--	NS
Proportion of marginal land in and around the parcel	NS	--	NS
Size of the parcel	NS	--	NS
Assessed value of the parcel	NS	--	NS

NS = Not significant at .05 level.

3. Ownership type (single or joint)
4. Length of time the parcel has been held
5. Amount of contiguous urban development
6. Land value (value per acre)

the procedure was able to classify 61.5 percent of the 400 observations in Greensboro and Winston-Salem correctly. The ability of a discriminant analysis to classify parcels correctly as either "sold" or "held" can be significantly changed when each of the two sample cities is calibrated separately. In the Greensboro subsample, the classification substantially improved over the total sample; on the other hand, the classification was not statistically significant for Winston-Salem. (See Table 2.)

TABLE 2

COMPARISON OF ABILITY TO CLASSIFY PARCELS CORRECTLY AS EITHER SOLD OR HELD FOR COMBINED AND SEPARATE SAMPLES

Sample	Sample Size	Percent Correctly Classified	Statistical Significance of F-test
Combined	400	61.5	.0001
Greensboro	200	74.5	.0001
Winston-Salem	200	61.5	NS

NS = Not significant at .05 level.

The analyses also indicate a tendency for landowner characteristics to be less important in their effect as one either moves toward the center from a ring around the edge of the urban area or as one moves outward from this ring. Table 3 shows the effect of dividing Greensboro into three separate concentric rings. The first ring consists of the area within four miles from the CBD high value corner; the second ring, from four to six miles; and the third ring, over six miles. The inner and outer rings have lower percentages correctly classified than the middle ring.

TABLE 3

PROPORTION OF SAMPLE CORRECTLY CLASSIFIED AS EITHER SOLD OR HELD IN EACH OF THREE CONCENTRIC RINGS IN GREENSBORO

Concentric Ring	Percent Correctly Classified	Statistical Significance of F-test
Less than 4 miles	60.0	NS
4 to 6 miles	84.8	.0001
Over 6 miles	74.1	.0001

NS = Not significant at .05 level.

The research reported above demonstrates the existence of statistically significant relationships between landowner and property data generally available to the planner and the tendency of landowners to sell or to hold their land. Further, the discriminant analysis has revealed that this relationship can be expressed in a way that is directly useful to planners, that is, "sold" vs. "held" classification of each parcel for which predictor data are available, instead of merely a statistical index. We believe that the development and use of this rather simple model are feasible in the many planning agencies and universities where appropriate data are available, including smaller agencies with limited resources. The index developed for Greensboro was able to classify correctly from 60 to 80 out of every 100 parcels for the test data on which it was calibrated. It should be noted that this still leaves a substantial number of misclassifications, and that there is no assurance that a model calibrated on a past 10-year period will be as successful for a future period. Nevertheless, the research suggests that a significant predictive capability may be possible.

The Developer's Locational Decision

Three decisions are described in Figure 1 above to carry the land from the state or urban interest to the state of being physically developed for residential use, state four. They will be considered as related subdecisions in one overall locational decision made by what we consider to be the key decision maker in these middle stages of land transition, e.g., the residential developer.

In general, a site may pass from the state of urban interest to the state of active consideration for residential development when any one of several agents assumes initiative to contact other agents regarding the possible sale of a tract of land for residential purposes and not merely for further holding in anticipation of capital gain. If the developer feels that a tract may generally fill the specifications for the market he is seeking to meet, or that there exists a potential demand for housing appropriate to a specific site called to his attention, and if he can obtain a tentative agreement from the landowner to sell, he then proceeds to the next decision stage in his locational decision process -- the land purchase decision. It represents an entrepreneurial locational commitment in the technical production process for manufacturing the new residential housing supply. When the developer decides to purchase a site, he generally is making a commitment not only to an investment in land but also to the much broader investment in a particular residential development which is to be produced on the site. The land purchase decision is crucial in the spatial pattern of conversion of the land to urban housing. The prior decision to consider the land is anticipatory to this decision; the latter decision to develop the land is anticlimactic to this decision, for the experience in our study area suggests that development typically follows within less than five years and probably in a form not much different from the development programmed at the time of purchase. Once the land is purchased it is again the developer who is the principal agent in deciding the rate at which the property holdings are to be converted to completed residential packages.

