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by

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A TRANSPORTATION LAND USE MODEL FOR RURAL AREAS

This paper examines the interaction of transportation and land use in rural areas. The spatial distribution of employment and population is complicated by many factors such as accessibility, income variance, prices, geographical characteristics, and government intervention. This analysis attempts, by using two-stage least squares, to isolate the impact on employment and household density of changing transportation cost as measured by accessibility.

The report is divided as follows. The first section describes the conceptual problems involved in constructing a land use model for a rural area. The next section investigates the usefulness of past theories, and the third section examines applied modeling attempts for application in rural areas. Next the model is presented, followed by a description of the empirical results. The final section states some conclusions.

Problems

Economic analysis is often complex since everything seems to depend on everything else. This interdependence problem is especially important between transportation, land use, and the spatial structure of urban areas. As urban growth continues, journey-to-work trips increase. The evidence of decentralization is clear and the pace of suburbanization has accelerated in the past decade. This

trend has increased trip length for journeys to work by private automobile. In many cases, suburbanization has also created new transport demand. This interaction is clearly illustrated in Lowry's analysis of Pittsburgh, which will be discussed in the section dealing with theoretical models. Increases in transport efficiency are soon absorbed by more development of homes and employment. This interdependence has affected the analysis of transport problems. Mitchell and Rapkin (1954) pointed out that different types of land use generate different traffic flows. This changed the emphasis and forced engineers from analyses of flows to studies of location and land use. Thus, if residential density and the location and patterns of households and employment could be predicted, then it might be possible to forecast future volume of traffic using trip generation techniques such as gravity models. This approach is still unsatisfactory since it assumes transport flows dependent on land use. The interdependence, i.e., that transport also influences land use patterns, was finally appreciated in Wingo's (1961) study of transportation.

Given the difficulties associated with interdependence, there are still special problems with rural areas which present a unique set of problems. First of all, rural areas by their very nature have low levels of population and a correspondingly small number of households. Also, commuting distances to and from employment are either very short or inordinately long and time cost may be relatively low. Traffic congestion has

not usually been a serious problem in rural areas. All of this would suggest that the impact of a transportation change would be very small in magnitude. Whereas urban models can deal in a macro framework because of the magnitude of the numbers, rural models must deal with transportation impacts at a micro level. This means that rural models in general must be able to measure changes of a much smaller magnitude and must have a much greater level of sensitivity to achieve the same probability of a reliable forecast.

The second serious problem with rural models deals with data availability. The data sources for urban areas are numerous and in much more detail than for rural areas. Urban models, for example, can use the U. S. Census - Standard Metropolitan Statistical Data which can provide information at the tract or block level. The equivalent detail does not exist for rural areas. At best, one can use Census county or subcounty data with the assumption that aggregation bias is not serious enough to warrant nonuse. In summary, rural land use studies involving transportation require greater sensitivity at a micro level, but the data available may not be of sufficient disaggregation to allow the necessary empirical estimates.

Theoretical model development has come under the influence of varied disciplinary groups and technical specialists. This multidisciplinary approach has led to a variety of model structures. The author will not attempt to survey all possible relevant models, but will instead survey

a few major theoretical contributions that relate to the effects of transportation on land use.

Theoretical Models

Lowden Wingo's (1961) study focused on the way urban transportation cost affects land rent and the demand for residential land. The demand per household for residential land is a function of the rental value of land, assuming the elasticity of demand is constant. Following Von Thunen and Ricardian theories, Wingo assumes that marginal land at the outer limits of the city commands a zero rent, with land closer to the city having rent equal to the savings in transportation cost. Transportation cost is a function of distance and population. His model then uses an equilibrium relationship that equalizes the supply and demand of residential land for the urban area.

As discussed by Alonso (1964) and Mills (1972), Wingo assumes that land and commuting are the only goods and that all commuting costs are budgetary. This is because Wingo's classical equilibrium mechanism assumes that savings in transportation cost equals the rent on land. Alonso has shown that locational equilibrium exists when it is impossible to increase utility by any combination of location change and adjustment in goods and services consumed. Thus, other models which take account of non-budgetary commuting costs such as leisure foregone and other services may be superior approximations.

