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Foreword

There is more continuity in the material presented in this RECORD than might be apparent at first observation. A report on the panel discussion of whether model building and the computer will solve our economic forecasting problems, and the paper by Boyce and Goldstone describing a regional economic simulation model for urban transportation planning, relate directly to forecasting methods and their application. The Gamble, Raphael and Sauerlender paper describes the application of a method closely allied to forecasting: the input-output technique. The other two papers—by Trier and Kubitz and by Sawhill and Ebner—relate in one way or another to the observed impact of highway construction on an isolated rural community and an urban residential community, respectively. All of the information contained in this publication should be of special interest and value to highway and transportation researchers and planners.

The question posed for the panel discussion is a provocative one: "Will model building and the computer solve our economic forecasting problems?" This discussion, which constituted an entire session of the 45th Annual Meeting, was sponsored by the Committee on Economic Forecasting to highlight a trend which has recently become more and more pronounced among forecasters, and one which has caused a considerable concern in some quarters. From the remarks of the panelists and of the discussants it seems evident that economic models and computers are actually only tools which may be used by forecasters to produce better forecasts. When their true function is recognized, forecasters of economic quantities should not only be able to make better forecasts, but also to revise and update them with much less difficulty.

Boyce and Goldstone deal with the application of a regional model, originally developed for water resources planning, in the forecasting of future population and employment for use in urban transportation planning. The model consists of a set of recursive difference equations describing the demographic and employment sectors of a metropolitan region and its growth. Computer simulation studies on the model enable the testing of alternative assumptions and hypotheses concerning the region's future.

The paper by Gamble, Raphael, and Sauerlender is based on research performed at Pennsylvania State University. An input-output analysis for a "microregion"—Clinton County, Pa.—was applied in measuring the economic impact of new highways on the region. This application required addition of further sectors to the model, and the development of certain new inputs which had to be estimated. This is an interesting application of techniques not heretofore considered to be applicable to this type of research.

Trier and Kubitz described the impact on a rural community of a new modern highway which provided access to a village in Arizona, long considered to be the most isolated village in the United States. Although presented in an abridgment in this RECORD, this material is of special interest to those concerned with the impact of highways on underdeveloped areas.

The last paper, by Sawhill and Ebner, is presented in abridged form and deals with the effects of two newly constructed freeways that traverse rather than circumscribe and established residential neighborhood in Seattle. The research reported on was conducted in 1964 and 1965 under the sponsorship of the Automotive Safety Foundation. Although at the time of the study it was difficult to determine precisely what the total economic impact on this area will be, observed decreases in traffic volumes and accidents on the existing street network represent definite gains to the area.

Contents

Will Model Building and the Computer Solve Our Economic Forecasting Problems?

Background to Panel Discussion

C. A. STEELE, Deputy Chief, Economics and Requirements Division, Bureau of Public Roads; Chairman, Committee on Economic Forecasting

This panel discussion of the question of whether model building and the computer will solve our economic forecasting problems is sponsored by the Committee on Economic Forecasting of the Department of Economics, Finance and Administration. The Committee is of the opinion that an open discussion of this question by experts in the field of forecasting and the application of forecasting will be one of the most useful contributions that it can render at this time because of the timelines of the subject. Some explanation of how this program can to be set up is, perhaps, in order.

In the fall of 1959, some of us in Public Roads became concerned about the accuracy of economic forecasts that had been used as a basis for estimates for highway needs prepared by the state highway departments and the Bureau of Public Roads. We had observed that in past years the record in economic forecasting for the measurement of highway needs had been almost exclusively one of woeful inadequacies. There were indications, however, that with a longer period of experience on which to build, the availability of more accurate and detailed statistics, and better techniques to be applied, the record in recent years had been improving.

Accordingly, E. L. Kanwit, now Secretary of the Committee of Economic Forecasting, T. R. Todd and I decided to collaborate in a study in which previous forecasts would be examined with the aim of determining if they had been inadequate and, if so, why, and what might be done toward making future forecasts more adequate. After rather extensive analysis, we concluded that some recently made forecasts had not failed by any means to serve the purposes for which they were prepared, and that there seemed to be no need for future failure in economic forecasting, particularly at the national level, if the forecasts were made intelligently and with due consideration being given to all essential factors. The result of our investigation was a paper entitled, "Need We Fail in Forecasting?" which was presented before the Annual Meeting of the Highway Research Board in January 1960, and published in Bulletin No. 257.

The paper evoked considerable interest and discussion in certain quarters, which resulted in formation in late 1960 of the Highway Research Board Committee on Economic Forecasting. The Committee was created with the aim of studying the types of economic forecasts required for the proper planning, design and administration of the highway transportation function; studying the past record of such forecasts; and investigating methods by which the forecasts were made with the objective of determining better methods that could be applied in making similar forecasts in the future.

The Committee has not attempted to conduct research with its own forces but has, instead, relied on stimulating, coordinating, and evaluating research conducted by others. The Committee has maintained close contact with two projects designed to study forecasting methodology. One was a study of forecasting techniques undertaken

Sponsored by Committee on Economic Forecasting and presented at the 45th Annual Meeting.

by the University of Missouri under contract with the U. S. Bureau of Public Roads. Professor Robert W. Paterson has been the director of this study, the final report on which has been completed in preliminary form and is now undergoing minor revision. The other project has been a study with a similar objective conducted under the direction of the Virginia Council for Highway Investigation and Research at the University of Virginia. The final report on that study, entitled "Phase Three: Forecasting and Estimating," prepared by Ira F. Doom and Marvin Tummins, was released in November 1965 by the Council. The Committee has also from time to time distributed to its members copies of various recent forecasts of economic factors relating to highways and has also distributed lists of recent publications relating to forecasting.

Some members of the Committee have recently become concerned about the reliance that is seemingly placed in some quarters on model building and the use of the computer in solutions to economic forecasting problems instead of placing reliance on common sense and experience of the forecasters that have been so important in the past. It was decided to recommend to the Highway Research Board that a panel discussion to deal with the question of whether model building and the computer can be expected to solve our economic forecasting problems be scheduled for the 45th Annual Meeting. The suggestion was accepted and the Committee proceeded to acquire a chairman, panel members, and discussants. It was decided that in order to avoid any possible bias in favor of the position held by certain Committee members the chairman and the members of the panel would be selected from outside the Committee membership, although the discussants would be selected from the Committee roster.

We were especially fortunate to obtain as our moderator Dr. Sidney Goldstein, at that time Chief, Economics and Requirements Division, Bureau of Public Roads, (but now Associate Director, Office of Economic Research, Assistant Secretary of Commerce for Economic Development); a member of the HRB Department of Economics, Finance and Administration, and Chairman of its Committee on Indirect Effects of Highway Improvements. In selecting the panel we sought representation from those, both on and off the campus, concerned with the theoretical aspects of the question; from those who are makers and users of forecasts in connection with planning activities of one kind or another; and from representatives of industry who have a direct concern with forecasting, especially short-range forecasting.

We were very successful in obtaining our panelists. We sought what we believe to be outstanding representatives of their fields. One of them, Dr. Chinitz, who was selected to represent the university point of view, changed his affiliation before the meeting from the University of Pittsburgh to the U. S. Department of Commerce; however this makes him no less desirable as a member of our panel.

Obtaining our discussants from among Committee members was not so easy. When Professor Bassie, of the University of Illinois, advised at the last moment that he would be unable to be here, Dr. R. W. Paterson, Director of the Bureau of Business and Government Research at the University of Missouri, kindly consented to step in the breach. Dr. Robinson Newcomb was also scheduled to be a discussant, but could not attend; consequently, we are limited to two discussants, Dr. Paterson and myself.

Opening Remarks

SIDNEY GOLDSTEIN, Chairman

I must admit that I was quite pleased when asked to chair this session. The subject was interesting to me and to the large number of you who responded by being present. I suspect that your curiosity was piqued by the provocative manner in which the panel subject was stated: "Will Model Building and the Computer Solve Our Economic Forecasting Problems?" Such a provocative question requires a philosophic stand on the part of the panelists, drawing upon their individual experience in short- and long-term forecasts. And I assure you that the Committee has sought to represent various viewpoints on economic forecasting by individuals who have also been associated with transportation problems.

If we examine the HRB program this year, we can find sessions dealing with traffic models, trip generation models, activities allocation models, land use models, all indicating a preoccupation with the need to build realistic representations of the present for us in predicting the future. Some of these are bolstered by theories of behavior, empirical induction and some by happenstance. Yet most of such models accept economic forecasting results as their basic input.

In hearing the various viewpoints today, we will note that some will be intrigued by the mechanics of the computer or the mathematics and solution aspects of model building efforts; others see alternately, problems and possibilities in depicting and predicting the economic aspects of human behavior and still others see no limit in terms of integrated systems analyses.

We expect that our conferees will shed some light on the problems and solutions and we suspect there may be considerable agreement among our panelists despite their backgrounds.

Remarks by Panelists

NATHAN CHERNIACK, Transportation Economist, The Port of New York Authority

•IN my effort to answer the question posed for discussion, I shall limit myself to the field I have some knowledge of; namely, types of research needed for a proper understanding of urban passenger transportation problems.

We are constantly being called upon to forecast changes in future passenger travel resulting from socio-economic changes or to estimate changes in travel behavior that would result from changes in travel impedances along existing or proposed transport facilities. On the basis of such estimates, mature policy decisions are being formulated for actions with respect to transport facilities. We are discharging our assignments to the best of our current understanding of passenger travel behavior.

To the extent that our forecasts have been based on empirical approaches, they have at least been endowed with a degree of validity. On the other hand, we must certainly be aware that current behavioral models must still be considered as mere hypotheses of how humans behave in the abstract; they will have to be tested and repeatedly validated before they will evoke sufficient confidence to be used as effective aids to mature judgment. In the field of human behavior generally and in travel behavior, in particular, we do not now have generally acceptable and dependable behavioral principles to fall back on. Moreover, it will be decades before we shall have developed general rationales of travel behavior in which we shall have a high degree of confidence.

