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Discussion

Hays B. Gamble

The main contribution of the paper by Liew and Liew

appears to be one of adopting a methodological approach (interregional input-output) to the analysis of the effects of changes in transportation costs. They assume a 5 percent change in such costs, but the effects on trade coefficients are quite slight, well within the normal variations that exist, solely because of errors in data measurement. Moreover, they use 1963 data, which are too old to have much meaning. Their findings are therefore really quite meaningless, and any merit of the paper must rest on the methodological adaptation of interregional input-output. I think this point should be stressed.

Authors' Closure

The empirical results presented in our paper should be considered as an illustration of the working of the model. The data need to be updated for current policy evaluation, but the implications of the empirical results should provide interesting insight for transportation planners and the freight industries.

We are not sure precisely what "errors in data measurement" means. The effect on trade coefficients is simply a result of the simulation of the model. Elsewhere, we compiled the effect on trade coefficients under varying degrees of change in transportation cost, and the impacts are significant.

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Quantitative Technique for Estimating Economic Growth at Nonurban, Limited-Access Highway Interchanges

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A quantitative modeling technique for estimating the economic development that is likely to occur at a given nonurban interchange site on the Interstate highway system is described. It was important that the model be easily implemented by using secondary data on economic, demographic, geographic, and other characteristics. A sample of 128 nonurban Pennsylvania interchanges was selected. Problems in the quantification of variables and restrictions imposed by the lack of data for certain variables were discussed. Simple, multiple, and stepwise linear regressions were useful in identifying promising variables for the modeling technique. The structural design of the model was formulated by using 15 exogenous variables that define the economic, demographic, geographic, and traffic environment and the following five endogenous variables: service stations, restaurant seats, motel rooms, industrial developments, and other commercial developments. The forecasting model consisted of a set of simultaneous linear equations. The simultaneous-equation model usually gives better estimates than single-equation models. A two-stage least-squares technique was used to estimate the parameters of

the model. All equations of the model were statistically significant. The model can be a useful tool in helping planners to predict land use changes at existing or proposed nonurban interchange sites. When applying it to a specific interchange, the user is cautioned to observe the total environmental setting for peculiar or unique characteristics.

An important provision of the Federal-Aid Highway Act of 1956, which authorized the Interstate highway system, was the prohibition on roadside developments such as gasoline stations, restaurants, and motels with direct access to Interstate rights-of-way. Since traffic to and from a limited-access highway must be channeled through an interchange and highway users traveling long distances do not ordinarily want to go far from an interchange in search of gasoline, food, or lodging, an interchange is

an advantageous location for the construction of establishments such as service stations, restaurants, and motels.

Just as many present trade centers, towns, and cities can trace their origins to the existence of transportation crossroads such as river junctions and railroad connections, which provided improved linkages between local land uses and distant land uses, the interchange area also offers an opportunity for community development by reason of improved access between land uses (1). The development of commercial or industrial establishments, recreational facilities, residential units, and the above-mentioned highway-oriented establishments at an interchange stimulates general business activity, creates new jobs, increases income, and expands the tax base of the community.

The spontaneous economic development of an interchange community is a complex phenomenon. There is considerable variety in the economic sectors—residential, commercial, industrial, etc.—that form communities, and the growth pattern of one community will differ from that of another. For example, the speculative withholding of land from the market may delay the growth of the community, whereas the establishment of a new industrial plant close to a residential area may substantially promote community growth.

THE PROBLEM

An Interstate highway may create new market potentials and make possible a change in the mix of goods and services that a community can offer; this will affect the balance of the economic sectors of the community. Not all interchange areas have the same potential for economic development. This is supported by the fact that some have developed in a very short period of time while others have shown no development even after many years.

The volume of traffic entering and exiting various developments in an interchange area is of particular importance to transportation planners. Their concern centers on present and/or changing land uses that have high rates of trip generation. The capacity and safety of a highway system that may currently be adequate can be subjected to severe strain as adjacent land uses change. One of the key elements in solving the problem of the premature obsolescence of interchanges is the ability to forecast probable land use developments.