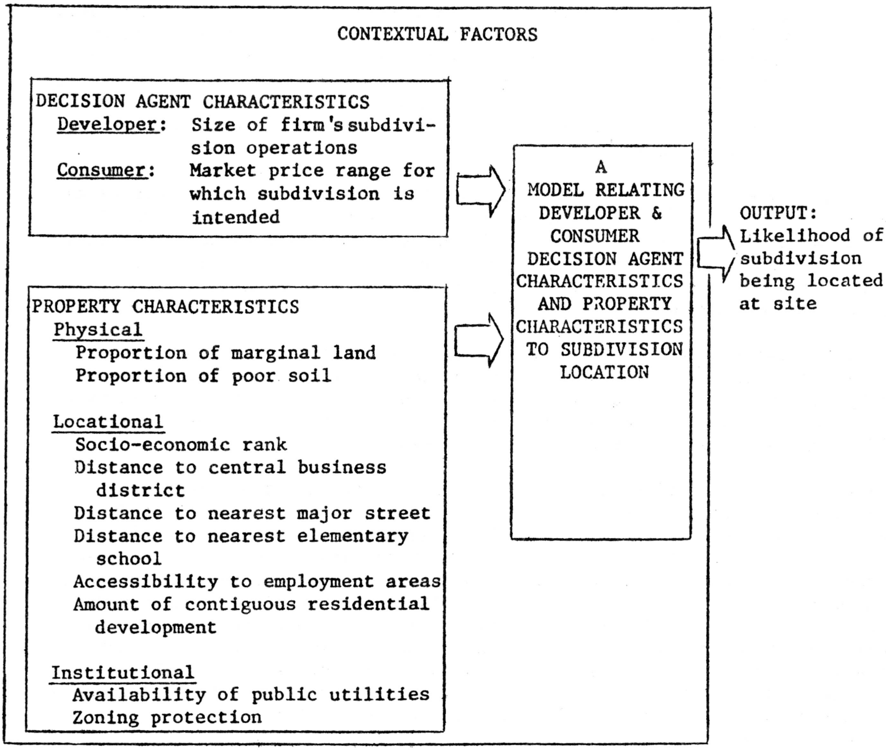
The analytical framework for the developer's locational decision is delineated in Figure 4. It is similar to the framework used in analyses of landowner's decisions to "hold" or "sell" land (see Figure 3 above). The empirical analysis is based on this conceptualization and uses the variables indicated therein. In the analyses the decision agent and contextual characteristics are considered as intervening variables. They are hypothesized to modify substantially the more basic association between property characteristics and subdivision location in some regular way but to remain nevertheless secondary to them in the model. The statistical associations between property characteristics and the location of subdivisions are classified by type of developer and market so that we can note whether and how these basic relationships change with (1) the consumer market for which the subdivision is intended, (2) the type of developer making the locational decisions, and/or (3) the change in contextual factors between two development areas.

The general suppositions examined are as follows:

(1) The spatial distribution of subdivision plats (representing the sample developers' location decisions) is associated with the

FIGURE 4

ELEMENTS IN THE DEVELOPER'S RESIDENTIAL
SUBDIVISION LOCATION DECISION



spatial distribution of site characteristics suggested by literature and in-depth interviews.

(2) The type of developer making the locational decision affects the associations. (This hypothesis is derived from the concept that the developer's selection of site characteristics will depend in part on his own operating characteristics, thereby leading to variation in locational behavior among different types of developers).

(3) The intended market for the subdivision will affect the associations with site characteristics. (This hypothesis is derived from the concept that the developer's decisions will depend in part upon his expectations of the market's residential preferences for those site characteristics which are also components of the output residential package, thereby leading to variation in location among different markets).

The sample was taken from the same two medium-size North Carolina cities as the landowner's sample, e.g., Greensboro and Winston-Salem. Also the same circular study area 35,000 feet in radius with the center being located at the high value corner of the downtown business district was delineated for each city. In each case, the study area covered not only the city limits but also substantial portions of the surrounding county.

The site characteristics and dependent variable were measured for a sample of small zones within the study areas. These zones, hereafter called cells, were created by superimposing a grid over the study area. Each cell in the grid is a square, 1,000 feet on each side and containing approximately 23 acres. There are 3,980 such cells in each of the two study areas.

The total sample consists of three subsamples utilizing two time periods in the Greensboro area (1958-60; 1961-63) and one in the Winston-Salem study area (1961-63). Each subsample included all the cells receiving subdivision within the three-year time period. For example, the Greensboro 1958-60 subsample included all of the cells in which developers filed subdivision plats in the County Courthouse between January1, 1958 and December 31, 1960. In addition, each subsample also includes a random sample of approximately 300 cells selected from the cells which were available to receive subdivision during the time period, but which did not actually receive any. Table 4 shows the number of cells in each subsample classified in each of the two categories: not receiving subdivision (hereafter referred to as "unsubdivided") or receiving subdivision (hereafter referred to as "subdivided").

TABLE 4

NUMBER OF CELLS IN EACH SUBSAMPLE CLASSIFIED AS EITHER SUBDIVIDED OR UNSUBDIVIDED

Subsample Description	Number of Cells Not Receiving Subdivision	Number of Cells Receiving Subdivision	Total Number of Cells in Subsample
Greensboro, 1958-60	289	281	570
Greensboro, 1961-63	296	233	529
Winston-Salem, 1961-63	298	175	473

A multivariate measurement was made on each cell to record the value of each independent variable (property characteristic) as well as the classification of the dependent variable (subdivided or unsubdivided).

The intervening factors are actually built into the measurement of the dependent variable. Thus each cell is not only classified as subdivided or unsubdivided but also as to whether:

(1) the intervening variable, market type, for which the subdivision is intended, is in the low or high price range (if subdivided):
low--average residential package less than $20,000
high--average residential package over $20,000

(2) the intervening variable, developer type, is small or large, i.e., whether the cell was subdivided by a large development firm (averaging over 100 lots per year in output) or by a small development firm (averaging less than 100 lots per year).

(3) the intervening variable, contextual factors, was associated with:
Greensboro in time period 1958-60,
Greensboro in time period 1961-63, or
Winston-Salem in time period 1961-63.

This way of measuring contextual variables is crude at best and yet it enables us to vary the context of residential development in terms of time period and city.

Ten independent or predictor variables were selected to represent the site characteristics hypothesized in the conceptual framework to influence locational decisions. The following is a list and short description of each:

Physical Characteristics

Proportion of marginal land: measures proportion of vacant land in the cell which is not suitable for residential building because it is subject to flooding, has poor drainage, or slope of 15 percent or greater (rounded down to tenths).

Proportion of poor soil: measures the proportion of vacant land in the cell which is not suitable for on-site sewage disposal due to poor permeability of the soil coupled with insufficient density standard (rounded down to tenths).

Locational Characteristics

Socio-economic rank of the location: an index based on occupation, education, income, and housing value census characteristics of the census tract in which the cell is located.

Distance to nearest major street: measured in tenths of a mile along street system to nearest access point on major street defined primarily as radials.