At the present state of the art, we should therefore avoid producing the impression that computerized models will invariably yield more precise forecasts, will disclose startling discoveries not previously sensed through experience, or that they will eventually supplant human intuitive decision-making talent. We are still a long way off from that eventuality.

COMPUTERS

To be sure, we presently have at our command, increasingly sophisticated high-speed electronic computers. They can handle prodigious numbers of figures to produce accounting statements, in accordance with generally accepted accounting principles; they can produce statistical tabulations from millions of figures, in every conceivable area, in accordance with standard statistical specifications; they can carry through complex computations in the physical sciences whose models have been tested, revised and repeatedly confirmed by scientists throughout the entire world; they can perform computations in outer space in seconds, can produce outputs on the basis of continuous inputs, in accordance with models of celestial mechanics.

In some of these areas of accounting, statistics and physical sciences, with the magnitudes of figures and the complexities of computation encountered under present-day situations, it would be impossible to carry on without computers.

In transportation analysis and forecasting, particularly in large metropolitan regions where analyses of travel patterns and their determinants have become quite complex, electronic computers in conjunction with empirical models have become important and effective tools for developing an understanding of urban travel behavior. In recent decades, sufficient data on trips and correlative socio-economic data have become available to permit the establishment of empirical relationships that do have rationales underlying them. Such empirical mathematical models that express understandable relationships and that accord with observed experience, when combined with the use of computers that organize, digest, and analyze the voluminous data, do yield reasonable and dependable forecasts of future travel volumes. Under the present state of the art, these are highly desirable techniques. In utilizing these techniques, it is essential, however, to keep constantly in mind that the accuracy and validity of computer outputs of models are never any better than the accuracy of the basic data inputs, the validity of the functional relationships expressed in models, and the assumptions underlying those relationships.

Unfortunately, the availability of modern computers with their tremendous computational and data organizing capacities has led some researchers into a misuse of this valuable tool. Observing the marvels of modern computer performance, many researchers in the behavioral aspects of urban transportation have attempted to utilize the computer to help them make the "great leap forward," from 4 percent samples of urban households to push-button decisions to select the best of proposed alternate transportation facilities. Aware of the high order of the computation capabilities of computers, they have developed complex mathematical models which purport to show scientifically the exact relationships between large numbers of variables depicting the many characteristics of urban dwellers and their transportation responses. In developing these seemingly precise mathematical models, they seem to have overlooked the important facts that there are few, if any, fully validated and generally accepted behavioral principles which can be incorporated in current behavioral models, and few realistic measurable inputs for the computers to digest. Complex mathematical models founded merely on a series of assumptions as to human behavior rather than on factual data, in conjunction with the use of the computer, have thus created an aura of mathematical precision which is completely misleading. It is no wonder, then, that there has been widespread lack of confidence in computer outputs based on such unrealistic models.

It will not be amiss to point out to behavioral researchers that in astrophysics, to go from Tycho Brahe's observations of the motions of celestial bodies, to Kepler's empirical laws, to physical laws of celestial mechanics, to Isaac Newton's law of universal gravitation and finally to push-button missiles, took several centuries. Hence, the complete confidence in outer space explorations.

BEHAVIORAL MODELS

Human behavior is far more complex than are the motions of celestial bodies. Behavioral science is far more elusive and formidable than was celestial mechanics in the seventeenth century. Unlike characteristics of inanimate objects, people's habits and tastes keep changing significantly over time. Hence, it would seem to be in order to pass on to behavioral scientists generally, and researchers in travel behavior in particular, the advice to "make haste slowly." Only after developing useful empirical models can we begin inducing logical behavioral models to explain why empirical models seem to work. And it will also be incumbent upon us to demonstrate and repeatedly confirm their validity. We shall have to develop techniques for predicting their socio-economic determinants too, before we shall have acquired confidence in the ability of behavioral models to yield more precise and more dependable prognostications of future travel behavior than those given by empirical models. Even the most sophisticated computer cannot guarantee the validity of current behavioral models nor the dependability of projected local socio-economic inputs, until dependable factual data are developed. These must still be the researcher's continuing earnest pursuits.

In the current literature on travel behavior, one gets the impression that behavioral models, as a rule, exhibit a number of inherent serious weaknesses. For use as tools in resolving urban passenger transportation problems, behavioral models usually contain entirely too large a number of interrelated variables. In many instances, inputs are neither readily measurable nor predictable. Small differences in the relationships among them sometimes exert powerful leverages on the end products. Parameters of dynamic human behavior have usually not been explicitly stated. Even where they were, they had not been tested nor validated.

A typical behavioral model of urban residential growth, for example, might be described compactly, as in the following.

Future homeseekers of various characteristics, such as age, income, and status are first determined from demographic projections of age-distributed populations for entire study areas, on the basis of birth, death, and migration assumptions. These homeseekers, as "economic men," are then assumed to go through mental linear-programming gymnastics to optimize their travel behavior, under various zonal accessibility and transportation cost assumptions. They hopefully maximize their locational advantages on the land assumed to be available. In the process, they bid up prices of competitor homeseekers, within the constraints of their assumed budget limitations. They meet maximized prices of land and homes, made available through speculative acquisitions by potential land owners and builders, subject to community zoning and development policies. All these numerous inputs are fed into computers through properly designed algorithms. Computers digest these inputs. They are then presumed to bring forth outputs in the form of locational decisions which in the aggregate, will hopefully describe the spatial distributions of households in the study areas, at specified future dates. With such a model we can thus produce undependable outputs much faster with computers, if we are patient enough to wait through the data processing period.

In current mathematical treatment of human behavior, particularly in regression equations, stimuli have usually been treated as if they were forces and subject to laws of mechanics. Now, when mechanical forces are applied in any sequence, they invariably produce the same end result. Mechanical forces can, therefore, be added vectorially, in any sequence, to obtain the same end result. In human behavior, the same stimuli applied in different chains of sequences may produce different end responses.

Unlike mechanistic behavior, human behavior does not appear to react to stimuli uniformly, either in different types of environment, or over time. Do both city and suburban familes with the same characteristics, react transportation-wise in identical ways? Or is the environment the real determinant of behavior, much as some identical chemical reagents react differently under different temperatures and pressures?

Again, people seem to adjust themselves, somehow, in a way to avoid anticipated undesirable end results. Static behavioral models, calibrated on the basis of current data, cannot therefore be used with confidence, dynamically, either as predictors of future trips or as simulators for policy decisions.

It may, therefore, eventually be necessary for human behavior researchers to emulate Isaac Newton, who in the development of his law of universal gravitation, to explain the empirical laws of Kepler, was forced to invent the calculus. Human behavior researchers may have to invent a calculus of human behavior. Such a calculus would reflect the fundamental differences between the interactions of human behavior and those of mechanical forces. Riders with significantly different incomes and occupations may nevertheless be homogeneous with respect to modes of transportation, as reflected in their values of comfort and convenience, and thus choose the same modes in the same proportions.

EMPIRICAL TRAVEL BEHAVIOR RESEARCH

To get on with current action-oriented planning of transport facilities, some planning tools have been and will have to continue to be forged, based on empirical studies. Empirical relationships that have been established between urban passenger movements and socio-economic factors, have at least produced planning rules-of-thumb without intellectually satisfying explanations as to why they happen to work. Empirical models predicated on simple, understandable concepts have been expressed in relatively simple mathematical equations. In large urban areas, however, the voluminous data depicting travel patterns and socio-economic determinants in small areas, have required the use of computers in developing and calibrating empirical models. Computers have also been useful in developing future travel volumes, based on such empirical models, provided of course, there was confidence in the stability of the relationships which had been incorporated in these empirical models.

For example, under empirical approaches, most urban passenger movements have been conceived to be determined by three essential factors: (a) residential or origin areas where trips are generated, (b) nonresidential or terminal areas to which trips are attracted for various social and economic activities, and (c) the travel ways that reflect the spatial impedances through which movements occur between residential areas of trip generation and nonresidential areas of trip attraction.

Empirical models have usually been able to produce logical, reasonable and dependable outputs with only a few and truly independent variables. Thus, person trip generations in residential areas have been logically associated with one major factor, namely, car ownership. This factor has stood as proxy for population and for households of different stages and incomes.

Again, person trip attractions, like CBD work trips for example, have been associated with CBD employment.

Trip attractions are usually concentrated; trip generations are usually diffused over urban residential areas. Consequently, trip attractions could be more effectively sampled in nonresidential trip attraction areas than through household interviews. There, they would be assembled with less effort, than comparable sizes of samples obtained at widely dispersed households in study areas. Much larger numerical cells of person trip linkages would thus be available for correlations with such travel impedances as distance, time, cost, discomforts and inconveniences.

Choice-of-mode studies (currently referred to as "modal split" studies) could also be readily made via all available alternate travel ways, if assembled in nonresidential areas of concentrated trip attractions to show linkages with widely dispersed trip generating areas. Empirical correlations based on trip linkage data and travel impedances, assembled in areas of trip attractions, would turn out to be much sharper, more realistic than those based on similar data assembled at households. More effective techniques for forecasting future trip linkages would be possible than those assembled at households and based on iterations of matrixes of current trip linkages between every zone of trip generation and every zone of trip attraction, in study areas.

Let me cite a specific example. In recent years, samples of journeys to work to the Manhattan CBD in New York City, were collected at desks and benches of employees in the CBD instead of at their homes. In conjunction with U.S. Bureau of Census journey-to-work data, these local surveys opened up entirely new vistas of understanding, of work trip linkages and choice-of-mode patterns of employees in the Manhattan CBD.

It appears that 23 (out of 24) counties in the New York-New Jersey-Connecticut Region, as workshop counties, draw most of their employees (close to 90%) from workers resident in the same or contiguous counties. On the other hand, Manhattan (New York County, the 24th), as a workshop county which contains the Regional CBD, draws only one-third of its employees from Manhattan, some two-thirds from other counties in the Region.