The basic purpose of planning and regulating development at an interchange area is not ordinarily to restrict but to encourage growth. If changes in land use at interchange areas are not adequately considered, they can result in social and economic losses to the highway user, the interchange community, and the state. To the motorist, the consequences of inadequate land use planning may result in delays, increased accident exposure, higher operating costs, visual blight, and excessive energy consumption. To the local communities and state authorities, these consequences are even more burdensome, causing expensive highway redesign, installation of corrective traffic controls, and the loss of employment opportunities and tax revenues because of marginal and/or inefficient land use. Finally, all consequences of inadequate planning contribute to degrading the environmental quality of interchange areas.

On the other hand, an adequate land use plan will encourage the most efficient use of land, coordinate mainline and cross-route levels of service with traffic generated by land uses, meet the public's need for access and services, stimulate the growth of employment opportunities and tax revenues, and maintain a desirable environmental appearance.

This investigation is primarily concerned with the de-

velopment of an econometric model for predicting selected highway- and non-highway-oriented developments that are likely to occur at a given nonurban interchange site. A very practical consideration is that the model be designed so that it can be implemented easily by using secondary data.

PREVIOUS STUDIES

Several models have been formulated to forecast potential economic development at nonurban Interstate highway interchanges. Stein (2) reported that most states had initiated some form of interchange development study during the 1960s, often with the cooperation of the U.S. Department of Transportation (then the Bureau of Public Roads).

An extensive study in Michigan by Ashley and Berard (3) analyzed the development that occurred near 66 interchanges on a 290-km (180-mile) span of I-94. The investigation was conducted 3.5 years after the opening of the highway. A classification scheme attempted to provide a predictable pattern of benefits for other or future interchanges by comparing them with similar classes of interchanges on existing facilities (Ashley and Berard defined benefits as the enhancement or increase in value of adjoining lands as a result of the location and construction of a highway).

Fowler, Stocks, and Sanders (4, p. 16) developed a mathematical model that would make it possible to predict the extent of highway-service business growth at nonurban interchange areas. Their study used multiple linear regression in an analysis of 79 interchanges in eight states in the eastern United States. The model, which was composed of three equations, was designed to predict the amount of service station, restaurant, and motel development per interchange. A bias was introduced in the results by the elimination of interchanges that lacked service stations, restaurants, or motels.

Pendleton (5) examined aerial photographs and monitored land use before and after the construction of interchanges on toll and nontoll roads. He mentioned that the development of a forecasting model was beyond the scope of his work but laid a foundation for future interchange modeling work. Pendleton's work pointed toward two factors that should be included in any future mathematical forecasting programs: (a) the amount of development that existed before the construction of the interchange and (b) the distance between the interchange and an urban population center.

In a study of 105 nonurban interchanges in Pennsylvania, Twark (6) developed a simultaneous-equation model for predicting service stations, restaurants, motels, non-highway-oriented businesses, and average annual rate of growth in market value of real estate in the local interchange community. A two-stage least-squares procedure was used to estimate the parameters of the model. The resulting numerical coefficients (or parameter estimates) were based on nonurban interchanges that, on average, had been open to traffic for only 4.8 years.

In Alabama, Mason and Moore (7, p. 106) attempted to forecast aggregate levels of development by interchange design. Two models of interest were highway-oriented development at rural interchanges and service-station development at rural interchanges, which explained 26 and 29 percent, respectively, of the variance from the means. The researchers concluded that, because of limited sample sizes and data problems, it was not possible to develop a statistical statement that would have a high degree of reliability.

Epps and Stafford (8) statistically investigated the relation between the amount of interchange development and

the characteristics of interchanges. The analysis consisted of using multiple regression techniques to relate the amount of development to a series of variables that represented traffic flow and demographic and locational characteristics. A regression equation was developed for each of the three highway-oriented types of businesses: service stations, restaurants, and motels.

Corsi (9), in a study of 15 Ohio Turnpike interchanges, designed linear multiple regression equations to forecast total land use, residential land use, highway-oriented and non-highway-oriented commercial land use, and industrial land use.

Researchers at the University of Texas at Austin (10, p. 58) reviewed many studies of rural interchanges and suggested that an ideal methodology for studying highway interchanges should include a long, continuous study period; encompass the interchange area of influence; and have independent variables that reflect physical, social, and economic factors necessary to characterize a community's development and potential for growth.

So far, these models have been based on the premise that future economic growth is a function of the economic, geographic, demographic, and traffic parameters of the specific site. The problem with most previous studies is that the models are inadequate for predicting future development, either because of the short range of time or because of aggregation of data for statistical purposes. The techniques used in the work described in this paper attempt to overcome some of the major deficiencies of previous studies.