Alonso's study is a static model assuming a one dimensional and continuous urban space with the only dimension being distance from the city center. All employment and sales are assumed in the urban center.

Alonso develops a theory in which households consume goods, housing, and commuting distance. The prices of housing and the cost of commuting depend on distance. The household maximizes utility with respect to goods, housing, and distance, subject to a budget constraint which equates expenditures on goods, housing, and commuting cost to the income of the household. A bid curve for each utility level is derived from maximization conditions. Using a bid price curve and a function showing the market price of land at each distance, an equilibrium location is determined.

The same approach is used to develop a firm's bid price and locational equilibrium. Alonso then develops a theory of market equilibrium for urban land markets. Households or firms are placed a specified distance from the urban center based on the slope of their bid price curves. Those with greater slopes will be closer to the center.

Mills points out that Alonso's analysis breaks down because the assumptions are not sufficient to establish the conclusion. Different solutions can result depending, for example, on whether coalitions or perfect competition exist. The results discussed by Alonso's theoretical urban structure can be derived if one assumes the conditions of perfect competition.

Muth's (1969) study concentrates on housing markets with little emphasis on the location of non-housing activities. Muth assumes that households consume goods and housing services. Muth does not have transportation in the sector of possible goods, but includes leisure. The price of housing services is a function of distance whereas the cost of commuting is a function of distance and income. Households behave in a competitive fashion in that their purchases do not affect other prices. Households maximize utility subject to the constraint of prices, transportation cost, and income.

All employment is in the central business district (CBD); thus distance is measured from the city centers. Muth assumes that producers are competitive and employ the amounts of land and other inputs that maximize profits at each distance. The model also assumes that land not used for housing is used for transportation and other purposes.

Given a Cobb-Douglas production function for housing services with constant returns to scale, Muth arrives at a value of housing services which declines exponentially with distance. Assuming the price elasticity of demand for housing services is minus one and that expenditure on housing services is proportionate to the number of households, population or household density would also decline exponentially. A recent study by Kau and Lee (1976) has demonstrated that for many cities, the exponential function is an inappropriate functional form for describing the relationship between density and distance.

Lowry (1964) developed a model describing the spatial relationships for the Pittsburgh metropolitan area. The area is composed of 496 tracts divided into several retail, export, and housing sectors with land supply and employment in exports being exogenous.

Employment in any one of the retail sectors can be described by:

$$(1) \quad EMP_i^T = a(b \sum_j^n \frac{POP_j}{T_{ji}} + cEMP_i)$$

where

EMP_i^T = tract retail employment;

POP_j = population in tract j;

T_{ji} = a measure of transportation cost between j and i;

EMP_i = total retail employment; and

a, b, c = constants.

This equation relates to the gravity model approach which assumes, in this case, that retail shopping is proportional to population and inversely proportional to distance or distance squared.

Population in each tract is assumed to depend on access to employment,

$$(2) \quad POP_j = e \sum_i^n \frac{EMP_i}{T_{ji}} .$$

Thus population and employment are determined simultaneously. The basic framework of the Lowry model as described above has become the foundation of many applied simulation models. It would be redundant to discuss all these models in this study,

but reference will be made in the next section to a number of direct descendents of the Lowry model.

Applied Models

The BASS (1968) model integrates national and regional economic forecasts of employment and population with a land use assignment model to provide estimates of land use for six categories of residential use and for manufacturers, wholesaling, agricultural, commercial, and public use for two areas surrounding the San Francisco Bay. The BASS model is a set of integrated submodels for employment, population, and their location. The model makes predictions of future land use by five- and ten-year periods to the year 2020. The authors emphasize that the forecasts for various land absorption coefficients should, because of limited data, be regarded as probabilities rather than exact predictions.