Among the distinguishing characteristics of work trips to the Manhattan (the Regional) CBD, were the following:

1. The Manhattan CBD, with about 2.0 million jobs, employs a much larger proportion of females (45%) than other workshop areas (30%).

2. The CBD draws much larger proportions of female clerks from the region's female clerical labor pools with low trip costs than from pools with high trip costs to the CBD.

3. Male executives, on the other hand, are much less sensitive to trip costs; the CBD, therefore, draws larger proportions of executives from the Region's male executive labor pools in distant suburban residential areas.

4. Work trip linkages thus appear to be related to two major factors: (a) sizes of specific types of labor pools in the Region's dormitory areas and (b) trip costs from these labor pools to the CBD.

5. Workers' choices of travel modes (or modal splits) on the other hand, depend, in the first place, on whether there is or is not mass transit available between a dormitory area and an area of employment. Secondly, where there is mass transit available, the proportion of workers who choose mass transit in preference to autos depends largely on whether the mass transit terminals are convenient (a) to both the site of employment and the home, (b) only to the site of employment, (c) only to the home, or (d) to neither the site nor the home; the proportions who choose mass transit drop significantly in that order.

These conclusions are cited briefly in the belief that conclusions like these should form the bases for hypotheses and models of CBD work trip patterns. They should be subjected to tests throughout the nation wherever applicable and practicable. Such tests would either disprove the hypotheses, modify them or endow them with sufficient validity to raise their status to validated theories. The theories would then be tested as predictors, under future socio-economic and travel impedance conditions or simulators under assumed policy changes with respect to operations of transport facilities.

SUGGESTIONS

If we wish to solve some of our economic forecasting problems sooner and more effectively, it is suggested that we adopt the following time-tested procedures.

1. Make periodic resurveys of CBD work trips; there is where our transport problems are to be found, on weekdays. Keep accumulating a historic series of comparable CBD work trip bench marks.
2. Inaugurate periodic assembly of a series of local urban socio-economic statistics, specially tailored to meet the peculiar needs of urban transportation research; thus, overcome present serious inadequacies of data on basic determinants. For example, periodically assemble car ownerships in small residential areas: all types of employment (white as well as blue collar) in CBD's and other small urban workshop areas.
3. For feedback purposes and for continuing improvement in forecasting techniques, let us be courageous enough to prepare periodically, (a) short-range verifiable forecasts of local socio-economic factors and (b) forecasts of verifiable segments of person trips. For example, forecast auto registrations for small areas, verifiable from annual state records of car registrations; forecast CBD work trips, by occupational groups, to small CBD zones, verifiable from continuing state records of covered employment.
4. On the basis of subsequent recorded data, determine the overall forecasting errors. Distinguish them between (a) errors in predicting future socio-economic determinants and (b) those that result from either unstable parameters of empirical models or unrealistic functional relationships incorporated in behavioral models. This practice will be highly rewarding.
5. Develop a simple, acceptable generalized hypothesis that will intimately relate the functions of local transport facilities in contributing toward local socio-economic activities. It should describe how the fundamental factor of urban population growth starts in motion the expansion of local activities which create the need for more travel and hence for improved and expanded transport facilities. It should also describe the return portion of the cycle: how new and improved transport facilities themselves, in turn, by reducing travel impedances, tend, in conjunction with other amenities, to stimulate local activities that, then, spatially redistribute expanding populations within urban areas. Such an hypothesis would give direction to urban passenger travel behavior research.

CONCLUSIONS

In summary I would conclude that at the present state of the art of travel behavior research, if we really intend to redeem the promises of models and computers, we should avoid escaping into the never-never land of deductive, data-less, library-produced mathematical model-building, founded on so-called postulates of motivating human values about which we know little and agree on even less. We should avoid pretending that computerizing current travel behavioral models and hypothetical inputs, do in fact, represent simulations of real human behavioral interactions; they do not.

Computers certainly are most powerful tools for analyzing the prodigious numbers of possible permutations and combinations of suspected socio-economic effects on travel behavior. But we must continue to develop specially designed adequate data on the travel determinants, crystallized around hypotheses induced from such data which today we do not have and which we sorely need. Analysts, with the aid of modern mathematics, could then instruct computers skillfully enough to distill ounces of real valid behavioral models of travel demand from the tons of statistics we shall be producing.

BENJAMIN CHINITZ, Deputy Assistant Secretary for Economic Development, U. S. Department of Commerce

[Dr. Benjamin Chinitz has provided a brief statement of the points he made in his discussion.]

•MY own experience suggests that models are inadequate for capturing two very significant aspects of economic growth. The first is the capacity of a region to adjust to economic change. By that I mean the ease or difficulty with which a regional economy confronted with a decline in the demand for its traditional industries can reorient its economic assets—management, labor, capital, and other resources—in new directions and develop new kinds of industry. This is a problem in identifying turning points rather than trends and is, therefore, not very amenable to the kind of formulation which is typical of such models.

The second difficulty with models is the problem of incorporating the feedback from transportation to economic development. The models are typically designed to forecast the economy and work out the implications for transportation investment, but the reverse relationship in which investments in transportation affect the shape of economic development is not readily taken into account.

JOEL DARMSTADTER, Associate Director, Center for Economic Projections, National Planning Association

•I consider my appearance here similar to that of a representative of the National Association of Home Builders, responding to the question "Will Public Housing Solve Our Housing Needs?" This is because I am not a computer specialist, and, at best, a builder of rather simplistic economic models. Since I could give an affirmative answer to the question only at peril to my job security, you must allow for at least some bias in my discussion of the topic.

I will not belabor a self-evident point: that the question which forms the topic of this session is designed to needle us into debate rather than to commit us to firm answers, for economic predictability is obviously a matter of degree, varying with innumerable factors. My own preference is to consider how model building and the computer can improve ways of making projections—not because I want to subordinate problems of accuracy or reliability, but because I think it appropriate to broaden our perspective on these issues.

Although it takes no more than a simple, symbolic or algebraic representation of even a tautological process to have a model, for practical purposes we regard a model as a statistical, and often sophisticated embodiment of complex and theoretical behavioristic or structural relationships. The enormous resources of the computer have tremendously enlarged the feasible scope of economic models; nevertheless the computer is still a tool—one whose usefulness is governed by the attributes and limits of the model which it is supposed to serve. This possibility for meaningful use of computers in model building in general and projections in particular is probably a major development in economics during the past several decades. What we have seen is a three-pronged confluence of forces:

1. The active interest in macro-economic theory and its increasingly acknowledged applicability to planning problems, where the growing interest in planning, in turn, reflects increased confidence about the controllability of events;
2. The great advances in empirical knowledge on both aggregative and highly detailed levels; and
3. The demonstrated ability to advance the linkage between theory and empiricism through computer processes and modern data processing.

Thus, modern computing facilities are no longer a major obstacle to testing or to effective implementation of a model irrespective of its size; however, this does not mean that the larger the number of equations and the more disaggregated the variables, the more useful will be the contribution of the model. It may in fact mean that we have created a monster, that we have lost expositional control over the model, and that implications of the model elude us. This leads to the most obvious of points: that the limits of computer capabilities extend well beyond the limits of their usefulness in economic analysis; in other words, that the available supply of computing time should not automatically create an equivalent demand by economic model builders. The rather poor short-term forecasting record that Zarnowitz, in his National Bureau study, is finding for sophisticated econometric approaches, compared to simple, judgmental estimates, underscores this point—as does the succession of familiar computer jokes: right or wrong the computer always being accurate; or the computer, replete with more answers than we can digest, beginning to generate the problems to which it has answers.

Obviously, there are forecasting problems which can be handled in an uncomplicated, "uncomputerized" fashion. Thus, while in Daniel Suits' 32-equation econometric forecasting model of the United States economy, successful implementation obviously requires both a complex model formulation and computer facilities, a simple consumption function might be wholly adequate for aggregate projection purposes and analysis of overall fiscal policy without necessitating recourse to enormous data processing facilities. As to our own experience in computer use at the National Planning Association, I imagine it parallels the experience of many others—and that is its "trivial" and unglamorous but absolutely indispensable role in elimination of sheer computational drudgery. Computer handling of multiple correlations, iterative procedures, and innumerable other operations has significantly freed manpower for needed analytical tasks.

Let me now revert to the matter of the relative accuracy which we can strive for in forecasting. A short review of some of the factors bearing on accuracy can help more clearly to define the areas where formal models and/or computer processes may be of significant assistance to the forecaster. (And, incidentally, I am here using "forecasting" and "projections" interchangeably; strictly speaking, I am talking about projections as the representation of hypothetical forecasts.)

There is first the matter of the time span. I do not think anyone would seriously argue that projections to the year 2000 (and these—painful and self-conscious as one feels at having to prepare such estimates—are in increased demand for such types of program-planning as transportation, recreation, and water resources) should place major reliance on solutions generated by a formal model. Rather, the analyst wants to be able to introduce critical judgments about technology and substitutability of industrial materials, population and consumer behavior, and policy. This does not mean that important "submodels" within the projections (say, estimates of electric power requirements) might not advantageously be cast within some kind of model structure and programmed for solution; and, obviously, if a computer can free us from routine and tedious, but necessary and time-consuming calculations, it allows more time for analysis and contributes indirectly to improved projections.

Next, the question of detail, industrial and geographic. If one's needs are satisfied by just a simple GNP estimate (say, ten years hence) then a model might have some expositional value, but really, the estimation—following arithmetic interrelationships among population, labor force, employment, and productivity—can be carried forward without an elaborate framework or computational system. This acknowledges the fact that a number of macro-aggregates behave in fairly predictable ways even though the extent to which this predictability reflects chance offsets among components or "historical law" often eludes us. As scholars, this unknown nags us; as pragmatists, it need not bother us too much.

