Predicting Transportation Impact in Northeast Georgia

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The Georgia Transportation Planning Land Use Model was designed to emphasize (a) the flexibility of estimating changes in key socioeconomic variables, (b) the use of explicit judgmental intervention in the modeling process, and (c) the key role of the model user in developing and implementing models. This paper describes the general structure of the model and summarizes the implementation of an experimental model for a 17-county test area in north Georgia. The socioeconomic data were collected for 159 counties in Georgia from 1950 to 1970. These data provided the empirical basis for a two-stage, multiple regression analysis that was designed to measure the specific influence of changes in accessibility on economic development. The influence of a proposed highway improvement program on future development and land use was assessed for the 17-county test area. The results from testing the model indicate that, if we are able to predict changes in accessibility that result from highway improvements, then with some confidence we can predict changes in population, employment, housing densities, and incomes. Estimated changes in these key socioeconomic variables can be translated into estimates of land that will be required for future development. This estimate can be made under any set of public constraints hypothesized. A technique for using the model in the transportation decision process is presented.

Current applications of modeling techniques for land use are designed to capitalize on the advantages associated with a computer-oriented technique and to avoid some of the major disadvantages identified with earlier modeling efforts. As shown in Figure 1, the Georgia Transportation Planning Land Use Model has three distinguishing features:

1. Alternative approaches are used for estimating the key exogenous variables as well as for the locational assignment algorithms,
2. Judgment by the model user is explicitly provided for at key junctures in the modeling process, and
3. The model user assumes an important participating role in model planning, development testing, and implementation.

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The state employment and population forecasts are integrated with national forecasts through the use of the shift-share technique and of econometric and input-output models that are made available to the state of Georgia. The output of these models is judgmentally compared with employment and population estimates made by the U.S. government and other agencies and by the Georgia Office of Planning and Budget.

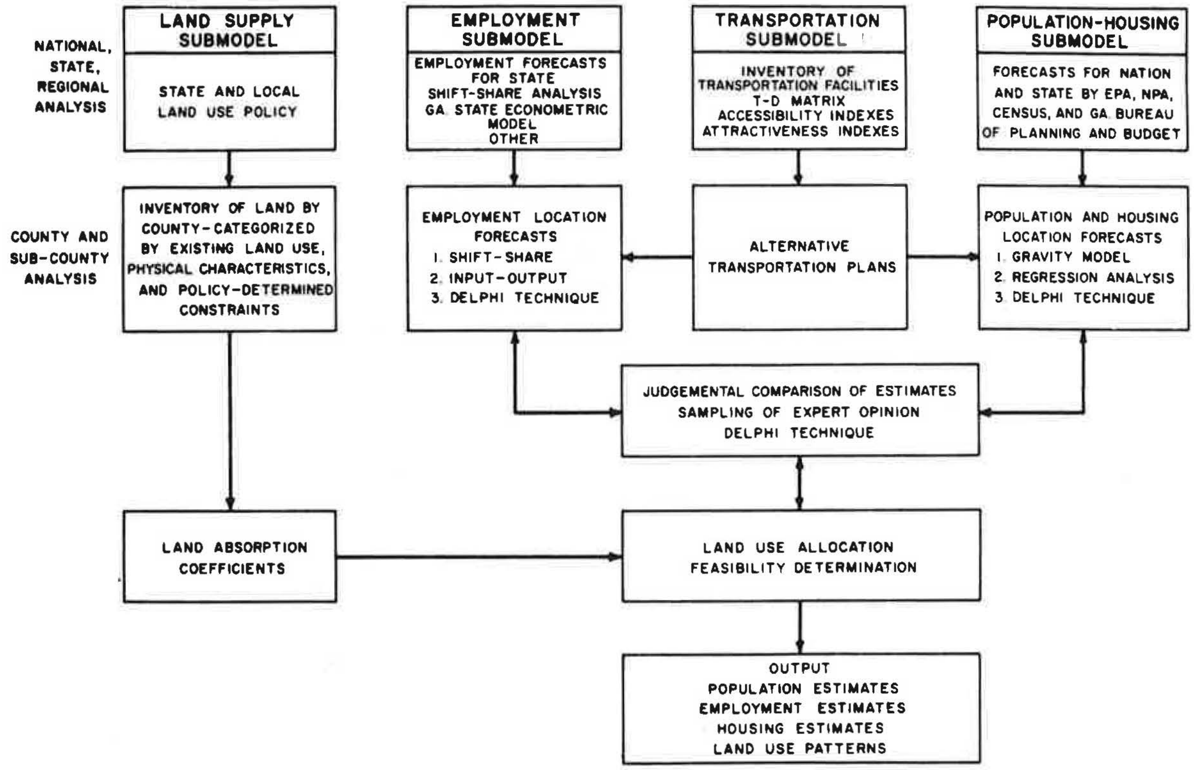
Also shown in Figure 1 are several techniques for estimating employment, population, and households at the national, state, and county levels. These techniques are also integrated by judgmental comparison. The interaction between these estimates and the land supply and transportation submodels is discussed below. The shift-share, input-output, and Delphi techniques are supplemented by trend extrapolation and judgment in the estimation of employment by counties; employment is a key variable used in forecasting future growth and economic impacts.