Experiments with the BASS led to the development of the PLUM model [see Goldner (1968)] for land-use allocations and small zone forecasting. The gravity allocation equation was replaced by the logged reciprocal transformation which disaggregated into three types. The PLUM model allowed the more complete simulation of trips, and various parameters such as population were adjusted through time in conformity with forecasts of employment and population.

Putnam (1975) (1973) has further developed the PLUM model into an Integrated Transportation and Land Use Model Package called ITLUP. This model attempts to incorporate the principal reciprocal relationships between land use and

transportation. The model was developed to investigate the feasibility of balanced development of land use and transportation facilities.

The ITLUP model uses base year estimates of the spatial distributions of activity and transportation network from the PLUM model to generate estimates of trips in the given study area. Future network characteristics and base year data are then used to generate a spatial distribution for the projection year. This results in a new estimate of trips which in turn are inputted into the transportation network. The newly generated network is then used to project spatial distribution of activities. Iterations continue until equilibrium is reached. The Putnam model (1976) is a useful and successful attempt to integrate transportation and land use modeling.

The Regional and Urban Studies Subregion Land Use Model developed at Oak Ridge (1974) National Laboratory is a simulation model which allocates regional population and employment to subregions based on relative subregional attractiveness. Mathematical formulations are used to compute indices of attractiveness. In general the model is deterministic but has a stochastic algorithm for the generation of individual manufacturing plants. The model is designed to be transportable and is structured to provide feedback to the operator. The model requires a rather extensive data base which may be a hindrance for future use in other locations.

The above review was not meant to be comprehensive. A selected number of applied models were briefly described

to give the reader a basis of comparison. For a more comprehensive review, see Batty (1972), Boyce, et al., (1970), Brown, et. al., (1972), Goldner (1971), Harris (1968), Lee (1973), and Sweet (1962).

The Theoretical Model

Previous studies of the interactions of a transportation system and household formation have been referred to earlier. This section describes the model used in this study to predict future land use under various transportation scenarios.

Individuals in both urban and rural areas make a fixed number of trips to and from their place of work and to some sort of business center. The business center may be a metropolitan center or a rural general store. It must be remembered that a large percentage of the rural population in the U. S. is non-farm. The percentage of the U. S. rural population engaged in non-farm employment has grown from 28.1% in 1820 to 77% in 1960. It will be later suggested and explained that the growth of non-farm population (ruralization) is partly the function of reduced transportation cost between rural and urban areas.

A change in highway routes, such as a newly constructed freeway through a rural area, could dramatically change the transport cost of the residents. The question, then, that needs to be answered is: What are the effects of changing transport cost in rural areas? Following Muth and others, we could argue that the price of housing would be a function of distance from employment in urban areas if we hold constant

the effects of other amenities in the area. How, then, does changing, i.e., reducing, the transport cost affect the price-distance relationship of housing? An exogenous decrease in the cost of transport decreases the cost incurred in living in any given location, thus affecting both the consumption and location of housing.

Transport costs are functions of distance and wage rates. The wage rate reflects the value of an individual's time in transit. Each urban or rural resident incurs some positive transportation cost and, therefore, must make a choice of residential location between the competing claimants of place-of-work, environmental amenities, and urban areas. Once an optimal location is chosen, any change in transportation cost between these competing claimants will change residential location.

Reduced transport cost produces an increase in real income which affects locational changes in housing. Both the direct reduction of transport cost and the indirect effect on income may have the effect of shifting the new household equilibrium further from the main center of employment along transit routes.

A second impact of reduced transportation cost is upon local residents in an isolated rural area. The effect of the changing transport cost on individuals employed in rural locations is not so clear. Some of the rural labor force will now find it to their advantage to commute to the urban center because of the reduced transport cost. If we assume that the cost of living in rural compared to urban areas is lower, then

we might expect lower wage rates for rural workers. If we assume that the net effect of changing transport cost is a movement of urban dwellers to rural areas, then the new urban settlers will bid away the land and residential homes from the local inhabitants, forcing them to move further away from the newly formed transit route.