On the other hand, if we are interested in substantial detail (say, manufacturing output projections at the three-digit level) or in aggregates that must be corroborated by disaggregated analysis, then, both the discipline of an organized model and the computational resources of an electronic computer are vital. We need take note only of the three-minute solution by "inversion" of an 85-sector input-output coefficient matrix.

In the generation of detail, the forecaster must consider the importance which is likely to be attached to the numbers by the user. I do not mean the margin of error historically calculated for a given series. I refer to the point at which the sheer volume of data output exceeds the forecaster's physical capacity for examining and modifying the results on the basis of judgment, assuming, of course, that even with built-in model constraints, this "red flag" function can never successfully be left in its entirety to the computer. We have recently been putting partial reliance on a computer program to develop some regional migration and commutation forecasting factors, as based on census data. In examining some first run results, we notice that there would be some future commuting from a Pennsylvania county to Hawaii—nothing much, of course, but the mere idea seemed intriguing. It seems that in the historical series constituting the data input, there was indeed a recorded case of a commuter to Hawaii who, given the small size of the county in question, got himself converted into an extrapolated trend for the future.

A word now on forecasting accuracy in relation to alternative assumptions, particularly with respect to policy variables. It is old hat to state that projections are no better than the assumptions on which they are constructed. Miscalculate long-run trends in women's labor participation rate or future levels of defense spending (let alone short-term forecasts of cyclical turning points) and the projection will turn out to have been inaccurate—inaccurate, most likely, not because the model was not sufficiently comprehensive, or because the computer was incorrectly programmed, but because there were events that are simply impossible to anticipate in timing, magnitude, or in their very occurrence, with sufficient exactitude to be meaningfully projected. This danger of inaccuracy is not lessened, but its consequences for planning are, when we provide projections in alternative formulations.

Though overlapping, two major reasons for providing alternatives may, in this light, be conveniently distinguished. First, it is useful to indicate a range of likelihood as dictated by possible long-range variability in the behavior of the indicator being projected. Second, it is instructive to consider explicitly the consequences of, and thereby weigh the desirability of adopting (exogenously) assumed alternative policies.

A projection is after all only a conditional or hypothetical estimate subject to misinterpretation of past events, to distorting random disturbances, to uncertainty about future trends, and to unknowns about policy adoption and policy repercussions. The specificity likely to be attached to a single set of projections can be forestalled by providing alternatives, keyed to varying assumptions. Parenthetically, most of us have the human impulse of wishing to be right, and alternative projections are a tempting means of protecting one's illusions of infallibility. Hence the need to guard against going overboard in the other direction, i.e., a proliferation of alternatives as a "bet-hedging" device. But subject to this restraint, reasonable conjecture over prospective alternative developments is a distinct aid in the continued evaluation of current trends and their implications for the future.

The relevant aspect of this, from the standpoint of this discussion is that policy variability (as illustrated by recent defense increases) can upset our attempts to count on models to attain unattainable degrees of accuracy in a given projection, that the concern with accurate forecasting might be meaningfully joined with consideration of alternatives. Indeed, the job of constructing alternatives can be so time consuming, involving a multiplicity of model formulations, that here is a prime candidate for applying high-speed computational procedures. Thus, the construction of a projected all-out mobilization model with all its formidable analytical requirements can serve a vital planning purpose even if its accuracy in forecasting is never put to an actual test.

One of the things to which we have been devoting a good deal of effort at NPA is the conceptualization of, and a start at using, a three-pronged model approach to economic projections. This involves a normative or target projection which is designed to express and to probe policies needed to achieve the fullest growth potentials of the economy, but under conditions which do not involve recourse to controls or which otherwise depart from established practices and institutional arrangements; a "present-policy" projection—a hypothetical forecast which assumes little change from the present in growth-promoting policies (i.e., which assumes existing tax rates and allows for little expansion in the per capita level of government programs); and a so-called "judgment" projection which is a probabilistic forecast, allowing for slippage from targets, on the one hand, but assuming adoption of new policies (partly as a consequence of the implications of the present-policy projection), on the other. To make this approach operational and valuable for decision-making and planning, we hope to benefit from the concurrent development of a disaggregated man-machine input-output model of the U. S. economy, which is particularly designed to respond to the stipulation of exogenous policy variables.

To come back, then, to the question, as originally posed: "Can Model Building and the Computer Solve Our Economic Forecasting Problem?" They could—

- If this were a Utopia, where economists had complete knowledge and a complete statement of the structural equations describing the behavior of the economic system.
- If we had the mathematical aptitude to solve such a system or to know when and why it had no solution.
- If we possessed all the required data for the list of exogenous variables and for estimating the parameters of the structural relationships.
- And if we had the computers with a capacity to handle the required computation at allowable costs.

If this idyllic state existed, the answer would be "yes"—not only would we be able to foretell results, but we could determine them, since policy makers could bring their proposed policies to the economist who would, in turn, describe the results of each contemplated action; with impact on, and responses by, consumers and businessmen determined, the policy makers could use this information to select the "best" course of action.

Before this Utopia overtakes us, though, there are a few constructive pursuits to which we might well apply ourselves. We might, for instance, strive, where feasible, to deploy model building and computers more than we are now doing to problems of national goals, economic policy, and important program planning areas. (Computers which permit instantaneous, nationwide confirmation of airline reservations, let alone those which track satellites, might help with the creation of a national job-man matching system which would relate job opportunities and available workers nationally, regionally, and locally.) By moving in this direction, we may arrest a growing divergence between the mechanistic and over-abstruse world of the econometrician and a world which needs to solve problems other than those merely of improving forecasting accuracy. If we can use model building and computers to help in explaining and answering policy questions (note that I say "help" in explaining and answering them, not that we can expect explanations and answers from the computer) then we might be doing ourselves a real service.

JOHN A. FRECHTLING, Forward Product Research Manager, Ford Division, Ford Motor Company, Marketing Research Department

•THE more I stare at the title for this session, the more I realize that I am to be followed by two discussants, more commonly known as critics, the more inclined I am to say, "Why not," or "One may certainly hope so." However that really would not be much fun. Furthermore, the question opens up with vast territory of the how and why of advances in knowledge. This certainly gives all of us room for valiant charges without dangerous collisions. Nevertheless, I hope to say a few things which will be considered outrageous enough to provoke fairly lively debate.

What are the dangers associated today with forecasting practices, particularly in the use of computers? They may be succinctly summarized as "Why think, it's so much easier to compute." I suspect that the gap between the toolmaker, the computer specialist and the user with a general training in economics, political science, engineering, etc., is greater today than in the past. The completely educated man must be much rarer today than a century, or even fifty years, ago. More and more people must be specialists, particularly in the earlier years of their working lives before administrative work gives them at least superficial contact with a broader range of viewpoints.

What are the results of this increased specialization? In work by the economist, engineer, etc., the canned program is picked up and used regardless of its applicability to the problem. For example, the seasonal adjustment programs pioneered by the Census are extremely useful tools perhaps 95 percent of the time. But in the other 5 percent, their uncritical use leads to quite absurd results.

Let us look at the other specialist—the one with his principal training in statistics, mathematics and computer usage. His pitfall is usually the rediscovery of what has been known by, say, economists for a generation or so. Recently, I heard an administrator with more than average responsibilities recount with awe their discovery, via computer, that sales of appliances using one type of power were very much influenced by the price and availability of the alternative power source.

I do not know how these inefficiencies can be avoided. I suspect they are inherent in change, even when it may be called progress.

Another aspect of the matching of problem and method is the data problem. While I am not sufficiently well trained in fundamental statistics to draw an airtight case, I am very much afraid that our ability to use more complex methods is outrunning the quality of the data. That is to say that observational and sampling errors are too large to justify such complex manipulations as are now so easily made.

Widespread use of computers should, however, assist materially in solving the "data problem." Along with providing better primary data, computers should be utilized effectively in many of the routine processing operations leading up to data used by the economic forecasters.

We must guard against the danger of insisting on very accurate data when accompanied by a rejection of any analysis which cannot be cast in rigorous mathematical form. In some areas, accurate data are hard to obtain, they are qualitative, their usefulness is linked very much to interpretation by particular people. It is most unfortunate if the trend toward computers and mathematical models is accompanied by lesser appreciation of the skillful interpretation of history.

What are our forecasting problems? First of all, I should like to make it very clear that the problem of economic forecasting has very, very little to do with the annual fall rites of estimating next year's GNP, employment, auto sales, etc.

The heart of the problem is in the use of forecasts. I do not deny that a forecast of next year's activities is of some use. However, in the auto industry and I am sure in many others as well—the real payoffs are in correct assessment and programming of the next four months sales and in the longer-run forecast of capacity requirements. An accurate forecast of next year's sales is of little use unless it also develops the corresponding pattern of monthly sales. But given the lead times existing in the auto industry, production programming seldom requires more than a five or at times six months forecast.

An accurate annual forecast is of no use if three to five years previously an incorrect estimate of capacity requirements was made.

Accurate forecasts are important as they contribute to profits. Before deciding what a particular forecasting problem may be, it is essential to have a clear understanding of lead times involved.

And I must now add a clear understanding of the probable error of the forecast. How does the computer and model building help here? The short-run profit-oriented forecast is very much one of particulars. In our business, it involves body styles, equipment, place. It is not one forecast, but a multitude of forecasts relating expected demand, inventory levels and production. Here the computer stars by providing many more forecasts than formerly were obtained by essentially manual methods from different sources. While judgment and special knowledge may be brought to bear on final plans, the computer's forecasts have the prime virtues of uniformity.

Furthermore, since one of the prime functions of inventory is obviously to absorb forecasting errors, which is practically given, a study of such errors is useful in planning inventory levels. So, give the computer a high score on contributions to many short-term forecasting problems.