Distance to nearest elementary school: measured in tenths of a mile to nearest school within school district in which the cell is located.

Accessibility to employment opportunity areas: an index of distance weighted by employment size.

Distance to central business district: measured in tenths of a mile along most direct route.

Amount of contiguous residential development: the amount of already existing residential land use within the cell being measured plus the three most extensively developed adjacent cells.

Institutional Characteristics

Availability of public utilities and services: combined index of availability of water, sewer, fire and police protection.

Zoning protection: index based on protection from incompatible use provided by zoning ordinance.

Kendall's Tau_c (henceforth referred to simply as Kendall's Tau) is used as a univariate index of order-association between site characteristics and subdivision type. A stepwise discriminant analysis computer program is used in the multivariate analysis.

Site Characteristics and Subdivision Locations. -- Kendall's Tau indices were calculated to measure the relationship between individual site characteristics and occurrence of subdivision in a combined sample -- Greensboro, 1961-63 and Winston-Salem, 1961-63. Column one of Table 5 shows the results of these analyses.

The analyses indicate that the socio-economic rank of the site is the single site characteristic most able to distinguish the type of sites where subdivision occurs from the type of site where it does not occur. Level of zoning protection, distance to the nearest major street, and availability of public utilities are next most important. Subdivision is more likely to occur at locations of higher socio-economic rank, locations having higher level of zoning protection, locations having public utilities available, and locations slightly farther from arterial and other major roads. In addition, subdivision is also slightly positively related to access to the central business district and to proximity to existing residential development. These two relationships would simply suggest that development begets more development.

We would tentatively conclude that the influence of the locational characteristics is somewhat spotty and inconsistent compared to the institutional site characteristics. On the basis of these first analyses, we would conclude also that physical characteristics have the least influence on subdivision location.

Impact of Decision Agent Characteristics. — The effect of the intervening variables, subdivision price range and developer size, on the univariate statistical relationship between site characteristics and subdivision size can be examined in Table 5. Several general findings are immediately observable by comparing the first column to the other four columns. The indices in the first column, which describe the relationship of site characteristics to subdivision regardless of developer size or price range, are not as strong as the indices in the other four columns, each of which specifies either a developer type or a price range in describing the "subdivision" category of the "unsubdivided vs. subdivided" dependent variable. We tentatively conclude that the strength and even the direction of the relationship of site characteristics to subdivision location depends substantially on the decision agent characteristics associated with the subdivision -- on the type of developer making the locational decision and on the type of consumer implied by price range of the subdivision.

We can also compare the relative impact of developer type with that of price range by comparing Columns 2 and 3 (referring to developer size) to Columns 4 and 5 (referring to price range). It appears that the influence of site characteristics on location of subdivision is dependent more on developer size than on price range. This is true of both the locational and the institutional categories. The socio-economic rank of the location is the notable exception. Price range of the subdivision is strongly related to the socio-economic rank of the location; higher price range subdivisions are especially strongly attracted to locations having higher prestige as measured by the socio-economic variable.

Anticipating an attempt to build a spatial allocation model based on the developer's locational behavior, our examination of decision agent characteristics suggests than an attempt to preclassify subdivision by decision agent types may be helpful. Classification by developer size appears to help more in the spatial allocation problem than an attempt to preclassify by price range. Furthermore, comparing the indices of Column 2 with those of Column 3 of Table 5 suggests that large developers' locational decisions are not only substantially different from small developers', but are also more strongly related to a larger group of site characteristics, i.e., larger developers' locational decisions appear less random than those of smaller developers' in that they are more strongly and systematically associated with site characteristics.

TABLE 5

KENDALL'S TAU INDICES FOR EXAMINING THE EFFECT OF DEVELOPER SIZE AND PRICE RANGE (COMBINED SAMPLE OF WINSTON-SALEM, 1961-63 AND GREENSBORO, 1961-63)

Site Characteristics	Unsubdivided vs.: (1) Subdivided (any developer size, any price range)	(2) Small Developer Only	(3) Large Developer Only	(4) Low Price Only	(5) High Price Only
<u>Physical Characteristics</u>					
Proportion of marginal land	NS	NS	NS	NS	NS
Proportion of poor soil	NS	.06	NS	NS	NS
<u>Locational Characteristics</u>					
Socio-economic rank	.23	.15	.22	NS	.38
Distance to central business district	-.05	.12	-.24	-.12	.06
Distance to nearest major street	.14	.12	.10	.10	.18
Distance to nearest elementary school	NS	.13	-.12	NS	NS
Accessibility to employment areas	NS	-.10	.18	NS	NS
Amount of contiguous residential development	.09	NS	.19	.11	NS
<u>Institutional Characteristics</u>					
Availability of public utilities	.09	-.09	.27	.11	NS
Zoning protection	.18	NS	.31	.19	.09

NS = Not significant at .01 level.

TABLE 6

COMPARISON OF KENDALL'S TAU FOR THREE DIFFERENT SETS OF CONTEXTUAL FACTORS

Site Characteristics	Combined Sample: Winston-Salem and Greensboro	Winston-Salem 1961-63	Greensboro 1961-63	Greensboro 1958-60
Physical Characteristics				
Proportion of marginal land	NS	NS	NS	NS
Proportion of poor soil	NS	NS	NS	-.09
Locational Characteristics				
Socio-economic rank	.23	.19	.28	.17
Distance to central business district	-.05	NS	-.06	-.10
Distance to nearest major street	.14	NS	.21	NS
Distance to nearest elementary school	NS	.08	NS	-.19
Accessibility to employment areas	NS	.08	NS	.15
Amount of contiguous residential development	.09	NS	.14	.21
Institutional Characteristics				
Availability of public utilities	.09	NS	.16	.21
Zoning protection	.18	NS	.24	.16

NS = Not significant at .01 level.