GENERAL MODEL

The goal of this study is to develop a model that identifies the interrelationships among the important factors that lead to interchange development and to provide planners with a guide to the estimation of potential development in nonurban interchange areas. When they know the probable level of interchange area development, state and local planners can prepare a reasonable land use plan for the interchange that provides adequate highway service levels and fulfills other community needs.

There are problems involved in attempting to develop a means of predicting economic development in interchange areas. Some of the initial points to be established involve proper definition of (a) the interchange area, or "interchange community", and (b) the economic development or "economic growth" of an interchange community. Another problem is how to quantify the various factors that determine the differences in the economic growth of interchange communities.

The geographic area to be included, or the boundary of the interchange community, is not easily determined. Some authors have used the term "interchange area" rather loosely to cover the entire vicinity in which the existence of the interchange may stimulate intensive use of land that would not otherwise have been located there (11, p. 106). Others have used the term "area of influence" to mean the area in the vicinity of the interchange that is affected by the facility (12).

Various studies have found that, for nonurban interchanges, the majority of new economic development occurs within 0.8 km (0.5 mile) of the interchange (13, p. 72). Some arbitrary limitation of the area of the interchange community is necessary, and the boundary chosen will have some adverse effects on the applicability of the model to interchanges where exceptional geographic or topographic conditions lead to important developments farther away. This study considers the interchange community as the area located within 0.8 km of the interchange.

Since the economic growth of a community is such a

complex process, any description of the state or level of development for a given community must involve the measurement of the many characteristics of that community. To predict the development of the community as a whole, each of the variables that measure a particular characteristic or sector of the community would have to be predicted. Because of the interrelationships of these variables, each one affects the growth of the community and is in turn affected by that growth. For example, as a residential community grows, a need develops for service facilities such as grocery stores, gasoline stations, and variety and drug stores, and this development encourages further residential expansion.

The economic growth of an interchange community is considered to be determined by two types of factors: (a) endogenous variables, which describe the state or levels of economic development for the given community, and (b) exogenous variables, which affect the level of economic development of the interchange community but are not generally affected by the growth that takes place.

It is assumed here that the entire model can be presented as a system of simultaneous linear equations in which each equation describes how a particular aspect of economic development (endogenous variable) is determined by other relevant endogenous and exogenous variables. Such an equation describes a particular "structure" of the economic community and is called a structural equation of the model. Any one of the structural equations in the model will have the same mathematical appearance as that of an ordinary multiple regression equation. However, the parameters of a structural equation in a system of equations generally cannot be derived by using ordinary regression techniques. Other suitable methods have been developed, one of which should be used.

The method of estimation used in this research is the two-stage least-squares technique (14, p. 376). The estimates of the parameters of the structural equations obtained by this technique are asymptotically unbiased.

By appropriate definitions, the system of structural equations can be represented by the following matrix form:

$$YA = XB + e \quad (1)$$

where

Y = endogenous variables,

X = exogenous variables,

A and B = respective parameters of the variables, and
e = aggregate effects of the unspecified variables.

The solution of this system of equations would be

$$Y = XBA^{-1} + eA^{-1} \quad (2)$$

which can be written

$$Y = XC + u \quad (3)$$

where $C = BA^{-1}$ and $u = eA^{-1}$. The above solution is the matrix representation of the "reduced" form of the structure.

The importance of the structural equations can be illustrated by their ability to estimate the marginal effect on different types of development at an interchange when the level of some other type of development has been determined to be different from that predicted by the reduced-form equation. For example, the reduced-form equations may estimate the economic potential of some

particular interchange to be very small. However, if for any reason the site should be selected for a large motel, this would change the potential of the interchange, and the structural equations could be used to estimate the effect of the motel on further development of the interchange, such as the likely appearance of service stations and restaurants.

An enormous number of variables may influence the economic development of an interchange community. Many of these variables may have very slight effects, whereas others are not quantifiable. Still others may be unique for a given area. It is not practical to include all of these variables in a model. The model therefore specifies only the variables thought to be most important. The net effect of the excluded variables for each equation is then represented by the disturbance term e .

A review of related literature revealed that there is considerable variability among interchanges. This suggests that a relatively large number of observations should be required before generalizations are made with any degree of confidence.