On the longer-run forecasts, the ones on which investments are based, computers' contributions do not lie so much in the field of making the forecasts as in investigating their properties. The longer-run forecast should furnish not only some idea of the course of average sales in a period, say, three to ten years out, but also of expected fluctuations. The investment plan depends on not only the average or standard volume but also on expected fluctuations. Capacity and costs must be related not just for averages but for expected deviations from such averages before final investment decisions are made.

I should like to make a short digression here on the virtues of this standard volume approach and its implications for economic forecasting. Because of the violently cyclical nature of the industry in past years, it is not surprising to find the standard volume concept stressed in the automotive industry. However, I am certain that many other businesses—in particular, the business of Government—could benefit from more explicit statements of average and cyclical performance five years out.

Perhaps I am pleading in slightly different form the superiority of rules to authority. Both derive from man's analysis of his problems. But rules, i.e., standard volumes, are the product of analysis and reflection several years before a crisis; authority depends on almost simultaneous analysis and action and then must wait as lags are worked out. Given these conditions, I am fairly sure that hindsight is better than foresight, and foresight is usually considerably more effective than ad hoc decisions.

Considering the contribution of models, there have been models as long as persons of analytic bent have attempted to reduce the diversities of observed experience to a small number of basic relationships. So model building is not really new. Of course, econometric work requires a more specific formulation of the model than was necessary in a more literary era.

Conversely, I believe that one can make a good case that many models for which specific formulations are possible are becoming less applicable to investigation of general economic problems. If the change in economic structure is being affected (as I am sure it is) by the very rapid advance of technical knowledge then one must doubt the applicability of today's models to tomorrow's rapidly changing economic environment. Of course, this is not an argument against mathematical models, but rather one for introduction of a priori probabilities into them. In the post-war period, many forecasts based on econometric work fell short because the environment after the war was radically different from that embodied in the data incorporated in the models. As one looks forward to 300 million Americans by 1990 or 2000, one certainly questions the applicability of much of today's experience to the problems of that day. But this is only 25 years away.

A good example of the impact of changing technology on economic forecasting techniques is afforded by the evaluation of the Keynesian model. Obviously, Keynes drew on the experience of the England of the 1920's in formulating his general theory. And for that England, a simple relationship between consumption and income made sense. But to transfer such a simple relationship to America, even in the late 1930's, let alone 1965, is obviously impossible given the sizable investment decisions being made by consumers for cars, television, housing, etc. So the consumption function is elaborated; more independent variables are added; different types of consumption are introduced. What is left of the original brilliant theory? Progress in solving problems of economic theory lies in new simplifications to a greater extent than in elaborations of existing models.

I think our present position with regard to computers is as follows:

1. Their talents are admirably suited for routing short run forecasts;

2. Their use in more fundamental research may be abused by lack of understanding of economics by computer specialists, of mathematical properties by persons trained in economics; and

3. Computers will, as a byproduct of their use in essentially bookkeeping areas, make a contribution to improved data.

Model building will continue. The apparent speed-up in technological change will insure that problems will proliferate at least as fast as we solve old ones. Therefore, any forecaster worrying about technological displacement by some young crewcut XYZ769 is really needlessly concerned about the perils of automation.

KENNETH J. SCHLAGER, Southeastern Wisconsin Regional Planning Commission

•I am convinced that the primary reason for my appearance on this panel is that I am the only person who was naive enough to answer the panel question in the affirmative. Nonetheless, I will not disappoint the sponsors of this session and will answer with an only slightly qualified "yes." The only qualification necessary is that I would insert the words "help solve" in place of solve in the question. Economic models are a powerful aid but not a substitute for human judgment.

Unlike the other panelists, I cannot present any overall evaluation of the effectiveness of model-based economic forecasting, but I can only share my experiences in the use of an economic simulation model as applied to forecasting in a land use-transportation study in southeastern Wisconsin. This model, designated the regional economic simulation model, will provide the primary subject matter of my presentation.

The function of the regional economic simulation model is to provide a series of conditional forecasts of regional employment and population that are sensitive to public and private policies such as investment in certain industries and the state and local governmental tax structure. These forecasts are then translated into needs for land that must be satisfied in the land-use plan. Since the transportation system is then designed to serve the land-use pattern in the land-use plan, socio-economic forecasts play a crucial role in the overall planning process.

The specific forecasting needs of the land use-transportation study are based on the lead time requirements of various activities in the planning process. To implement a plan, certain commitments such as land acquisition (or reservation) must be made in advance. Facilities must be designed to satisfy expected usage during their life cycle. Forecasts must be of sufficient accuracy to allow these commitments to be made with confidence. In general, the forecasting accuracy requirements become less stringent for longer period forecasts, but specific forecasting accuracy requirements must be determined based on the technical and political nature of the planning function involved. A sensitivity analysis of the effects of forecasts on the land-use plan in a separate mathematical model permits the determination of quite specific forecasting accuracy requirements.

Most transportation studies in the past have developed these required forecasts of population and employment by extrapolation of past trends in individual industries. Although such forecasts do provide an indication of future demand for land and transportation facilities, trend extrapolation has certain inherent shortcomings:

1. It ignores the structural interrelationships existing within the regional economy. Industries such as retail trade and medical services are so heavily dependent on the income generated by base manufacturing industries that independent forecasts for such industries are extremely questionable.

2. It assumes that current trends will continue independent of public and private decisions attempting to modify these trends. Such a forecast procedure is insensitive to any changes in public or private policies including the land use-transportation plan itself. Since many observers feel that the most important effects of a pessimistic

economic study are the changes in public and private policies that are made to reverse its pessimistic conclusions, continuation of current trends may be a poor measure of future employment and population.

3. It ignores the basic information-feedback nature of public and private decision-making. Such decisions are based on continuous evaluation by governmental officials and business men of the current situation and perceived trends. The economic time history resulting from such a process is characterized by dynamic changes in directions not readily forecast by trend extrapolation methods.

It is hoped that the regional economic simulation model will alleviate to some degree the shortcomings of current trend extrapolation methods. Since the model is still at the experimental stage of development, "conventional" forecasts have been developed in southeastern Wisconsin to provide both a basis of comparison and a "backup" if the model does not fulfill current expectations.

A second, but extremely important use of the model, not possible with traditional time series extrapolation, is the determination of the effects of the land use-transportation plan on the regional economy. The feedback effect of the plan will be determined by varying the transportation cost inputs, as they are affected by the plan, in the model.

An additional use of the model, not now part of the program of the Southeastern Wisconsin Regional Planning Commission, but of great potential importance for the region, is that of industrial development. The model should be extremely useful in evaluating the effects of local governmental decisions on the regional economy and the relative importance of individual industries in this economy.

LAND USE-TRANSPORTATION PLANNING PROCESS

A system block diagram illustrating the functional relationships in the planning process is shown in Figure 1. Although this diagram specifically represents the planning sequence related to the formulation of a regional land use-transportation plan, it is typical of other planning sequences.

The first function in the planning sequence is that of employment and population forecasting. The execution of this function using the regional economic simulation model provides the primary subject of the report. The need for and required characteristics of such forecasts are better understood in the light of the succeeding functions in the process.

In the second function, aggregate land-use demand requirements are determined by applying a conversion coefficient usually designated as a design standard to each employment and population category. Such a multiplication and summation will result in a detailed classified set of aggregate demands for residential, industrial, commercial and other land uses. These aggregate demands provide one of the primary inputs to the third function, plan design.

Plan design lies at the heart of the planning process. Obvious as it may seem, it is necessary to emphasize continually that the end point of the planning process is a plan. All of the most sophisticated data collection, processing and analysis are of little value if they do not result in better plans or in their efficient execution.

The land-use plan design function consists essentially of the allocation of a scarce resource, land, between competing and often conflicting land-use activities. This allocation must be accomplished so as to satisfy the aggregate needs for each land use and comply with all of the design standards derived from the plan objectives at a reasonable cost.

The land-use plan design model assists in the design of a land-use plan. Given a set of land-use demands, design standards, land characteristics (natural and man-made) and land development costs, the model will synthesize a land-use plan that satisfies the land-use demands and complies with the design standards at a minimal combination of public and private costs. It is important to emphasize that the plan is the minimal cost plan complying with the design standards. It will be a pure minimal cost plan only if no design standards are specified. The rationale implies that there is no need to have a more expensive plan provided all of the design standards are satisfied.