The theory suggests that transit systems have little effect on rural areas except where the system increases the interaction between the urban centers and the rural areas in question. For example, reducing transport cost to rural areas would increase the demand for land by urban dwellers for second homes and for recreation sites. Also, given an adequate supply of labor, there would be a tendency for manufacturing firms which are sensitive to transportation cost or which are transport cost neutral but sensitive to land cost to move further from urban areas with the introduction of new transit systems. Both of these events would have the effect of increasing density in rural areas. However, it is important to be able to isolate the effects of changing per capita incomes and population from the effects of transportation cost on rural densities. This separation is important because rising incomes and increased population have had a direct and significant impact on the demand for rural land. The next section deals with the problem of isolating the separate effects of various parameters by the use of multiple regression.

Transportation and Land Use Planning

The theoretical framework of this study assumes that locational choice is the result of the desire to maximize utility subject to the specific constraints of accessibility, income, and prices. The model suggests that many factors complicate this pattern, such as the locational equilibrium of urban workers and households, the spatial distribution of employment, and factors associated with locational tastes and preferences.

The basic data incorporated into this study are taken from the 1970 Census data for the 159 counties of Georgia and from a Delphy study by Davis (1974). Simultaneous equations are used to reduce the bias which might result from treating certain explanatory variables as independent in conventional least-squares regressions when, in fact, they are jointly determined. Therefore, two-stage least-squares regression equations with population density (POP), household density (HSD), employment density (EMP), percentage of single family dwellings (PSF), and mean income (INC) as the dependent variables are used to determine structural relationships.

One might argue that selected explanatory variables included in the analysis, POP, HSD, EMP, PSF, and INC, are jointly determined. The first three variables are obviously interrelated since the distribution of population exerts a strong influence on the distribution of employment because employers reduce labor costs by locating close to workers. The percentage of single family dwellings (PSF) is a function

not only of population and household density but also of income. Therefore, it is a jointly determined variable. Income is obviously jointly determined with the other variables, such as employment.

Two-stage least-squares techniques are used to adjust for the existence of interdependence of the variables [see Johnson (1963)]. In this method of estimation, conventional least-squares regressions for each of the variables on the right hand side of a particular regression equation, which are treated as endogenous, are run on all the predetermined or exogenous variables in the equation system. Calculated values for the endogenous variables are obtained from these regressions. In the second stage, a conventional least-squares regression using the observed values of each of the exogenous variables on the left hand side of the equation is run on the calculated values of the endogenous variables from the first stage regressions and on the observed values of the exogenous variables appearing in the particular equation. If the equation is correctly specified, the coefficients obtained in the usual way from this second stage calculation are consistent estimators of the unknown true regression coefficients and are normally distributed in large samples.

The Data

Transport costs are difficult to measure directly, hence miles of road per square mile (MRA) for each county and the number of cars per capita (CPA) are used as proxy variables for intra-county transport cost. It is hypothesized that

where the costs of private automobile transport are low, especially if income is held constant, relatively more people will own autos. An increase in MRA will reduce transport cost and lead to higher densities and more autos. Therefore, the relationship between CPA, MRA, and population and employment density is positive. An empirical analysis may give possible insight into the magnitude of this relationship.

A population potential type model based upon a summation of the time required to travel to each of the other counties is used to measure accessibility. Most accessibility formulations have been based upon some measure of population, employment, or activity, weighted by distance or travel time [see Carruthers (1956)].

The formula used to calculate the accessibility for each county is:

$$(3) \quad ACC_j = \sum_{i=1}^{n} \frac{P_i}{T_{ij}}$$

where

j = the county for which the accessibility is being calculated;

$i = 1,\ldots,n$, i.e., all other counties;

P_i = population for county i;

T_{ij} = the travel time between counties i and j; and

n = 159 counties.

The proportion of the county's growth that took place since 1920 (GPOP) is an additional characteristic which might be related to transport cost and is included in the analysis

of population density. Counties and cities in areas which have developed after the introduction of the automobile generally have wider streets, more parking facilities, and are better suited to auto transport. Also, counties which have grown more rapidly since 1920 should be more nearly adjusted to modern auto transport. In Georgia, most of the growth has occurred since 1920 and a large portion of the counties are rural; therefore, the rapid growth since 1920 will probably lead to increasing densities.