PRELIMINARY ANALYSIS

A sample consisting of 128 nonurban Pennsylvania interchanges was selected. Data on economic, demographic, geographic, traffic, and other characteristics for each interchange were obtained from secondary sources and from direct observation, which involved visiting each interchange site.

Even though the important characteristics that describe an interchange community have been identified, there remains the problem of measurement. The goal of this research was to provide an easy-to-use method by which highway planners can predict future developments. The data must therefore be easily observable or available from secondary sources. The objective was to allow the measurement of the less refined variables that still provide a reasonable forecast of an entity. For example, investments such as service stations might be reflected better in annual dollars of retail sales or average number of employees, but such data were not readily available. To overcome the measure's inability to characterize the intensity of development, categories such as number of pumps, number of seats, and number of rooms were added to the initial measures of service stations, restaurants, and motels, respectively. In the same way, it would have been desirable to have demographic data for the interchange community in refining the research model, but such information does not exist in a basic form suitable for easy insertion into a forecasting model. It should be noted that variables that require extensive data collection may provide better results but could make the use of the modeling techniques costly for highway and planning agencies.

The data were analyzed by using descriptive statistics, simple correlations, and multiple regressions as aids in designing the general forecasting model. Service stations, the most frequent form of new development, average two stations per interchange, followed in order of frequency by other commercial developments (such as the businesses found in small community shopping centers), restaurants, motels, industrial developments, and, finally, public developments such as highway maintenance shops or state police barracks.

On the average, service stations, restaurants, and motels appeared to follow an approximate ratio of 4:2:1. The ratio of other commercial development to industrial development was approximately 3:1. Highway- and non-highway-oriented developments had an approximate ratio of 3:2. Although ratios among development levels may be important in the aggregate, they are often not accu-

rate for specific interchanges.

The basic data for the exogenous variables used in this study were the age of the interchange since its opening, the presence of zoning at the interchange area, the distance to the nearest urban area, average daily traffic (ADT) on the Interstate highway and cross route, and the population, area, and market value of real estate in the local community, the county, and the nearest urban area associated with the interchange. Combinations and ratios of some of the basic data were constructed to form 26 exogenous variables. For example, variables such as population and market value of real estate were placed on a common base, such as market value per capita and/or population per unit area. In addition, other variables were constructed to depict change over time. The exogenous variables were classified in four main categories: local community, county, nearest urban area, and ADT.

CORRELATION AND REGRESSION ANALYSIS

Correlation is often a useful aid in model building. As a further step in model construction, simple correlations were obtained between 26 potential exogenous variables and 13 potential endogenous variables. Few exogenous variables, with the exception of cross-route ADT, were consistently significant in the simple correlations across all endogenous variables. Significant correlations were obtained between the exogenous variables and industrial and other types of commercial development in all four main exogenous classifications, especially for the local community and ADT variables.

The representation of economic functions must incorporate the multiple facets of the real world. Since it was recognized that a myriad of economic, demographic, geographic, and highway parameters and their interrelationships influence the development of interchange areas, a multiple regression analysis was undertaken.

In view of the many pitfalls and possible data interactions involved in attempting to identify significant variables for the model, the prime consideration in adding, deleting, or modifying a variable was that a logical (though sometimes subjective) basis must be established for such changes. In some instances, because of various interactions, variables that appear significant in simple correlation analysis may not be significant when combined with other variables in a multiple regression analysis; in other instances, the reverse may be true.

Multiple linear regressions in which 1975 levels of development (13 potential endogenous variables) were used were run against all of the 26 potential exogenous variables. The low proportion of explained variation (R^2) obtained for truck garages and public developments—0.161 and 0.155, respectively—suggested that a model for forecasting these developments on the basis of the exogenous variables contained in this study would not be very accurate. These two variables were therefore dropped from further consideration as potential endogenous variables for the final model.

An extensive series of stepwise multiple linear regressions was useful in the identification of promising variables for the model. Many multiple regressions were examined and edited to add and subtract variables, which led to an increase in the proportion of explained variance. The extensive series of stepwise analyses indicated that selected equations were equally capable of predicting service stations and number of gas pumps. Service stations were selected as being more appropriate for the final model because they can be translated into traffic generation units for planning purposes more easily than the number of gas pumps. On the other hand,

Table 1. Endogenous and exogenous variables included in simultaneous-equation model.