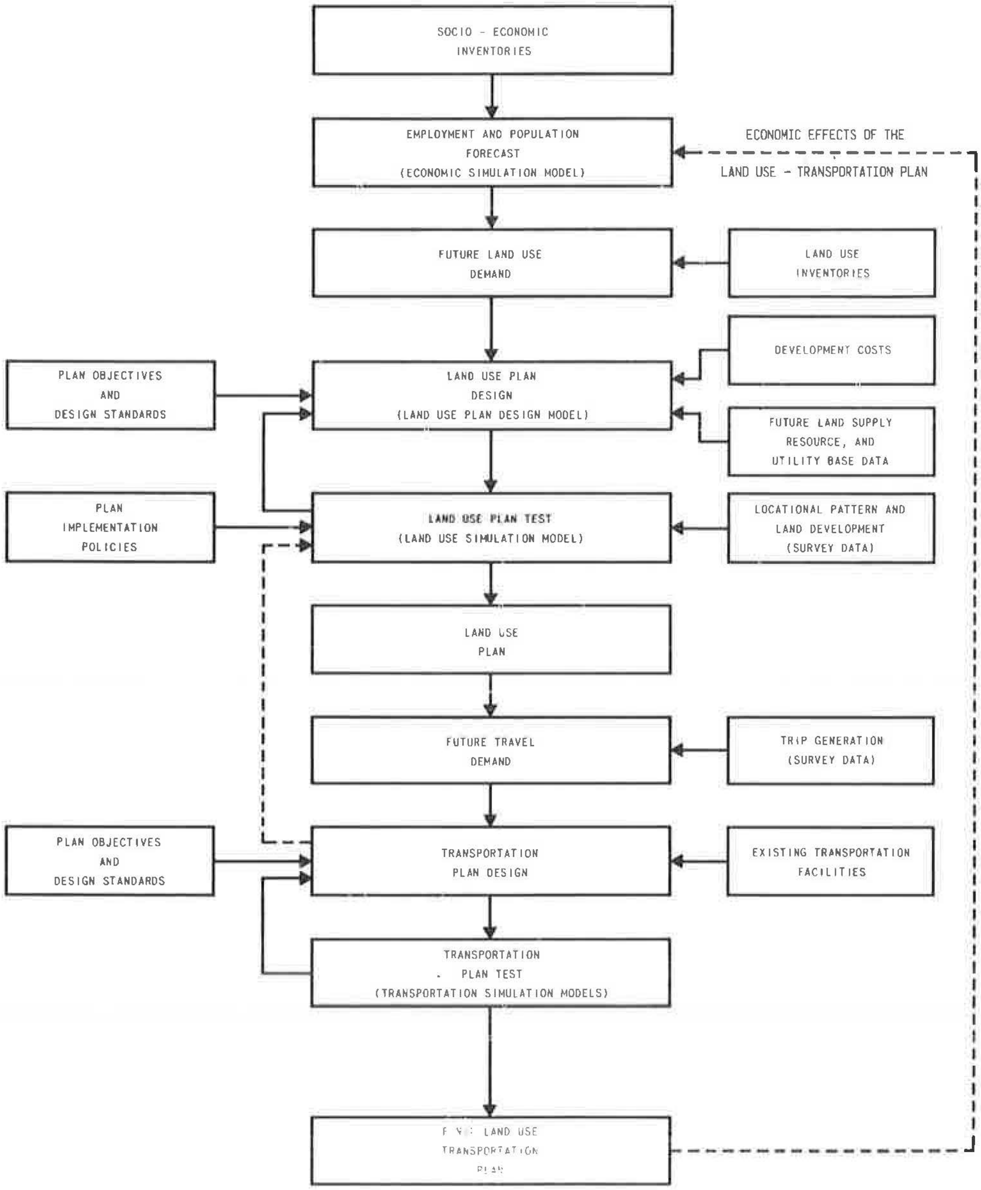

Figure 1. Land use-transportation study planning system diagram.

The plan selected in the design stage of the planning process must be implemented in the real world under conditions often adverse to its realization. Private decisions of land developers, builders and households often run contrary to the development of the land pattern prescribed in the plan. This problem of plan implementation is the function of the third stage of the planning process (Fig. 1): land-use plan implementation test.

If plan design is visualized as the development of the anatomy of the system, then plan implementation represents the physiology. Plan design emphasizes the structure of the system. Plan implementation considers the dynamics of changing land patterns over time. Flow is the key concept in dynamics, and the second model, the land-use simulation model, simulates the flows related to the emerging land pattern.

Land development in the land-use simulation model is portrayed as a series of interacting flows like the physiology of the body or a complex chemical processing plant. A continual stream of decisions made by land developers, builders and households, results in a changing land pattern and a continuous movement of households and business firms to new geographical locations.

Land-use development is simulated in the land-use simulation model by detailed representation of the decision processes of households and business firms influential in land development. Public land-use control policies and public works programs are exogenous inputs to the model. In practice, a number of experimental simulation runs must be performed with different land-use control policies and public works programs until a set of policies and programs are determined that result in the implementation of the target land-use plan. The feedback on the diagram between land-use development and land-use plan design accounts for the changes that will probably need to be made in the plan design to make it realizable. The output of the third stage of the process (Fig. 1) is a land-use plan capable of practical implementation.

The remaining stages of the planning sequence (Fig. 1) relate to the development of a transportation plan. The primary inputs to a transportation system are the trips generated as a function of land use. For this reason, the land-use plan is shown as an input to transportation plan design. No models are indicated in the transportation plan design function. None exists to my knowledge. Trip distribution and traffic assignment models may be used to test the plan intuitively designed by the transportation planner. As a result of a model simulation, the transportation plan network is revised until a satisfactory system is developed. A vast literature exists in the field of transportation planning and associated simulation models.

In the system diagram certain feedback relationships are designated by dotted lines. These feedbacks relate to the effect of a later stage of the planning process on an earlier stage. The most obvious is the accessibility effect of the transportation network on land-use development. This effect is explicitly formulated in the land-use simulation model by an accessibility factor that influences the flow of relocating households to each geographic area.

The other feedback, relating to the economic effects of the transportation plan, is more difficult to formulate explicitly. Decreased travel times may reduce the interregional costs of transporting goods, and adequate industrial sites may encourage new firms to locate in the region, but these effects, particularly the second one, are more difficult to measure and formulate.

SIMULATION MODEL CHARACTERISTICS

Both the regional economic simulation model and the land-use simulation model are dynamic process models which generate a synthetic history of the system variables over a period of time. Starting from a given set of initial conditions the difference equations used in the model permit the calculation of the change in the system variables during the first time interval. The new state of the system then becomes the new base for the change computations of the second time period. If A is the initial residential land area and a function dR expresses the change in residential land use in a given time period, then

$$R_t = R_{t-1} + (dT)(dR)$$

where

$Ro = A$;
$dR = f(x_1, x_2, \ldots, x_n)$;
R_t = residential land area;
dT = recursive time interval;
dR = rate of change of residential land use; and
$x_1, x_2, \ldots, x_n$ = other model variables influencing the rate of change of residential land use.

In general, the difference equations are sequential rather than simultaneous although an exception to this general rule exists in the land-use simulation model.

Both the regional economic and land-use simulation models are made up of a large number of equations of the foregoing type. Four classes of problems (1) exist in the development of simulation models of this kind:

1. The formulation of the basic functional relationships involved in the model,
2. The development of a computer program of the model,
3. The estimation of the parameters for the model relationships, and
4. The validation of the model.

ACCURACY REQUIREMENTS OF EMPLOYMENT AND POPULATION FORECASTS

Each function in the planning process (Fig. 1) requires output specifications. The primary specifications of the socio-economic forecasting function relate to accuracy as a function of horizon time. Some estimate of the reliability of the forecast for each 5-yr time increment into the future must be determined if the forecasts are to be useful in plan design and implementation.

The vital question, of course, is just how accurate must the forecasts be to be useful. To stress the need for forecasts in planning is only to state the obvious. A more difficult problem is to determine the effects of varying degrees of accuracy on the land use-transportation plan. The answer to this problem must be framed in the light of the important characteristics of spatial plans and the planning process.

1. A distinction must be made between incremental changes and structural changes in the plan. Minor variations in the land-use pattern or traffic flow will cause little concern, but excessive errors in forecasts may dictate a fundamental structural change in the regional land pattern or transportation network.

2. The continuous nature of the planning process must be recognized. Forecasts are not made for once and evermore. New information is used with the passage of time to update forecasts, plans and plan implementations, policies and programs to adapt to changing regional needs. The crucial element is the lead time required to implement the planning program properly.

Fortunately, it is possible using the land-use plan design model to determine the effects of forecast errors on the land-use plan. A sensitivity analysis of the land-use plan accomplished with parametric linear programming techniques will reveal the critical range of forecast error beyond which the basic structure of the plan would be modified. Such an analysis will provide detailed accuracy specifications for each of the population and employment categories. Through such an approach it will be possible to determine objectively forecast requirements and avoid the two subjective schools of thought on forecasts for regional planning. One extreme view has prophesied the doom of regional planning unless forecasts of extreme accuracy are somehow determined. Advocates of this viewpoint rarely provide suggestions for the techniques to be used for such giant strides in the state of the art. Aside from its technical naiveté, such a view automatically raises doubts about the utility of planning since the extreme difficulties in forecasting the future are only too well known.

Analysis also provides little support for the opposite view that forecast accuracy is of little importance since it only affects the timing of plan implementation and not the structure of the plan design itself. This view implies that the impact of all forecast errors is incremental and not structural. Although a sensitivity analysis of proposed land-use plans will not be available until later in 1965, preliminary analysis indicates that accuracy requirements will lean toward the second or "loose" view of forecast accuracy needs although not to the extreme advocated above. In other words, forecast errors within a reasonable range (10-20%) will not produce significant structural change.

The feedback (continuous planning) effect on accuracy is more difficult to analyze. In general, it serves further to alleviate accuracy requirements since it is not necessary to forecast beyond the time horizon affected by current plan implementation decisions. It is not necessary to have an accurate forecast of 1990 land requirements if they do not affect decisions being made in 1964.

Extensive analyses of forecast requirements for mathematical production planning models in manufacturing industries indicate that forecasts beyond a few months have little effect on an optimal production plan (2). Such analyses have not been performed in land-use and transportation planning. The only rule of thumb now in existence for transportation planning requires a facility life of 20 years. If an additional 5 years is required for planning, land acquisition, design and construction, then a 25-yr time horizon is indicated. The degree of flexibility for change in the initial 5-yr period is not clear, but even if a conservative approach allowing for no flexibility is taken, the tolerances allowed prior to structural effects on the plan design indicate that forecast accuracy requirements may be attained with current forecasting methodology.

MODEL ORGANIZATION AND RELATIONSHIPS

Basic Organization

The regional economic simulation model is a flow model. It can be physically visualized as analogous to a large chemical processing plant with a myriad of pipes interconnecting processing facilities. Rather than chemical liquids, the model flows represent materials, finished products (and services) and money in the regional economy. These flows in the model interconnect various industries, each of which receives certain flow inputs (labor, materials, capital equipment, etc.) and produces certain outputs (finished goods or services).

A diagram of the model is shown in Figure 2, which illustrates the basic nature of the model flow pattern, although for the sake of simplicity not all of the flows are shown. The three primary exogenous or outside variables are government, consumer and foreign purchases. These variables must be forecast as outside inputs to the model.

These consumer, government and foreign purchases flow to the industry (or business) sector of the national (and regional) economy. This flow subdivides between industries based on an input-output structure. The input-output structure designates the sales and purchasing pattern between industries. For example, a major purchase of electric utilities is coal. This purchase would be represented in the input-output structure by a percentage of electric utility purchases ordered from the mining industry.