An increasing income or a higher relative income in a county reflects employment opportunities, which would increase in-migration to the county. Therefore, income should be positively related to household, employment, and population density.

The prices consumers are willing to pay for housing and thei· locational choice ıre influenced by tastes and preferences. Consumers should be less willing to live in a county where a relatively high proportion of the dwelling units are substandard, since consumers have an inversion to living near such residences. Therefore, an amenity variable, the proportion of substandard dwelling units (SUB), is included in this analysis.

The percent urban population (URB) is used to reflect both employment and higher income opportunities that might not have been captured by the other variables and is expected to be positively related to the density variable.

Retail sales (RS) and total sales (TS, excludes retail sales) are used to measure consumer and industrial demand

for a given county. This would capture any cross-county movement by buyers thus reducing the problem of income being by place of residence.

The general structure of the reduced form equations is:

Dependent (endogenous) variable = f(MRA, GPOP, ACC, CPA, OR, TS, URB, RS, I, SUB).

The regression equations described above can be used to produce a predictive model. The coefficients of the variables give a specified correspondence between the determined and predetermined variables. If any of the values of the independent variables are changed, the effect of that change on the dependent variable can be measured. For example, assume that the dependent variable is housing density (HSD). If the coefficient of the ACC variable is a positive .82, the introduction of a transit system which increases the ACC value by 5% would result in a 4.1% increase in housing density. In this way, we can predict the effect of accessibility (ACC) on all the dependent variables, POP, EMP, HSD, PSF, and INC. We can in the same manner predict the effect of changes in incomes, employment, population, or housing preferences. It is important to note that the reduced form equations, not the final structural equations, are used for predicting the impact of changes in accessibility.

The predictive impact of a change in transportation mode, such as a new highway, is accomplished by using the

regression coefficient of the accessibility variable from the reduced-form equation of a two-stage model. The predictive reduced-form equations are presented in Table 1. These equations give the final demand impact of each of the exogenous variables on each of the endogenous variables. The corrected R^2 ($\bar{R}^2$) for population density (POP), household density (HSD), employment density (EMP), percent single family (PSF), and mean income (INC) are shown in Table 1. The $\bar{R}^2$ measures indicate that the system has rather good predictive power for the POP, HSD, and INC equations but poorer predictive power for the EMP and PSF equations. The accessibility variable is significant in all cases and, as expected, negative in the PSF equation. A one percent increase in accessibility is associated with approximately a one-half percent increase in population, employment, and household density and with a .04 percent increase in income. The same increase leads to a .3 percent decrease in single family dwellings, reflecting the fact that higher densities are associated with more multi-family dwellings.

The structural relationships of the variables represented in Table 1 are determined from data for the 159 counties in Georgia. For this study, the impact of a change in transportation mode is restricted to the effect of an improved highway in a 17-county area in Northeast Georgia. The impact of this improved highway is calculated by estimating the resulting new time-distance matrix and then computing a revised accessibility index for each county. This revised measure, which takes into account the recently improved highway, is then compared with

TABLE 1

Two-Stage Regressions for Population, Employment, Households, Single Family Dwellings and Income: Reduced Form Equations for 1970.

All Variables Are Logged

1. $$\text{POP} = -3.749 + \underset{(5.83)}{.534}\ \text{MRA} + \underset{(4.68)}{.087}\ \text{GPOP} + \underset{(9.46)}{.484}\ \text{CPA} - \underset{(-4.61)}{.396}\ \text{OR}$$
$$+ \underset{(1.39)}{.042}\ \text{URB} + \underset{(0.17)}{.015}\ \text{RS} - \underset{(-0.54)}{.646}\ \text{TS} - \underset{(-3.48)}{.453}\ \text{SUB} + \underset{(3.46)}{.462}\ \text{ACC}$$
$$\bar{R}^2 = .91$$