Impact of Contextual Factors. -- We have hypothesized that contextual (macro-environmental) factors would affect the relationships between property characteristics and subdivision locations. In order to examine the effect of contextual factors we have analyzed Greensboro and Winston-Salem separately, on the rationale that individual urban areas are likely to exhibit different contextual factors. Similarly we have analyzed the two time periods in Greensboro separately on the rationale that contextual factors in the same city may vary over time. However, we hope to find less change within a city over time than we would find between cities within the same time period since our intention to develop an operational model assumes that a relationship calibrated over one period of time for a certain city will hold for a later period of time in the same city.

We found that the associations vary substantially between the two cities and somewhat less so but still significantly between time periods in the same city. The patterns of site characteristics associated with subdivisions are distinct for each city, with the exception of physical characteristics, which appear unimportant in both cities, and socio-economic rank, which is consistently strong in both cities. In most cases associations are stronger in Greensboro than in Winston-Salem (see Table 6). For institutional characteristics there is less difference between successive time periods in Greensboro than there is between cities. Associations in neither time period are consistently stronger than those in the other for the whole array of site characteristics.

Specifying the developer type or the price range, while comparing the two cities and the two time periods, which we did on some analyses not show here, reveals somewhat similar findings. Our tentative conclusion is that the differences found between cities and time periods are not the same for all developer types and price ranges. There appears to be "interaction" between the effects of contextual factors and the effects of decision agent characteristics. Not only does this provide evidence that contextual factors should be considered in operational modeling; it is also further supporting evidence that attempts to preclassify subdivision development by developer type and consumer market is desirable.

A model for forecasting the spatial distribution of developers' subdivision location decisions. -- Part of our analyses of the spatial distribution of single-family residential subdivisions involved the application of the statistical technique of discriminant analysis. Based on these analyses of developers' locational decisions and using the mathematical form of the discriminant function as a model form, we have developed a pilot version of a producer-oriented discriminant model. The inputs are property characteristic vectors representing a site and the output is the likelihood of the subdivision occurring on that site. This section of the paper reports results of some preliminary tests in the use of the model. Adequate assessment of the effectiveness of the discriminant model form using site characteristics as predictor variables would require more exhaustive tests in a variety of cities, using a variety of configurations for the zones described by site characteristics and several time-period lengths. However, until further experimentation can take place, the results of our preliminary testing at least begin to suggest the general range of the predictive capability of the model.

An *ex post facto* prediction method is followed. That is, the parameters of the model -- the coefficients in the discriminant functions -- are calibrated by a discriminant analysis performed on a time period in the past for which data are available, specifically, the 1958-60 time period. These parameters are then used in the model to predict the probability of residential subdivision for a sample of cells in another past time period, specifically the 1961-63 time period in Greensboro. This is done by using the coefficients calibrated on the 1958-60 data in the discriminant model applied to the 1961-63 time period. The model produces a probability for each outcome of the dependent classification for each observation in the 1961-63 sample and then selects the category having the highest probability as the predicted outcome.

The *ex post facto* test of the prediction is made by comparing the predicted

TABLE 7. COMPARISON OF PERCENTAGE OF SAMPLE CELLS CLASSIFIED CORRECTLY BY DISCRIMINANT ANALYSIS AS OPPOSED TO THE OPERATIONAL DISCRIMINANT MODEL

Prediction approaches	Unsubdivided vs. subdivided	Unsubdivided vs. Small developer subdivision	Unsubdivided vs. Large developer subdivisions	Unsubdivided vs. Low price subd.	Unsubdivided vs. Medium price subd.	Unsubdivided vs. High price subd.	Unsubdivided vs. Small developer subdivision low price	Unsubdivided vs. Small developer subdivision medium price	Unsubdivided vs. Small developer subdivision high price	Unsubdivided vs. Large developer subdivision low price	Unsubdivided vs. Large developer subdivision medium price	Unsubdivided vs. Large developer subdivision high price
Discriminant analysis 1958-60 time period sample	62.6	55.4	77.9	69.8	60.5	78.7	65.4	NS	74.6	80.5	80.7	92.7
Discriminant analysis of the 1961-63 time period sample	68.2	66.2	81.2	66.9	72.1	83.2	NS	64.7	78.2	85.7	80.2	92.4
Operational discriminant model applied to the 1961-63 time period sample using discriminant function coefficients calibrated on 1958-60 sample	64.7	51.7	76.0	66.3	51.9	81.9	64.0	NS	77.9	77.5	74.9	92.4

NS = no variable was statistically significant @ .05 level in the discriminant analysis.

outcome of each observation with the actually observed outcome and summarizing these comparisons in a contingency table. From these contingency tables the percentage of correctly classified (predicted) outcomes is calculated.

Table 7 shows the results of these calculations. It shows several *ex post facto* prediction approaches and displays them in a way that will allow us to make a preliminary evaluation of the predictive capacity of the model. The first two rows show percentage of cells classified correctly using discriminant analysis for the 1958-60 and for the 1961-63 period, respectively. These percentages result from discriminant models that were calibrated on the same set of data for which the "prediction" is made. These can be considered as a kind of standard. That is, the percentages in the first two rows can be compared with the percentages classified correctly in the third row which refers to the 1961-63 period prediction using the model calibrated on the 1958-60 data. The approach used to obtain the figures in Row 3 would be closer to the approach required in an actual predictive situation faced, for example, by an urban planner. By comparing these percentages to those of the second row, we may ascertain the loss in predictive ability that is due to using previously calibrated parameters instead of parameters calibrated on the actual 1961-63 data. We can also compare Row 3 to Row 1, i.e., we can compare the 1961-63 prediction using parameters calibrated on the 1958-60 data to the 1958-60 prediction using the parameters.