The shift-share technique, combined with judgmental modifications of the regional share component, is also employed to allocate the projected employment for Georgia to substate multicounty regions. A description and evaluation of this technique are presented elsewhere (1, 2, 3, 4, 5, 6). In view of the apparent instability of the critical regional share component, multiple regression techniques are employed to identify the important determinant variables that affect the component. Forecasts based on the shift-share technique are compared to similar forecasts prepared by the U.S. Bureau of Economic Analysis (7).

This formulation is similar to previous model formulations in that the location of future employment influences housing and commercial location and public service development. The problems in forecasting employment by counties are of such dimension that two independent methods of estimation are required. The shift-share technique is supplemented by use of the Delphi technique in which a consensus of expert opinions is obtained.

The Delphi technique, a methodology for eliciting and refining expert or informed opinion, has gained increasing recognition in recent years at the Rand Corporation, the University of California, the University of Michigan, and elsewhere. The principal published works in this area are given elsewhere (8). The technique involves the

Figure 1. Framework for land use model used for transportation planning.



sequential administration of a questionnaire to a panel of experts in successive rounds. The answers of the group are summarized at the conclusion of each round, and the respondents are then asked to reconsider earlier responses in light of the summary. The theory of the technique is that successive iteration and feedback of group responses will result in a gradual approximation to the true prediction or value sought. The final results are expressed in measures of central tendency and dispersion for the group as a whole. Theoretically, the anonymity of the respondents and the absence of face-to-face discussion eliminate the probable distorting effect of dominating personalities who might be present in conventional group or committee discussions. The results of experiments in which the performance of groups in face-to-face discussion were compared with groups interacting through an anonymous questionnaire with controlled feedback have indicated that the estimates from the Delphi groups were more accurate than were those of the groups in face-to-face interaction (8).

Experiments using the Delphi technique were conducted at the Oak Ridge National Laboratory (ORNL) in a 222.38-km^2 (80-mile^2) study area in North Anderson County, Tennessee. Successful experimentation with the application of the Delphi method to predict land use in the ORNL test area provided the University of Georgia research team with an operationally tested, supplementary technique that could be used to estimate future land uses in the prototype corridor study in Georgia (9).

The Delphi results provided a scenario of future economic growth and employment for the 17 counties in the Georgia study area. If the Delphi forecasting technique is used over any extended planning period, a recurrent sampling of expert opinions is needed. This sampling would reflect the changing scenarios of growth as time proceeds and circumstances and conditions are altered. This sampling is of particular consequence when a major change in transportation is planned or effected in a given area.

Figure 1 shows how the results of the Delphi forecasting technique are integrated in the model with alternative methods of forecasting employment, population, and housing. Estimates of future employment by counties are based on model projections for the state as a whole, and these projections are allocated to individual counties by the use of the shift-share and regression analysis techniques. The alternative estimates of county growth are judgmentally compared and are used as the basis for estimating future county population, employment, housing, and land use patterns.