Type of Variable	Symbol	Description	Time Frame	Actual Data Year
Endogenous	Y_1	Service stations	t_{-5}	1975
	Y_2	Restaurant seats	t_{-5}	1975
	Y_3	Motel rooms	t_{-5}	1975
	Y_4	Industrial developments	t_{-5}	1975
	Y_5	Other commercial developments	t_{-5}	1975
Exogenous	X_1	Community population density	t_0	1970
	X_2	Change in community population density	$t_{-10} - t_0$	1960-1970
	X_3	Community real estate market value per square kilometer	t_0	1970
	X_4	Change in community real estate market value per square kilometer	$t_{-10} - t_0$	1960-1970
	X_5	Community real estate market value per capita	t_0	1970
	X_6	Change in community real estate market value per capita	$t_{-10} - t_0$	1960-1970
	X_7	Age of interchange since opening	t_{-5}	1975
	X_8	Cross-route ADT	t_0	1970
	X_9	Total ADT, cross-route plus Interstate	t_0	1970
	X_{10}	County population density	t_0	1970
	X_{11}	Change in county population density	$t_{-10} - t_0$	1960-1970
	X_{12}	County real estate market value per square kilometer	t_0	1970
	X_{13}	County real estate market value per capita	t_0	1970
	X_{14}	Change in county real estate market value per capita	$t_{-10} - t_0$	1960-1970
	X_{15}	Nearest urban area population to distance ratio	t_0	1970

the equations were substantially better able to predict restaurant seats and motel rooms than number of restaurants and number of motels.

SIMULTANEOUS-EQUATION MODEL

A major attribute of the simultaneous-equation model is that it usually gives better estimates than single-equation models. As indicated previously, developing the particular structure of a general model that can reasonably be expected to describe and predict economic development at interchange sites is a complex task. The relevant variables must be identified and classified into endogenous and exogenous categories.

Statistical theory alone does not provide firm guidelines for the inclusion or exclusion of a particular variable in any given equation of the simultaneous-equation model. According to Wonnacott (15, p. 300), "Prior belief plays a key role, not only in the initial specification of which variable should be in the equation, but also in the decision as to which should be dropped in light of the statistical evidence."

The results of the preliminary analysis suggested that the endogenous and exogenous variables given in Table 1 be included in a simultaneous-equation model. Table 1 also identifies the time frame for each variable. Assuming the present time to be t_0 , the planning year forecasted is t_{+5} , and the exogenous variables are based on their levels at t_0 or changes in the variables from t_{-10} to t_0 .

Next, the structural equations must be constructed, and the parameters of the equations then have to be estimated. There are as many structural equations as endogenous variables, since each equation explains the level of a particular measure of development in terms of the levels of all other variables. Equation design followed the general criterion of using a limited number of easily measured and time-lagged variables. The format of the final set of equations, which is given below, was designed to forecast service stations, restaurant seats, motel rooms, industrial developments, and other commercial developments:

Equation	Item Forecast	Variables Included	
		Endogenous	Exogenous
1	Service stations	Y_2, Y_5	$X_2, X_8, X_9, X_{11}, X_{12}, X_{14}$
2	Restaurant seats	Y_3	$X_5, X_8, X_9, X_{11}, X_{12}, X_{13}, X_{14}$

Equation	Item Forecast	Variables Included	
		Endogenous	Exogenous
3	Motel rooms	Y_2	$X_2, X_3, X_4, X_8, X_9, X_{10}, X_{11}$
4	Industrial developments	Y_2, Y_5	$X_2, X_3, X_5, X_7, X_9, X_{10}, X_{11}, X_{13}, X_{15}$
5	Other commercial developments	Y_1, Y_4	$X_1, X_2, X_4, X_6, X_7, X_{10}, X_{15}$

The statistical method of estimation chosen for this study is the two-stage least-squares technique, which comprises a system of reduced-form equations and a corresponding series of structural equations.

A reduced-form equation is an ordinary multiple regression equation that expresses an endogenous variable (Y_i) as a function of the entire set of exogenous variables (X_i 's). Since there are five endogenous variables, there will be five reduced-form equations. The first reduced-form equation for service stations would appear as follows:

$$Y_1 = \beta_0 + \beta_1 X_1 + \beta_2 X_2 = \dots + \beta_{15} X_{15} \quad (4)$$

The equations for restaurant seats, motel rooms, industrial developments, and other commercial developments would be similar in nature. The system of reduced-form equations can be viewed as providing a rough estimate of the economic potential at an interchange.