The table shows that the predictive capacity of the operational model in the 1961-63 time period using parameter coefficients calibrated in the 1958-60 sample ranged widely from a very unsatisfactory 51.7 percent for "small developer" subdivisions to a highly accurate 92.4 percent for the "large developer" subdivisions. This compares with the ranges of 55.4 to 92.7 percent and 66.2 to 92.4 percent in the 1958-60 and 1961-63 periods, respectively, when the model is used to predict for the same sample on which it was calibrated. Percentages correctly classified by the operational model in the 1961-63 period were consistently slightly lower than percentages obtained in the 1961-63 sample. But, they were sometimes higher than those obtained in the 1958-60 period. The fluctuation in predictive capacity from one dependent classification system to another is consistent through all three samples. For example, high price subdivisions and large developer subdivisions were more accurately classified than other types of subdivisions in all three approaches while small developer subdivisions were less accurately classified in all three approaches.

Figure 5 illustrates another means for comparing the model's prediction with the actual outcomes. It shows the actual location of zones receiving subdivision (regardless of developer type or price range) in the 1961-63 period in Greensboro superimposed on the contour map of probabilities for receiving subdivision forecasts by the operational model. The contour map is produced by a University of North Carolina version of the Harvard Computer Graphic Laboratory's SYMAP program. With the exception of the cells receiving subdivision in the eastern sector, which are Negro subdivisions limited to these less attractive locations, the distributionof actual subdivision activity tends to fall within the zones of higher probability. At the same time it can be seen that a great number of zones that received no subdivision also were tagged with relatively high probabilities.

Some qualifications. -- Of course, there are limitations to be considered in evaluating the results of the research. Concerning the analysis, there was some inconsistency between the observed associations and those expected on the basis of earlier interviews and the literature on the subject of residential location. Also, the sample was limited in geographic area to two North Carolina cities. Furthermore, less than ten developers were actually represented in the "large developer" category, although they accounted for a large number of subdivision decisions. A change in locational behavior of one or two or replacement of several of these decision makers could substantially change the spatial pattern of subdivisions because each such decision maker accounts for a relatively large proportion of that pattern. All of these factors would suggest that the results might very well change substantially if the analysis were done in other study areas. In other words, there is a greater than usual danger that the results of the analysis could

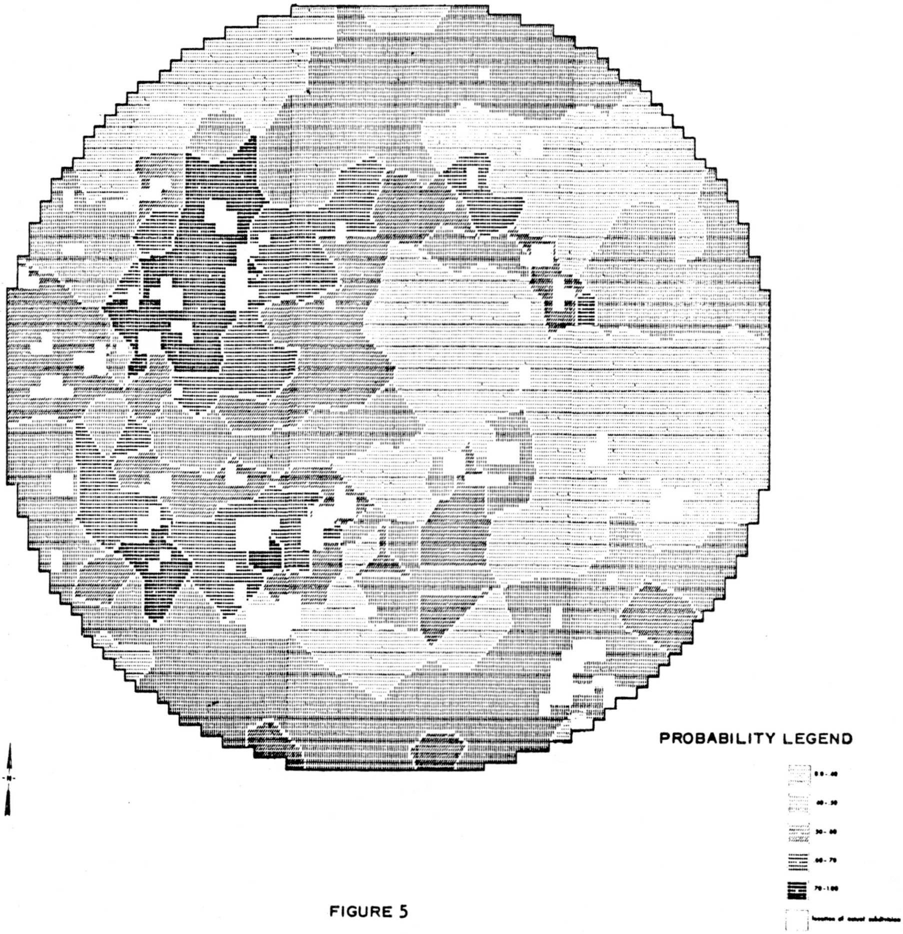


FIGURE 5

MAP SHOWING LOCATION OF ACTUAL SUBDIVISION OCCURRING IN THE 1961-63 PERIOD SUPERIMPOSED ON THE PROBABILITY PATTERN FORECAST BY THE MODEL reflect an unusual situation rather than the general situation. This does not invalidate the procedures, although it does suggest that further testing is certainly necessary.