The steps shown in Figure 1 should be viewed as a continual process for reviewing and updating data and estimates rather than as a one-time forecast. The computerization of the various techniques and submodels is an effective means for measuring and testing the probable impact that alternative transportation plans may have on future land use and development in any selected test area.

PREDICTING THE INFLUENCE OF CHANGES IN ACCESSIBILITY

The basic data incorporated into this study were taken from 1970 census data for the 159 counties of Georgia and from a Delphi study by Davis (9). Simultaneous equations were used to reduce the bias that might result from treating certain explanatory variables as independent variables in the conventional least squares regressions; the explanatory variables are jointly determined.

A two-stage, least squares, simultaneous technique is used to adjust the interdependence of the variables (10). In this method of estimation, conventional least squares regressions for each of the endogenous variables (on the right side of a particular regression equation) 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 that uses the observed values for each of the exogenous variables (on the left 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 that are 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. 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 relations.

Five endogenous variables are used in the model. The equations that follow describe the reduced form relations between the dependent and independent variables.

$$\begin{aligned} POP = -3.749 &+ \underset{(5.83)}{0.534MRA} + \underset{(4.68)}{0.087GPOP} + \underset{(9.46)}{0.484CPA} - \underset{(-4.61)}{0.396OR} \\ &+ \underset{(1.39)}{0.042URB} + \underset{(0.17)}{0.015RS} - \underset{(-0.54)}{0.646TS} - \underset{(-3.48)}{0.453SUB} \\ &+ \underset{(3.46)}{0.462ACC} \quad \bar{R}^2 = 0.91 \end{aligned} \tag{1}$$

$$\begin{aligned} EMP = 4.670 &+ \underset{(3.12)}{0.686MRA} + \underset{(2.27)}{0.101GPOP} + \underset{(0.33)}{0.041CPA} - \underset{(-4.72)}{0.963OR} \\ &- \underset{(-1.40)}{0.100URB} + \underset{(1.41)}{0.311RS} + \underset{(0.60)}{0.170TS} - \underset{(-4.31)}{1.343SUB} \\ &+ \underset{(1.45)}{0.463ACC} \quad \bar{R}^2 = 0.68 \end{aligned} \tag{2}$$

$$\begin{aligned} HSD = -5.538 &+ \underset{(7.30)}{0.674MRA} + \underset{(4.49)}{0.084GPOP} + \underset{(8.51)}{0.439CPA} - \underset{(-3.07)}{0.263OR} \\ &+ \underset{(1.86)}{0.056URB} + \underset{(1.73)}{0.161RS} - \underset{(-0.62)}{0.073TS} - \underset{(-2.47)}{0.323SUB} \\ &+ \underset{(3.75)}{0.504ACC} \quad \bar{R}^2 = 0.91 \end{aligned} \tag{3}$$

$$\begin{aligned} PSF = 4.420 &+ \underset{(2.91)}{0.117MRA} - \underset{(-1.60)}{0.130GPOP} - \underset{(-3.65)}{0.821CPA} + \underset{(2.89)}{0.108OR} \\ &- \underset{(-0.89)}{0.118URB} + \underset{(1.41)}{0.057RS} - \underset{(-1.81)}{0.094TS} - \underset{(-2.68)}{0.153SUB} \\ &- \underset{(-5.61)}{0.329ACC} \quad \bar{R}^2 = 0.51 \end{aligned} \tag{4}$$

$$\begin{aligned} INC = 9.646 &- \underset{(-1.92)}{0.041MRA} - \underset{(-3.14)}{0.137GPOP} + \underset{(1.98)}{0.237CPA} - \underset{(-1.07)}{0.213OR} \\ &+ \underset{(0.12)}{0.009URB} - \underset{(-0.21)}{0.005RS} + \underset{(0.39)}{0.011TS} - \underset{(-15.89)}{0.485SUB} \\ &+ \underset{(1.45)}{0.045ACC} \quad \bar{R}^2 = 0.90 \end{aligned} \tag{5}$$

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 intracounty transport cost. (SI units are not given for these variables in this model inasmuch as the operation of the model requires that these variables be in U.S. customary units.) It is hypothesized that when the costs of private automobile transport are low, especially if income is held constant, relatively more people will own automobiles. An increase in MRA will reduce transport cost and lead to higher densities and more automobiles. Therefore, the relation between CPA and MRA and population and employment density is positive. An empirical analysis may give possible insight into the magnitude of this relation.