The importance of the structural equations is in their ability to estimate the marginal effect on different types of development at an interchange. The reduced-form equation may show the economic potential of an interchange at one level. If a restaurant were built at the site, the economic potential for the interchange might have increased, since the structural equation might suggest the likely appearance of service station or motel development. For example, the structural equation for service stations would be as follows:

$$Y_1 = f(Y_2, Y_5, X_2, X_8, X_9, X_{11}, X_{12}, X_{14}) \quad (5)$$

where the function f is assumed to be linear and

Y_1 = number of service stations,

Y_2 = number of restaurant seats,
 Y_5 = number of other commercial developments,
 X_2 = change in community population density,
 X_8 = cross-route ADT,
 X_9 = total ADT (cross-route plus Interstate),
 X_{11} = change in county population density,
 X_{12} = county real estate market value per square kilometer, and
 X_{14} = change in county real estate market value per capita.

In addition to providing a description of the marginal effects of the relevant endogenous variables (Y_2 , Y_5) and exogenous variables (X_2 , X_8 , X_9 , X_{11} , X_{12} , X_{14}) on service-station development Y_1 , the structural equation can be used for forecasting purposes.

Note, however, that unlike the reduced-form equation for service stations, which contains only exogenous variables as predictors, the structural equation contains two endogenous variables (Y_2 = restaurant seats and Y_5 = other commercial developments). Values for these variables can be "preset" to simulate differing conditions, or they can be estimated by using the reduced-form equations. These estimated values (\hat{Y}_2 , \hat{Y}_5) would permit the structural equation to forecast service stations Y_1 . The equation would appear as follows:

$$Y_1 = f(\hat{Y}_2, \hat{Y}_5, X_2, X_8, X_9, X_{11}, X_{12}, X_{14}) \quad (6)$$

Similarly, the remaining four equations can be identified by referring to the preceding text table and then to Table 1 for the description of variables.

RESULTS AND RELIABILITY OF THE MODEL

The model is designed to use information that would be available and inexpensive to obtain. The model forecasts on a 5-year time horizon (t_{+5}) by using data from a model base year (t_0) and from 10 years before the base year (t_{-10}). In this study, the model base year was 1970. Hence, $t_0 = 1970$, $t_{-10} = 1960$, and $t_{+5} = 1975$. Data necessary for t_{-10} and t_0 can usually be obtained from secondary data sources, whereas t_{+5} requires only a determination of years elapsed since the opening of the interchange to traffic.

Estimates of the parameters (i.e., regression coefficients or β -values) for the reduced-form equations are given in Table 2. Estimates of the parameters for each of the five structural equations, along with levels of statistical significance, are given in Table 3. The levels of significance for the two-stage least-squares method are only approximate because the estimated parameters

Table 2. Regression coefficients for reduced-form equations of the model.

Variable Symbol	Service Stations	Restaurant Seats	Motel Rooms	Industrial Developments	Other Commercial Developments
X_1	0.000 422 82	0.075 927 33	0.056 178 56	-0.000 992 84	0.003 967 48
X_2	-0.010 280 53	-0.997 604 56	-0.270 139 77	0.004 882 91	0.025 292 85
X_4	-0.000 001 18	-0.000 149 70	-0.000 058 74	0.000 001 02	-0.000 000 22
X_4	0.000 002 18	0.000 274 92	0.000 107 86	-0.000 001 18	-0.000 003 27
X_5	-0.000 057 05	0.026 105 43	0.002 678 48	0.000 013 43	-0.000 373 50
X_6	-0.000 017 83	-0.011 052 28	0.000 075 90	0.000 009 86	0.000 679 03
X_7	-0.042 111 40	-6.892 275 00	-0.417 441 43	0.037 839 47	0.092 237 64
X_8	0.000 277 33	0.032 658 78	0.014 450 38	-0.000 030 43	0.000 089 24
X_9	0.000 007 41	-0.000 410 62	-0.001 792 69	0.000 047 94	0.000 068 93
X_{10}	-0.010 774 29	-2.053 554 78	-0.454 444 64	-0.001 601 66	-0.017 508 35
X_{11}	-0.021 350 43	-3.402 202 53	-0.865 929 38	-0.000 794 56	-0.020 186 76
X_{12}	0.000 003 55	0.000 623 27	0.000 138 61	0.000 000 75	0.000 005 10
X_{13}	-0.001 139 06	-0.194 786 76	-0.043 188 11	-0.000 427 32	-0.001 374 53
X_{14}	0.001 275 09	0.196 495 65	0.055 376 36	0.000 361 40	0.001 716 75
X_{15}	0.000 003 45	0.001 991 82	0.000 766 93	-0.000 021 09	0.000 029 90
Constant term	4.419 570 22	512.566 808 64	97.497 337 29	-0.005 572 36	1.971 363 26

Table 3. Structural equations.