The model itself also has important limitations. Several features make it a partial model as opposed to a comprehensive one. That is, it is very much biased to the developer's viewpoint and does not give a balanced view of the overall residential growth process. It also is limited in purpose to spatial distribution and casts no insights about the amount or quality of growth. And the output is thus far limited to likelihood distribution; it is not an allocation model in the sense that it will actually distribute a given number of acres or other units of subdivision. Further, the model is limited to one sector of the residential market -- new, single family, subdivision development. Thus it does not contribute to our understanding or prediction of other aspects of urban change--the rental and used housing stock, the decay of older housing stock, or the non-residential urban land uses. Further, the model is relatively short range and makes no provision for iteration as it is now programmed. It produces a forecast for one time period only and does not yet allow "growing" a city over a substantial length of time by utilizing feedback from earlier time period forecasts to affect later time periods and by exogenously updating of site characteristics between time periods. Lastly, the model is a classification model and not a performance model. That is, it is based on discriminant analysis which is designed to answer the question, "What group or subdivision type does this zone most closely resemble?" rather than the question, "How much subdivision is this zone likely to receive?"

The Consumer's Decisions

To this point we have been discussing the single-family residential subdivision production side of the housing market. In order to obtain a more complete understanding of the residential change we need to examine the other side of the urban growth process -- the consumer decision chain. In this section of the paper we want to describe our conceptualization of the decisions which lead a household or population of households to select a particular type of residence.

This conceptualization and the analyses used to examine it are based on a national survey of the residential preferences and moving behavior of 1,476 metropolitan households (Butler, Chapin, Hemmens, Kaiser, Stegman, and Weiss, 1968) and two smaller studies of the residential decision process, one of 29 households (Armiger, 1966) and the other of 180 households in Greensboro, North Carolina (Weiss, Kenney, and Steffens, 1966).

The moving process as we conceptualize it for purposes of analysis has two stages. The first is the decision to move out of the present place. This includes the decision about the type of move -- within the neighborhood, outside of the neighborhood but within the metropolitan area, or migration out of the area. The second stage is the selection of the new dwelling unit. In analyzing these two decisions, we will uitilize an analytical framework similar to the ones used above for the landowner and the developer (see Figure 6).

The decision to move. -- The more specific list of factors analyzed in the decision to move and the results of the analyses are enumerated in Table 8. The table shows that the life cycle indicators (age of head, family type, household size) consistently reported in the literature are significant, as are race and past moving behavior. Households planning to move tended to be larger, younger, full families with the eldest child under six, or nonwhite. They also tended to have moved more recently than those not planning on moving and to have migrated from out of state on the prior move or to have formed a new household. The three characteristics associated with employment that were examined, (socio-economic status of occupation, location of head's work place, and expectations about staying on at the present job) were weak.

Concerning attitudinal characteristics of households, Table 8 shows that households who are dissatisfied with their neighborhood or dwelling unit and those that have a higher social mobility commitment are most likely to move. Attitudes

FIGURE 6

ELEMENTS IN THE CONSUMER'S DECISION CHAIN FOR MOVING TO NEW HOUSEHOLD LOCATION

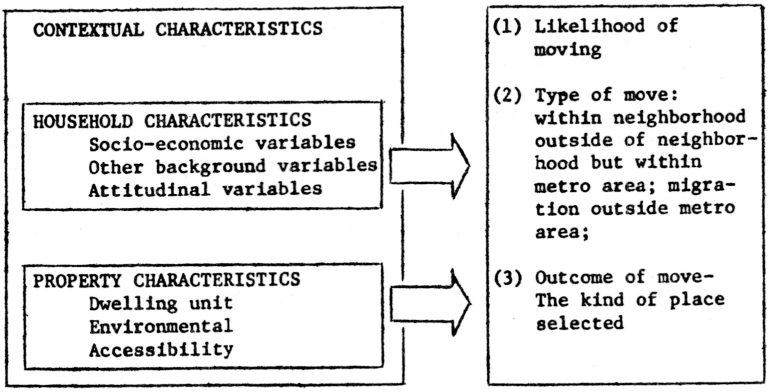


TABLE 8

PROSPECTIVE RESIDENTIAL MOBILITY*

Indicator Variables	Chi-square Level of Significance	Directionality: Mover Households Tend to be
Household Characteristics		
Socio-economic:		
household size	.02	larger
age of head	.001	younger
family type	.001	full families with young children
expectations about staying on job job	.05	heads expecting to leave job
employment-socio-economic status	NS	--
location of head's place of work	NS	--
length of residence in SMSA	.001	more recent movers
race	.001	nonwhites
location of household before last move	.01	outside state and no previous home
Attitudinal:		
satisfaction with housing, neighborhood	.001	dissatisfied
social mobility commitment	.001	high social mobility commitment
familism, urban-suburban orientation, neighboring, mental well-being, importance of neighborhood	NS	--
Residential Characteristics		
Tenure	.001	renters
Cost	NS	--
Dwelling unit quality (appearance, condition, etc.)	.001	living in worse housing
Neighborhood quality (appearance, noise, etc.)	.001	living in worse neighborhood
Location - central city or suburb	.001	living in central city
Accessibility to shopping, downtown, medical facilities, recreation, schools, churches	NS	--
Accessibility to head's place of	.001	living farther from work place

*Based on Butler, Chapin, Hemmens, Kaiser, Stegman, and Weiss, 1968, Chapter IV.

NS = Not significant at .05 level.

about family, consumership, urban-suburban orientation, neighboring, importance of the neighborhood in getting ahead, and mental well-being were not related to plans to move.