A model for potential population based on 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 on some measure of population, employment, or activity that is weighted by distance or travel time (11). The formula used to calculate the accessibility (ACC) for each county is

$$ACC_j = \sum_{i=1}^{n} P_i/T_{ij} \tag{6}$$

where

j = county in which the accessibility is being calculated;
$i = 1, \ldots, n$, i.e., all other counties;
P_i = population for county i;
T_{ij} = travel time between counties i and j; and
n = 159 counties.

The proportion of growth in the county (GPOP) that took place since 1920 is an additional characteristic that might be related to transport cost and is included in the analysis of population density. Counties and cities in areas that have developed after the introduction of the automobile generally have wider streets, have more parking facilities, and are better suited to automobile transport. Also, counties that have grown more rapidly since 1920 should be adjusted to modern automobile 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 inmigration to the county. Therefore, income should be positively related to household, employment, and population density.

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

The percentage of 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. The ratio of owners to renters (OR) and the percentage of single-family dwellings (PSF) are used to determine the relation between density and the structural type of dwellings and ownership that exist.

REGRESSION MODEL

In two-stage regressions, the predicted values of the endogenous variables are determined from the reduced form equations. These predicted values are then used in the structural equations to obtain unbiased estimates of the relevant coefficients. 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 0.82, the introduction of a transit system that increases the ACC value by 5 percent would result in a 4.1 percent increase in housing density. Thus, we can predict the effect of accessibility (ACC) on all the dependent variables, POP, EMP, HSD, PSF, and INC.

In the same manner, we can predict the effect of changes in incomes, employment, population, and 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.

Empirical Results From Regression Model

To predict the impact of a change in transportation mode such as a new highway, the regression coefficient of the accessibility variable is used from the reduced form equation of a two-stage model. The reduced form equations (equations 1 through 5) 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 given with equations 1 through 5.

The $\bar{R}^2$ measures indicate that the system has a 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 1 percent increase in accessibility is associated with approximately a 0.5 percent increase in population, employment, and household density and a 0.04 percent increase in income. The same increase leads to a 0.3 percent decrease in single-family dwellings. This decrease reflects the fact that higher densities are associated with more multifamily dwellings.

The relations of the reduced form variables represented in equations 1 through 5 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 test 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 that takes into account the recently improved highway is then compared with accessibility that is assumed constant for each of the 17 counties in Georgia. An accessibility measure is also computed that assumes a deteriorating highway condition resulting from increased congestion. The percentage differences for both the improved and the deteriorating transportation system are given below for each county.

County	Improved Highway	Deteriorating Highway	County	Improved Highway	Deteriorating Highway
Banks	0.80379	0.024	Jackson	0.13360	-0.042
Barrow	0.04621	-0.018	Madison	0.21128	-0.048
Clarke	12.80427	-3.860	Morgan	2.79430	-0.467
Elbert	0.05635	-0.013	Newton	0.00643	0
Franklin	0.12045	-0.023	Oconee	7.25719	-2.208
Greene	0.45325	-0.178	Oglethorpe	0.09290	-0.022
Gwinnett	0	0	Rockdale	0.00461	0
Hall	0.06580	-0.022	Walton	0.00938	0
Hart	0.06949	-0.018			

The estimated percentage changes given above are multiplied by the regression coefficients for accessibility in the reduced form equations (1 through 5) to derive estimates of changes in the five dependent variables.

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 Delphi study (9). Simple trend projections and the Delphi estimates conform very closely, except for housing in which there has been a dramatic shift toward multifamily dwellings in recent years. The trend projection gives much larger estimates for single-family dwellings in 1980 and 1990. It appears likely that the trend technique overestimates the future growth of housing, since it is based on the growth that occurred between 1950 and 1970. On the other hand, 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.