2. $$\text{EMP} = 4.670 + \underset{(3.12)}{.686}\ \text{MRA} + \underset{(2.27)}{.101}\ \text{GPOP} + \underset{(0.33)}{.041}\ \text{CPA} - \underset{(-4.72)}{.963}\ \text{OR}$$
$$- \underset{(-1.40)}{.100}\ \text{URB} + \underset{(1.41)}{.311}\ \text{RS} + \underset{(0.60)}{.170}\ \text{TS} - \underset{(-4.31)}{1.343}\ \text{SUB} + \underset{(1.45)}{.463}\ \text{ACC}$$
$$\bar{R}^2 = .68$$

3. $$\text{HSD} = -5.538 + \underset{(7.30)}{.674}\ \text{MRA} + \underset{(4.49)}{.084}\ \text{GPOP} + \underset{(8.51)}{.439}\ \text{CPA} - \underset{(-3.07)}{.263}\ \text{OR}$$
$$+ \underset{(1.86)}{.056}\ \text{URB} + \underset{(1.73)}{.161}\ \text{RS} - \underset{(-0.62)}{.073}\ \text{TS} - \underset{(-2\ 47)}{.323}\ \text{SUB} + \underset{(3.75)}{.504}\ \text{ACC}$$
$$\bar{R}^2 = .91$$

4. $$\text{PSF} = 4.420 + \underset{(2.91)}{.117}\ \text{MRA} - \underset{(-1.60)}{.130}\ \text{GPOP} - \underset{(-3.65)}{.821}\ \text{CPA} + \underset{(2.89)}{.108}\ \text{OR}$$
$$- \underset{(-0.89)}{.118}\ \text{URB} + \underset{(1.41)}{.057}\ \text{RS} - \underset{(-1.81)}{.094}\ \text{TS} - \underset{(-2.68)}{.153}\ \text{SUB} - \underset{(-5.61)}{.329}\ \text{ACC}$$
$$\bar{R}^2 = .51$$

5. $$\text{INC} = 9.646 - \underset{(-1.92)}{.041}\ \text{MRA} - \underset{(-3.14)}{.137}\ \text{GPOP} + \underset{(1.98)}{.237}\ \text{CPA} - \underset{(-1.07)}{.213}\ \text{OR}$$
$$+ \underset{(0.12)}{.009}\ \text{URB} - \underset{(-0.21)}{.005}\ \text{RS} + \underset{(0.39)}{.011}\ \text{TS} - \underset{(-15.89)}{.485}\ \text{SUB} + \underset{(1.45)}{.045}\ \text{ACC}$$
$$\bar{R}^2 = .90$$

TABLE 2

Population, Employment, and Housing Forecasts

in the 3-County Georgia Test Area Under

Three Transportation Assumptions

County	Variable	1970	1980a	1980b	1980c	1990a	1990b	1990c
CLARKE	Population	65,177	81,927	80,466	86,773	97,440	93,764	109,309
	Employment	25,386	33,138	32,547	35,103	41,201	39,744	48,974
	Single	11,716	13,614	13,785	13,047	15,556	15,949	14,287
	Multi	6,744	9,368	8,750	11,418	11,587	10,148	16,473
	Total*	20,554	26,538	26,022	28,251	31,746	30,524	35,9[illegible]7
MORGAN	Population	9,904	10,439	10,416	10,574	11,460	11,419	11,972
	Employment	3,550	3,816	3,808	3,865	4,054	4,038	4,244
	Single	2,629	2,999	3,004	2,972	3,405	3,416	3,294
	Multi	191	264	271	337	423	417	730
	Total*	3,020	3,520	2,512	3,570	4,147	4,196	4,360

TABLE 2 (Continued)

County	Variable	1970	1980a	1980b	1980c	1990a	1990b	1990c
OCONEE	Population	7,917	9,862	9,761	10,193	11,545	11,309	12,332
	Employment	3,010	3,588	3,551	3,709	3,856	3,777	4,120
	Single	1,956	2,575	2,593	2,514	3,308	3,355	3,154
	Multi	80	195	146	357	373	244	801
	Total*	2,607	3,489	3,450	3,617	4,607	4,505	4,951

*Total = Total households including trailers.