Some residential characteristics were related to plans to move, however. Those planning to move tended to be renters, those living in lower quality housing and in poorer quality neighborhoods, and those living in the central city. Prospective movers also tended to live farther from the head of household's work place. This was the only type of accessibility related to prospective mobility. Other types of accessibility measured, including accessibility to shopping, downtown, medical facilities, parks and playgrounds, school, and churches, were not related to prospective mobility. Neither was housing value.

Another dimension of residential mobility closely associated with the decision to move is the type of move in terms of distance: within the same neighborhood (approximately 28 percent were reported); outside the neighborhood but within the same metropolitan area (approximately 57 percent in this category); migratory or crossing metropolitan boundaries (approximately 15 percent). Not only is this an important dimension of residential mobility, closely associated with reasons for moving and the decision to move, but it is important also in our attempt to link the consumer's moving decision process to the housing production process. The type of move determines what proportion of households remains in the metropolitan and neighborhood markets for housing and what types they are likely to be. It will be important in later modeling efforts to be able to isolate intrametropolitan movers, who will enter a linking model to be allocated to the supply of housing, from migratory movers and intraneighborhood movers who may not need to be allocated.

Table 9 summarizes some of our analyses of respondent's most recent moves. Higher income households, white households, households who previously owned, households having a low familism attitude or a low evaluation of the importance of one's neighborhood in getting ahead, and those moving because of a job change are most likely to move across metropolitan boundaries. Nonwhite, low income, and rental households are the ones most likely to move within the same neighborhood.

The household's selection of a new dwelling. -- Table 10 summarizes some of our analyses of moving outcomes, i.e., the result of the consumer's selection of the new place. The most consistent household characteristics are race and income. Lower income households and nonwhite tend, more than others, to move shorter distances, locate in the central city, rent apartments, have fewer rooms, pay lower rent, or own cheaper housing. The poorest household characteristics for predicting the outcome of the move are age of head of household and the attitudinal indices of the familism, consumerism style, urban versus suburban orientation, social mobility commitment, and even a household's attitude about the importance of one's neighborhood for social mobility.

Residential experience, especially tenure, provides consistently strong relationships. Thus, not only are renters much more likely than owners to move, but they are also more likely to move shorter distances, to locations in the central city, to rent again, a smaller place, probably an apartment and to pay lower rents, or buy lower value homes. Other residential experience and household size were also good predictors for certain aspects of the dwelling unit; larger households and those who previously lived in larger places were more likely to move to larger places. Those who paid higher rent previously or owned more expensive places were more likely than their opposites to do so again. And those who rent were more likely to rent again than were owners, all as expected.

Another finding in the analyses of the national survey of households having implications for modeling in general and in particular for our attempts to link up with a producer model was the relatively weak role that accessibility played both in residential mobility and residential choice. Although distance to work was a factor in planned moves, no differences were noted between prospective

TABLE 9

HOUSEHOLD RESIDENCE CHARACTERISTICS AND TYPE OF MOVE: WITHIN NEIGHBORHOOD, WITHIN METROPOLITAN AREA, MIGRATION

Predictor Variables	Indices of Association: Kendall's Tau_c Index	Indices of Association: Kendall's Tau_c Significance Level	Indices of Association: Chi-Square Significance Level	Directionality: "Moves from Outside Metro Area Most likely Made by Households Who . . ."
Social Background				
Income	.18	.001	.001	higher income
Race	-.12	.001	.001	white
Household size	--	NS	.05	--
Age of head of household	-.04	.05	NS	--
Attitudinal				
Familism	.11	.001	.001	low familism attitude
Consumerism style	.04	.05	.05	low family consumerism
Social mobility commitment	-.04	.05	NS	high social mobility
Neighborhood contribution to social mobility	-.08	.001	NS	low neighborhood evaluation
Urban-suburban orientation	.05	.05	NS	suburban or mixed orientation
Immediately Previous Residential Character				
Tenure and dwelling unit type	.13	.001	.01	owned previous place
Move-Related				
Reasons for moving	not applicable		.001	job change or location-oriented move

NS = Not significant at .05 level.

TABLE 10

SUMMARY OF MOVING OUTCOMES RELATED TO HOUSEHOLD CHARACTERISTICS AND PREVIOUS RESIDENTIAL CHARACTER

Characteristic	OUTCOMES: Location: Central City or Not	OUTCOMES: Accessibility	OUTCOMES: Tenure & Housing Unit Type	OUTCOMES: No. of Rooms in Housing Unit	Housing Costs: Rent	Housing Costs: Value of Housing Unit
Household-Social Background						
Income	.40	.05	.31	.36	.45	.44
Race	.28	.16	.18	.15	.24	.13
Household size	NS	.11	.22	.36	.12	NS
Age of head of the household	NS	.05	.07	NS	.10	NS
Household-Attitudinal						
Familism	.06	.07	NS	NS	NS	NS
Consumerism style	NS	.08	NS	NS	NS	NS
Social mobility commitment	NS	NS	NS	NS	NS	NS
Neighborhood contribution to social mobility	NS	NS	.05*	NS	.10	.13
Urban-suburban orientation	.16	NS	NS	NS	NS	.11
Immediately Previous Residential Character						
Tenure and dwelling unit type	.27	NS	.36	.25	.08	.16
Previous rent	--	--	--	--	.48	.44
Value of previous place	--	--	--	--	--	.42
Number of rooms	--	--	--	.33	--	--

movers and stayers in regard to current accessibility to such services and amenities as grocery stores, shopping center, downtown, doctor's office, hospital or clinic, parks, playgrounds, and elementary schools. With respect to accessibilities of the residences selected after the move, whites obtained residences more accessible to services and employment than nonwhites, but there appeared to be very little differences in accessibility to work, services, and amenities between central city residents and suburbanites, rich and poor, or renters and owners. Nor was there evidence that households improved their accessibility as a result of the move.