The projected impact of a changed transportation system on population, employment, households, and single-family dwellings for 1980 and 1990 is given in Table 1 for the three counties directly affected by the proposed transportation improvement. The revised estimated forecasts for 1980 and 1990 are based on the projected changes in accessibility and on the regression coefficients for accessibility. Two projections are presented for both 1980 and 1990: The first assumption is a deteriorating highway condition, and the second is the introduction of an improved intrastate highway. The 1970 base year and assumption A data are from the Delphi study (9). The other data were calculated in our study.

The data given in Table 1 demonstrate that the projected changes in accessibility resulting from the improved highway facility significantly influence the relevant socioeconomic variables for Clarke, Morgan, and Oconee counties as hypothesized. The greatest change occurs for Clarke county. This county is the urban center for the area being considered, and the county most directly influenced by the improved intrastate highway.

Constraints on Land Use Allocations

In the absence of broad transportation policy goals, determination of the future usable land supply in the 17-county test area is estimated by eliminating the total estimated supply of land classified as vacant and agricultural in 1970: the amount of land currently identified as public and semipublic land, floodplains, land with slope exceeding 25 percent, and land having poor soil structure, drainage, or load-bearing qualities (12). The remaining supply of vacant and agricultural land after deducting public and semipublic land is classified as (a) usable with no present constraints, (b) marginally usable, or (c) unusable depending on the above characteristics. It is important to recognize that these classifications are based on specific assumptions concerning the relation between physical characteristics and usability and do not reflect specific planning or policy goals. The land supply submodel has the flexibility to alter these assumptions with respect to the criteria for usability and to introduce other policy or planning constraints.

Table 2 (7) gives the estimated land in square hectometers in 3 of the 17 test area counties. The land absorption coefficients, based on current use, are used to estimate future land consumption. No open space or recreation land was allocated. The developed land equals land currently in use for residential, commercial, industrial, public, and semipublic purposes. The latter purposes include national forest land, reservoirs, and lakes. The vacant-agricultural land includes all other land. The estimated land requirements for new development in 1980 and 1990, based on shift-share employment forecasts, are shown to be relatively small compared with available supplies. In general, it can be concluded from Table 2 that the available supply of usable but unused land greatly exceeds the total current hectares de-

Table 1. Population, employment, and housing forecasts for three counties in the north Georgia test area under three transportation assumptions.

			Assumption A		Assumption B		Assumption C	
County	Variable	1970	1980[a]	1990[a]	1980[b]	1990[b]	1980[c]	1990[c]
Clarke	Population	65 177	81 927	97 440	80 466	93 764	86 773	109 309
	Employment	25 386	33 138	41 201	32 547	39 744	35 103	48 974
	Single	11 716	13 614	15 556	13 785	15 949	13 047	14 287
	Multi	6 744	9 368	11 587	8 750	10 148	11 418	16 473
	Total[1]	20 554	26 538	31 746	26 022	30 524	28 251	35 977
Morgan	Population	9 904	10 439	11 460	10 416	11 419	10 574	11 972
	Employment	3 550	3 816	4 054	3 808	4 038	3 865	4 244
	Single	2 629	2 999	3 405	3 004	3 416	2 972	3 294
	Multi	191	264	423	271	417	337	730
	Total[d]	3 020	3 520	4 147	2 512	4 196	3 570	4 360
Oconee	Population	7 917	9 862	11 545	9 761	11 309	10 193	12 332
	Employment	3 010	3 588	3 856	3 551	3 777	3 709	4 120
	Single	1 956	2 575	3 308	2 593	3 355	2 514	3 154
	Multi	80	195	373	146	244	357	801
	Total[d]	2 607	3 489	4 607	3 450	4 505	3 617	4 951

[a]Current level of accessibility maintained.
[b]Decreased accessibility due to increased congestion on existing facilities.
[c]Increased accessibility due to improvement of existing highway facility.
[d]Total households including trailers.