The other input-output interconnections are accounted for in a similar fashion. The upper part of the model diagram represents the national economy. The lower part depicts the regional economy. Government, foreign, consumer and business purchase orders flow into the regional economy. A more detailed input-output structure interconnects the industries, governments and households in the regional economy. The regional economy differs from the national economy in that it is a "close" economy (it is technically only partially closed since imports-exports flow in and out of the region). The national economy is "open" in that government, consumer and foreign purchases are determined outside of the model. The regional economy is closed in that households (consumers) and government both consume goods and services and produce goods and services in the regional economy. Government is paid for these services through taxes and households by wages, salaries and dividends.

Inside each of the industries, "bookkeeping" computations are made to account for the short-term flows of materials, goods and money. Employment of hourly and salaried personnel depends on the level of industry sales and personnel productivity.

The key decision that modifies the flow pattern of the model over time is the investment decision. Investment in plant and equipment results in new levels of output and employment in an industry. In the model, investment takes place in response to anticipated sales and profit and the current capacity to produce. Investment in the public sector occurs in response to needs for public facilities and services as limited by funds available from taxes and debt.

The investment decision is the primary dynamic element in the model. The effects of changes in public (tax or investment changes) and private investment policies will be reflected through the investment decisions.

In summary, the model is a dynamic input-output feedback simulation model. It is behavioral and descriptive in its approach in that it attempts to simulate the way industrial investment decisions are actually made in the region and not how they should be

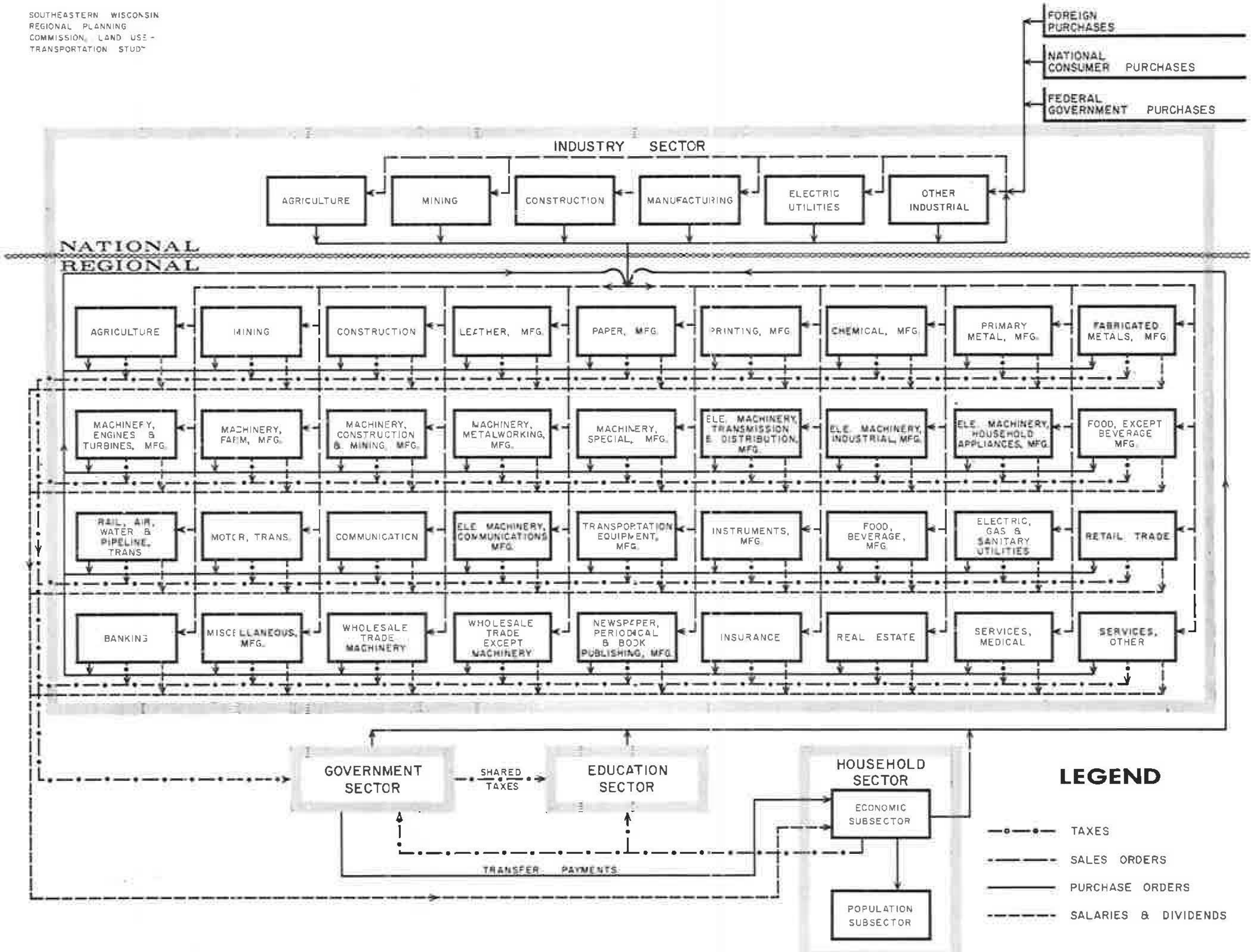

Figure 2. Regional economic simulation model.

made. The model is organized into a number of sectors that are interconnected by an input-output matrix. The model is recursive in its operation and sequentially generates a synthetic economic time history of the region.

Model Characteristics

The regional economic simulation model will be recognized as one of a class of inter-industry or input-output models pioneered by Professor Leontief of Harvard University in the 1930's (3). Although the original empirical investigations of Leontief and most of the subsequent applications of input-output models have been at the national economy level, a number of urban and regional economic base studies in recent years have used the static input-output structure to analyze a local economy and in a few instances to project industrial output and employment as a function of a forecasted final demand. Although the regional economic simulation model uses the Leontief input-output structure, it differs from previous urban economic models in a number of significant ways.

1. The model is dynamic and recursive in that it generates a synthetic time history of a changing regional economy rather than a single set of outputs for a given final demand.
2. The regional sector of the model is closed by generating household consumption of goods and services as a function of income received from the other regional sectors. In the static open input-output model household consumption (final demand) is determined outside the model.
3. The classic input-output model of current purchases is supplemented by a companion input-output matrix of purchases for investment. This addition was crucial in a capital-goods producing region like Southeastern Wisconsin.
4. A partial representation of the national economy is included in the form of the primary industrial customers of the region. This inclusion of an abbreviated national input-output matrix seemed preferable to the alternative of forecasting the national current and capital purchases by individual industry groups.

It is not contended that any of the above model characteristics are new to the field of inter-industry economics. All, except possibly 4 above, have been discussed in the literature (4). In fact, one economist, Chakravarty, produced a research publication (5) that has been invaluable in the evaluation of the model. Although, to the best knowledge of this writer, Chakravarty has not applied his model to an actual nation or region, his theoretical construct was exceptionally well developed and explained. It was unfortunate that this writer did not become aware of this work until late in the model development program. The basic characteristics of the regional economic simulation model such as the emphasis on investment, the household consumption function, the investment input-output matrix and the dynamic recursive operation were all developed at length by Chakravarty in his publication. Despite the earlier independent nature of the two research efforts, Chakravarty's model will be constantly referred to in the description to follow because of the elegance of his formulation.

While it is important to recognize the characteristics of the regional economic simulation model, particularly where they represent a change from more conventional economic base studies, it is also crucial to understand that the model represents an extension rather than a negation of previous work. An input-output structure is after all only an elaboration of the fundamental concept of inter-sectorial economic flows implicit in the concept of an economic base of a community. And while the dynamic nature of the model is new, the local multiplier is also really dynamic in the steady state sense that it represents the end point of a dynamic response to a change in equilibrium. Even the recursive dynamic nature of the model has been anticipated by Tiebout (6) in his excellent summary of economic base study practices.

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F. HOUSTON WYNN, Wilbur Smith and Associates

•THE past decade of research in transportation has seen a rather remarkable change in the approaches to transportation planning. Much of the change relates to the invention of new problem-solving techniques in science which, with the sophisticated new computational technologies, enable the investigator to compile and examine a multitude of facts and propositions about every facet of the transportation business.

National leadership in all major branches of transportation has tried to see to it that new knowledge is disseminated to interested persons wherever they are in the nation, has fostered cooperative investigation and identified missing links in the data chain, and has taken a hand in bringing investigators, problems and money into the necessary critical relationships which promote discovery of new insights and new methods.

The complexity of the transportation planning process has grown increasingly elaborate in recent years. There are two principal reasons for this. First, people in every type of activity have come more and more to realize the interdependence of transportation and markets, and the fact that mobility and access are the keys to successfully marketing of virtually every type of product or activity. Second, of course, is the ability to manipulate and compute in great detail, very quickly and cheaply.

The construction of transportation models is still at pioneering levels in many aspects of the work. For the planning process, some are seeking a set of "universal" models which will enable them to devise a quick and dependable handbook solution to whatever alternative set of land-use and demographic conditions they want to test. It appears likely, in fact, that more sophisticated models will soon permit something like this to be done on a larger scale, and with more confidence than at present.

The models used to test hypotheses are not the answer to the planning process, but merely tools which help to guide the judgments and policies which do constitute planning. The models themselves will never solve the forecasting problem. But without these new tools, planning efforts would be seriously set back by lack of an adequate base for the appraisal of alternatives.