Looking toward a consumer model. -- The analyses suggest the possibility of modeling the decision to move and the outcome of the move separately. This suggestion of separate models lies in our finding that household characteristics related to residential mobility appear to be different from those related to residential choice. Age of head of household and several social-psychological factors, for example, are significant indicators of mobility but appear to influence residential choice very little. Other variables, such as size of the household, influence the residential choice but not mobility. Some variables, such as race and tenure, are related to both mobility (decision to move) and to the characteristics of the outcome of the move (selection of a new place).

The residential mobility model would produce estimates of the numbers and types of household likely to move from zones defined within the market area. Census tract zones may be appropriate in size and census data may provide proxies for the predictor variables of age, race, family type, tenure, and residential quality of the environment (since households dissatisfied with their environment are more likely to move than satisfied households). Those mobile households who are not estimated to migrate out of the metropolitan area would be combined with estimates of in-migrants and newly formed households to comprise a pool of households which funnels through the residential choice model to be distributed among the units vacated by mobile households and the new units in subdivisions produced by the developer model. In a later refinement of the linked model system, the addition of a model representing the rental unit developer, the redeveloper, and the builder of homes on individual lots might be attempted.

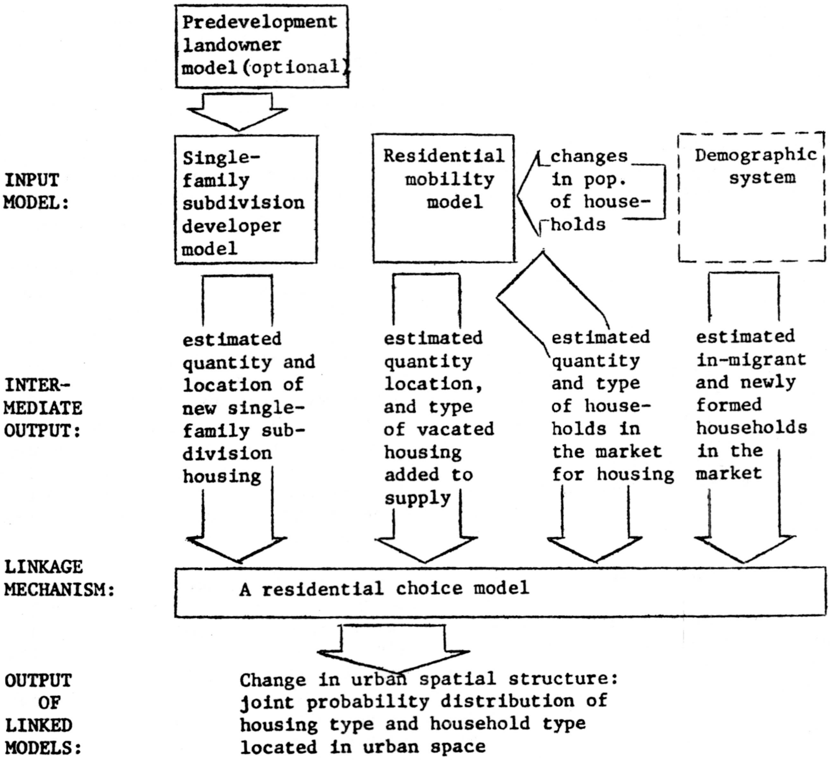
The findings relating to the relatively weak role of accessibility have implications for our efforts to link any housing production models with the household's mobility and residential choice models. First, a model based on these findings would probably differ substantially from many existing models in its deemphasis of accessibility as a determinant of residential location. Second, it implies that the output of the developer model should be described by characteristics additional to accessibility in order to be compatible with the residential choice model suggested by our consumer research. This will necessitate a new dimension being added to the developer model which currently emphasizes the locational decision. More specifically, since consumers seemed to be more concerned with the neighborhood and the dwelling unit than with accessibility, and since household characteristics were found to be related to such housing charactersitics as location in central city or suburb, tenure, number of rooms, and value or rent level but not accessibility, some of these additional housing characteristics will have to be incorporated in the description of output of the developer model in order to facilitate residential choice.

Summary -- Linked Models

A possible configuration of decision agent models is illustrated in Figure 7. The supply of new single-family subdivision housing units is created by the developer model, perhaps supplemented by a landowner model. The supply of vacated existing housing units might be created by the mobility model, since our analyses indicate that dwelling unit and neighborhood characteristics were related to mobility. The mobility model also estimates the intrametropolitan movers who along with estimated in-migrants and newly formed households provide the numbers and types of household seeking housing within the supply of new residential subdivisions, estimated by the developer model, and the vacated used housing, estimated by the mobility model. The residential choice model provides the basis for a linkage of the supply of and the demand for housing units. It provides the means to

FIGURE 7

A LINKED MODEL FOR
THE RESIDENTIAL DEVELOPMENT DECISION PROCESS



allocate housing supply to the households, or households to the supply of housing units. The resulting output describes the joint distribution of housing characteristics and household characteristics and their location in the urban spatial structure.

The total model is still in the first stage of construction, but the results of the already considerable work done on the separate parts are encouraging. The difficulties lie in making the several linked models compatible in input-output without weakening any one of them. If successful, it would provide a major step foward in modeling urban residential growth and signal the possibility of further linkage. By including a predevelopment landowner model, a redeveloper model, a rental unit model, a housing decay model, and also a nonresidential development model, we would be moving closer to a total system of models for simulating processes of spatial change in the urban environment.

FOOTNOTES

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