Table 2. Estimated usable land and new development for 1970, 1980, and 1990.

Year	Type of Land	Clarke County	Morgan County	Oconee County
1970	Developed	6 379	6 325	2 745
	Agricultural—vacant	25 848	85 866	45 471
	No constraints	11 419	70 739	24 411
	Marginally usable	11 398	7 645	17 309
	Nonusable	3 031	7 482	3 751
1980	New development	1 040.2	267.4	234.8
	Residential	820.8	262.8	178.4
	Industrial	142.5	3.3	54.6
	Commercial	76.9	1.3	1.8
1990	New development	2 002.1	602.3	522.9
	Residential	1 535.1	592.3	404.5
	Industrial	297.1	6.9	114.3
	Commercial	169.9	3.1	4.1

Note: Values are in square hectometers; 1 hm^2 = 2.47 acres.

veloped and those likely to be developed within the next two decades.

USING THE TRANSPORTATION DECISION MODEL

Forecasting future land development remains an art, not a science. The predicted economic growth and development for the three counties and a review of alternative policy determined from the constraints given in Table 2 rest on a series of assumptions and related outcomes about national and regional economic activity, demographic influences, and public policy constraints. The range of variation in these deterministic input assumptions and consequently in the resulting model output is large. Thus, the use of computerized econometric land use models that permit repetitive tests for the sensitivity of output forecasts to changes in the basic assumptions used in the modeling approach is justified. A consensus among the participants is required to formulate a transportation policy or project decision. This decision process is concerned with critical economic assumptions and public policy constraints, the reliability of model data and output, and the scenarios of future land use and development.

In conclusion, it should be emphasized that people, not models, make transportation planning decisions. Econometric models and land use simulation models, used in conjunction with multiple regression, Delphi, interpretive structural modeling, and other techniques, can facilitate the decision process. However, in the final analysis, it is the knowledge and judgment of those participating in the decision process who determine the quality of the transportation decision.

REFERENCES

1. C. F. Floyd and C. F. Sirmans. Shift and Share Projections Revisited. Journal of Regional Science, Vol. 13, No. 1, 1973, pp. 115-120.
2. L. D. Ashby. Growth Patterns in Employment by County: 1940-1950 and 1950-1960. Office of Business Economics, U.S. Department of Commerce, Vols. 1-8, 1965.
3. H. J. Brown. Shift and Share Projections of Regional Economic Growth: An Empirical Test. Journal of Regional Science, Vol. 9, 1969, pp. 1-18.
4. H. J. Brown. The Stability of the Regional Share Component: Reply. Journal of Regional Science, Vol. 11, 1971, pp. 113-114.
5. C. F. Floyd. The Changing Structure of Employment and Income in the Regions of the United States. Economic Development Administration, U.S. Department of Commerce, Vols. 1-6, 1971.
6. C. C. Paraskevopoulos. The Stability of the Regional-Share Component: An Empirical Test. Journal of Regional Science, Vol. 11, 1971, pp. 107-112.
7. OBERS Projections: Regional Economic Activity in the United States. Bureau of Economic Analysis, U.S. Department of Commerce, 1972.
8. O. L. Ervin and C. R. Meyers, Jr. The Utilization of Local Opinion in Land-Use Simulation Modeling: A Delphi Approach. Regional Environmental Systems Analysis, Memo Rept. 73-8, Oak Ridge, Tenn., Feb. 1973.
9. J. M. Davis. Seventeen County Study Area Delphi Forecast. Univ. of Georgia, Athens, Research Rept. 4, Dec. 1974.
10. J. Johnston. Econometric Methods. McGraw-Hill, New York, 1963.
11. G. Carruthers. An Historical Review of the Gravity and Potential Concepts of Human Interaction. Journal of the American Institute of Planners, Vol. 22, 1956, pp. 94-102.
12. M. J. Rowan. Structuring the Land-Use Submodel for the Transportation Planning Land-Use Model. Univ. of Georgia, Athens, Research Rept. 8, Aug. 1975.