Assumptions: a - Current level of accessibility maintained.

b - Decreased accessibility due to increased congestion on existing facilities.

c - Increased accessibility due to the improvement of an existing highway facility.

Note: The differences between 1980a and 1980b and between 1990a and 1990b for three of the counties were significant because those counties would be directly influenced by the hypothesized improved highway facility. The impact for the other fourteen counties was relatively insignificant. The predictions in Table 2 are point estimates within a confidence interval computed from the standard error of the accessibility variable for each equation. As such they should not be taken as exact predictions

the assumed constant accessibility for each of the 17 Georgia counties. An accessibility measure is also computed which assumes a deteriorating highway condition resulting from increased congestion. The percentage differences for both the improved and the deteriorating transportation system are derived for each county and is available from the author.

The estimated percentage changes in accessibility are multiplied by the regression coefficients for accessibility from the reduced-form equations in Table 1 to derive estimates of changes in the dependent variables.[1]

Using cross-section estimates, the Census data provide coefficients for accessibility at specific points in time; however, cross-section regression analysis does not provide estimated future values for the dependent variables. Projected values for the dependent variables population, employment, households, and single family dwellings for 1980 and 1990 are taken from the Davis' Delphi study (1974). Simple trend projections and the Delphi estimates conform very closely, except for housing which has experienced a dramatic shift toward multi-family dwellings in recent years. The trend projection gives much larger estimates for single family dwellings in 1980 and 1990. It is the opinion of this author that the trend technique overestimates the future growth of housing since it is based on the growth that occurred between 1950 and 1970. The Delphi technique may be a conservative estimate since the survey was taken during the depressed housing market years of 1974 and 1975. In any case, the purpose of this study is to provide a technique to measure

the impact of transportation on land use. The technique developed can be used with any type of projection procedure.

Table 2 presents the projected impact of the changed transportation system for population, employment, households, and single family dwellings for 1980 and 1990 for 3 of the 17 county study area. The revised estimated forecasts for 1980 and 1990 are based on the projected changes in accessibility and on the accessibility regression coefficients. Two projections are presented for both 1980 and 1990, assuming first a deteriorating highway condition and second the introduction of an improved intrastate highway.

Table 2 demonstrates that for three counties out of seventeen, Clarke, Morgan, and Oconee, the projected changes in accessibility resulting from the improved highway facility significantly influence the relevant socioeconomic variables as hypothesized. The greatest change occurs for Clarke County, which is the urban center for the area being considered and the county most directly influenced by the improved intrastate highway. The impact for the other 14 counties was insignificant and therefore not presented. The results for all counties are available from the author.

Conclusions

This portion of the study was undertaken to develop a technique to measure the impact of changes in transportation systems via measurements of changes in accessibility on various socioeconomic variables. Regression analysis was used to isolate the effects of specified economic and demographic

variables. Once these factors had been identified, the variance of the endogenous (dependent) variables resulting from a change in the transportation system was isolated.

The results indicate that the accessibility measure used in this study is a sensitive transmitter of changes in a transportation system. The accessibility coefficient derived from a reduced-form equation was used to forecast the impact of a transportation change. Using the reduced-form equations of a two-stage regression model provided a forecast of highway change impacts.

Preliminary results of this study suggest two changes in the analytical framework. The first is to construct a three-stage regression model which would provide a fully simultaneous system. The second is to modify the accessibility measure by investigating alternative functional forms. Both of these changes should add significant refinement to the model.

Footnotes

[1]The variables in the reduced-form equations presented in Table 1 are proxies of theoretical perceived variables such as transportation cost. This is partly the results of limited data availability in rural areas and partly because of limited data sources in general. Some of the variables have significant levels of correlation but none of the independent variables are significantly correlated with the accessibility variable thus reducing the possibility of serious multicollinearity involving accessibility. The possible existence of multicollinearity among the other variables does not significantly affect the bias or efficiency of the accessibility variable which is our major concern.

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