Variable Number	Service Stations ($R^2 = 0.364$)		Restaurant Seats ($R^2 = 0.812$)		Motel Rooms ($R^2 = 0.789$)		Industrial Developments ($R^2 = 0.334$)		Other Commercial Developments ($R^2 = 0.319$)	
	C	S ^a	C	S ^a	C	S ^a	C	S ^a	C	S ^a
\hat{Y}_1									0.642 596 76	0.03
\hat{Y}_2	0.002 745 50	0.02			0.191 492 34	0.0000	-0.000 307 30	0.41		
\hat{Y}_5			3.297 726 34	0.0000					0.180 183 44	0.42
\hat{Y}_4										
\hat{Y}_1	0.120 005 52	0.22					0.094 439 38	0.23	0.004 639 79	0.01
X_1									0.032 158 79	0.001
X_2	-0.004 565 31	0.03			-0.167 996 79	0.13	0.001 669 30	0.17		
X_4					-0.000 018 27	0.09	0.000 000 31	0.015		
X_4					0.000 063 74	0.05			-0.000 004 35	0.004
X_5			0.010 004 22	0.01			0.000 027 47	0.25		
X_6									0.000 250 60	0.02
X_7							0.038 955 90	0.09	0.127 598 55	0.04
X_8	0.000 162 97	0.01	-0.015 703 54	0.05	0.007 527 08	0.0002				
X_9	-0.000 015 57	0.33	0.003 468 90	0.11	-0.001 145 39	0.10	0.000 036 19	0.08	0.000 047 77	0.23
X_{10}					-0.015 858 51	0.28	0.000 816 85	0.14	-0.002 491 35	0.07
X_{11}	-0.003 984 43	0.32	-0.209 708 69	0.39	0.001 156 63	0.498	-0.000 040 46	0.497		
X_{12}	-0.000 000 07	0.40	-0.000 012 84	0.33						
X_{13}			-0.018 156 12	0.30			-0.000 164 66	0.04		
X_{14}	-0.000 194 16	0.11	-0.019 601 02	0.36					0.000 036 06	0.11
X_{15}							-0.000 023 50	0.02		
Constant	1.619 946 49	0.0001	85.753 694 26	0.07	2.960 407 55	0.40	-0.500 386 49	0.13	-2.487 985 89	0.06

Note: C = regression coefficient; S = probability significance level.

^a Uses a one-sided t-ratio and indicates the likelihood that the relation could have been a chance occurrence.

Figure 1. Comparison matrix of actual versus predicted numbers of service stations per interchange.

ACTUAL NUMBER OF SERVICE STATIONS	9	8	7	6	5	4	3	2	1	0
								1		
				1	2	1				
				1	1					
			6	3	2	2				
		7	15	3	2					
		5	14	7	1					
		16	17	1				1		
		13	6							
PREDICTED NUMBER OF SERVICE STATIONS										
	0	1	2	3	4	5	6	7	8	9

of the structural equations and their standard errors are not unbiased. Since, however, the technique does generate asymptotically unbiased estimates for the parameters, the relatively large sample size ($n = 128$) should provide a "rough" guide to significance levels.

Each equation was tested and found to be statistically significant by using the classical F-test at the 1 percent level or less. The proportion of explained variation ranged from approximately 32 percent for other commercial development to 81 percent for restaurant seats. A Student's t-test at the 10 percent level resulted in other commercial developments having the greatest number of significant variables (7) and service stations and restaurant seats having the least (3). The equations for motel rooms and industrial development each had five significant variables.

Cross-route ADT, as expected, was highly significant in explaining highway-oriented development—i.e., service stations, restaurant seats, and motel rooms. It was the most important factor in explaining service-station development and ranked second and third, respectively, in motel-room and restaurant-seat development.

The equation designed to forecast restaurant seating is one of the more capable developed in this study. The variable that provided the strongest relation with restaurant seats was number of motel rooms. This close association can be explained, in part, by the fact that many motel developments integrate restaurants as part of their services. This close association also held true in the structural equation designed to forecast motel rooms.

The most important factors that explained other commercial development were local community factors. Change in community population density was the most significant. This suggests a strong reliance of other commercial development (as defined in this study) on the local community in which the interchange is located.

To visualize the model's ability to forecast development, matrices were constructed to compare actual and forecasted levels. If the model predicted perfectly, all values would lie along the diagonal of a matrix. An example of the matrix for service stations is shown in Figure 1. The cell counts represent the number of interchanges. The model forecasted accurately within the

target ranges approximately 27 percent of the time for service stations, 46 percent for restaurant seats, 48 percent for motel rooms, 59 percent for industrial development, and 34 percent for other commercial development. The capability of the model to predict the level of development within two categorization units is higher than 90 percent for each endogenous variable.

CONCLUSIONS

The research reported in this paper has developed a method to forecast potential growth levels at highway interchanges. The model can be used in the planning and design of future interchanges and land use regulation. It is applicable to the study and simulation of the impacts of various interchange sites before the final location and design of a specific interchange. It can also be used in the redesign of obsolete interchanges.

In this study, a five-year planning horizon was used to develop a model that was essentially static in nature. Many of the interchanges in this study experienced an initial increase in service stations, motels, or restaurants but little change in subsequent years. On the other hand, non-highway-oriented developments tended to develop slowly and continued to grow as the interchange matured. Research into dynamic modeling would be desirable where the levels of the variables change over time and the sequences of the endogenous variables are described. Designing and determining the proper structure for such a dynamic model are complex tasks that could be aided by the results of this study.

The predictive capabilities of the model might be improved by using more refined measures of development than the "crude" measures used in this effort. A criterion of this study was to use easily discernible variables. However, attributing a value of one to an industrial development indicates its existence but gives no indication of the size or scope of the business, the space requirement, or the traffic generation potential.

One factor that might show promise as a measure is gross floor area of commercial and industrial development. Traffic generation rates for restaurants, shopping centers, and offices are expressed in units of gross floor area, which makes the model's results directly applicable (16, p. 135).

In addition, the total number of parking stalls or area for public and employee parking might provide a better rough measure of endogenous development than this study's method of "binary" measurement of one if a development exists or zero if otherwise, without regard to the extensiveness of the enterprise. Generally, it follows that the larger the development is, the greater is the number of employees and, on the average, the greater is the parking area. This may not hold true for a highly automated manufacturing plant or a development served by public transit.

Finally, the move to suburban and nonurban areas is still in progress in many American cities. Nonurban interchanges close to cities may become targets for rapid, possibly unrestrained, new development. The model may be applicable in the initial stages of urbanization. As the area urbanizes further, new equations would have to be constructed by using the methodology developed for the present model.

The user of the model should keep in mind that the parameter estimates for the model were based on historical data. Structural changes in the general economy, such as the cost and availability of energy or governmental policies, might significantly alter the values of the variables on which this model is based. To the extent that these changes occur, the model forecasts may tend to be inaccurate. Thus, an update of the parameter

estimates should be undertaken.

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Abridgment

Transportation Regulations in an Urban Economy: A Dynamic Model of Their Impacts

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An effort to assess the various economic impacts of vehicle restrictions and transit incentives in an urban setting by using a dynamic, interactive simulation model is discussed. The Manhattan central business district (CBD) serves as a focus for the modeling effort. The transportation actions studied are strategies proposed for the local transportation control plan, as required for New York City and most urban areas under the Clean Air Act of 1970. Changes to the CBD business sector (volume of business and employment), the transportation sector (vehicle volumes and mode splits), and the residential sector are studied. The model, which uses the Dynamo structure, is dependent on key simplifying assumptions joined in a feedback relationship in such a way that the effects on one sector influence changes in another. The model finds that the traffic-reduction strategies accomplish their goals only at the expense of economic well-being and that transit inducements alone have the snow-

balling effect of increasing business and vehicle activity in the CBD. However, combining vehicle-restraint policies with transit inducements can relieve congestion, primarily through modal shifts rather than reduced customer activity, so that the economic consequences are less onerous.

This paper discusses the effort to assess, through use of a dynamic, interactive simulation model, the various economic impacts of selected transportation policies and programs (1). The types of transportation actions examined are those developed as part of an urban area's