The great hazard is, of course, that too much dependence will be placed on the infallibility of the computer and that the planner may abdicate his responsibility to judge and refute the mechanical product of an arbitrarily programmed machine. Not only is there a real possibility that the planner may defer to the machine because he is overawed by the aura of mystery and infinite capability which surrounds it, but it seems likely that the complexity of the planning process sometimes transcends the abilities of the analyst in charge of a study to evaluate and coordinate the many steps in logic which are required for correct decision-making; too often the machine output is accepted as "the answer," not only by the layman but by the analyst himself, on the basis that it constitutes an impersonal judgment. In fact, whatever judgment is involved was that which sorted out the input data and specified the weighting and other manipulation processes which followed. The output has value in advising the planner of the results of such manipulation, but it rarely contains the final word and certainly is not in itself a judgment.

Some idea of the variety of elements to be considered in generating a "simple" projection of an urban travel pattern may serve to illustrate why the computer has been so eagerly accepted as a tool for collating many of the relevant facts. Urban traffic may be separated into the movements of people and the movement of goods. To some extent these overlap, since persons carry many of their purchases with them, carry their own luggage, and otherwise undertake personally to shift their goods and belongings from one locale to another. Most shipments of bulk goods are also accompanied by persons who drive the vehicle and transfer the cargo. The first category of exceptions is usually not distinguished from the movement of people, whereas the second is considered a basic component of goods movement.

Some of the more obvious considerations of person-travel result in several major stratifications, with many subsets of conditions in each as follows:

1. Demand (trip generation)—Varies markedly, hour by hour, day by day, by week and by season. Relates to routine activities of high frequency (daily), such as work, school, shopping; occasional trips of less imperative but semi-routine nature (weekly or less frequent) such as social-recreational visitation, personal business; and infrequent or rare events which may occur at random or seasonally, such as births, deaths, weddings, vacations.

Demands are modified by such factors as family size, age, income.

2. Selection of Mode—While the choice of mode is conditioned by decisions made at the demand level these are based primarily on the alternatives which are available in a particular environment. If the household has no car, chances are good that public transport will be used if the trip is made at all. Other modifying factors concern the characteristics of the modes available (relative speed, cost, levels of service); their suitability or social acceptability for the purpose (privacy, capacity, orientation); and the complexity of the conditions attendant to the use of one mode or the other (a subteen may have to be driven because he has no license to use an available car; a parent may forbid a bus ride because the return trip at night means a long walk on dark streets).

3. Travel Patterns—The decision to travel, and choice of mode to be used, both relate to trip orientation. Hour of performance, the amount of time required, the length (miles) of trip, topographic restraints and other considerations characterize personal travel and have the most profound effect on the extent and type of facilities which must be evaluated by the transportation planner.

4. Constraints—A number of constraints are implicit in any trip making within the city, many of them already mentioned. The cost of travel relates to purchase and maintenance of a car; the purchase in itself is a commitment to the mode for all or a large share of travel performed by the owner. Habit is a factor, and competition another. Political decisions and requirements color the travel picture: the regulation and control of traffic, decisions to provide or deny access, charge fees, provide new facilities, subsidize transit, operate school buses, etc. Lack of communication may preclude familiarity with some of the alternatives.

Goods transport also pervades the urban environment, from the shipment of bulk raw materials and fuels to the transport of manufactured goods, retail delivery services, construction and maintenance materials, garbage and trash removal, and a host of related activities.

1. Demand for transport relates to the places where raw materials are produced, the places where they enter manufacturing, the transfer to storage and warehousing operations, and the ultimate trip to the consumer for further refinement, remanufacture, or disposal.

2. Mode of transport for goods movement is far more an economic consideration than for personal travel, with strong competition among modes. Within urban areas, most bulk goods are moved by truck, the particular type of firm handling the work depending on size of shipment (small parcel, containerized cargo, truck-load, multi-truck), nature of product and type of packaging (perishable or fragile; bulk or packaged units), urgency, such as that associated with perishables (milk, fuel, flowers; fashion goods; valuable papers, money, etc.). A great variety of specialized trucks, differing in size, special cargo suitability (liquids, high-pressure gas, fuel, garbage, refrigerated units, plate glass carriers, armored trucks, etc.), and subject to special laws and ordinances.

3. Patterns of travel are highly specific to type of commodity. Largest vehicles are usually engaged in movement of large and/or heavy commodities over long distances, often consisting of raw materials, manufactured products in bulk, or, locally, large quantities of construction materials, waste haulage, and so on. Medium sized vehicles are frequently engaged in warehousing, furniture haulage, and bulky delivery functions throughout a community. Their patterns are not so heavily concentrated at industrial, construction and warehousing sites, but relate importantly to them. The bulk of truck travel consists of small units in delivery and service activities, based generally in warehouse, industrial and commercial centers but oriented towards land uses of all sorts, more or less according to the general intensities of activity.

4. Constraints on these activities relate to costs, competition, political privilege and sanctions, demand for special vehicle types, and so on.

All of these elements require some amount of recognition in developing models which are practical and useful in reproducing the current patterns of urban travel. This means measurements, often based on the analysis of elaborate surveys, which distinguish effects of each element and the factors which modify their behavior. This is a monumental task when all the great variety of urban activity is contemplated.

Add to this the need to prepare estimates of future demand or needs, based on the changes which are likely to occur. A very extensive understanding has to be built up (based on results of the initial analyses of behavior) if these projections are to be realistic. Once made, the models must be applied and travel values synthesized. It is in this process that the planner often gets lost, and it is little wonder that he is sometimes happy to accept the computer products as the answer to his needs.

Actually, it is just at this point that transportation planning is ready to begin, with the first step a critical (and skeptical) analysis of the computer tapes.

Discussion of Panelists' Remarks

ROBERT W. PATERSON, Director, Bureau of Business and Government Research, University of Missouri

The statements of the panelists were thought provoking, of great current interest, and I doubt that many people would disagree violently with what was said.

Messrs. Cherniak and Chinitz emphasized the need to pin the capacity of an area to adjust to change to a forecasting model, and this is certainly a conceptual problem rather than a technical one. That is, the computer cannot solve it, and until we know more about the underlying conditions of socio-economic pressures and the responses of people to them, model building will be of little usefulness.

It would appear that we must classify the kinds of problems that are subject to model building-computer approaches and those which are not, or which are only partially so.

From the discussion it appears that there are big and little problems. In the big problem category one is faced with concerns that are subjective. These are, in the main, problems having measurable characteristics but about which humans make differing value judgments. The data on commuters traveling into and out of a major city each day can be agreed upon by us. How best to create facilities for their transfers is subject to great debate. That is, shall we build highways for private use; shall we build highways sufficient for bus or group transit; shall we build a rail system; or shall we get by as best we can, all the while hoping that technology will produce a new form that is less expensive and faster than anything we now have? We can build models and design computer programs for forecasting demand and cost relationships under any one of these approaches, but we will end up with alternative estimates, not with a solution to the forecasting problem.

The little problems, which are the outgrowth of the bigger ones, can often be dealt with by model building and computers in ways that are operationally meaningful. These problems consist of and involve techniques for relating data to hypotheses. Thus, the little problems are technical in nature and computer programs can be written that will absorb massive amounts of data and provide better forecasts than have been possible heretofore. But they are partial rather than general forecasts.

The value judgments of individuals are rationalized by: (a) dollar votes for goods and services in the marketplace, and (b) ballots for political candidates and community programs.

Since popular tastes and preferences have the habit of changing and since these changes affect the operation of the economy and public programs, it is difficult to see how either model building or computer programs can accurately forecast future conditions unless we can anticipate the changes that will take place in public value judgments.

The computer is a tool in the sense that calculus, or marginal utility, or measures of central tendency are tools. To accentuate the computer as a big problem solution finder is to miscast its very great potential for solving little problems; already it is casting its spell upon the thousands of routinized operations that are carried on in the economy and in government.

So much for the philosophical aspects of model building and computer programs. The question was raised by the panelists, "How good are computers for forecasting very short-term conditions associated with Gross National Product and other macro-economic indicators?" My interpretation is that there is general agreement that computer programs for short-term forecasting are not very helpful to management. Perhaps part of the inadequacy is due to the relative infancy of such applications. Computer programming is a recent development. Forecasting by computer is only a few years old. Thus, there may be some startling developments in the next few years, but, if what I have said at the beginning is applicable, it would appear that we should not attach too much hope to this prospect.

In closing, one observation, not related to the topic of the discussion, seems to be appropriate. The rise of the computer has captured the imagination of the public and nontechnical managers of our various enterprises. Slowly, the public and members of organizations have identified the possession of a computer by a firm with management expertise, alertness, and creativity. Those firms having computers are, therefore, in a special class and others, who do not have them, seem to be relegated to second-class status. Thus, the computer has become a status symbol in the nation. Probably we have attached too much importance to the possession of these tools and not enough importance to what they will really do in terms of forecasting. We do know that they can do only what they are programmed to do. Thus, it is the imagination, knowledge, and creativeness of the programmer that is of paramount importance in determining whether computers will be of forecasting usefulness in the future.

C. A. STEELE

I have no serious disagreements with what anybody has said. It gave me considerable pleasure to find the panelists admitting to having the same problems and questions that I do about model building and the use of computers in economic forecasting. It is particularly cheering to hear some of them say, as Mr. Frechtling did, that he sees no danger of unemployment among forecasters as a result of model building and automation.

We did not get a "yes" or "no" answer to our question from the panelists, but, frankly, the Committee did not expect to get one. However, we got a lot of insight from the theorists, planners, and users of economic forecasts into how model building and computer applications can help the economic forecaster in doing a better job. A review of some significant points brought out by the various panelists will help to clarify this point.

Mr. Cherniack's five suggestions are very significant, particularly from the standpoint of the man "on the firing line" who is engaged in planning or operational activities for which he must have economic forecasts. I thought his fourth suggestion was especially significant; it is that, on the basis of subsequent recorded data, the forecaster should determine the overall forecasting errors made and distinguish them between (a) errors in predicting future socio-economic determinants, and (b) those that result from either unstable parameters of empirical models or unrealistic behavioral models.

Dr. Chinitz placed his finger directly on what seems to me to be one of the most bothersome problems in state and local-area forecasting when he said that the capacity of a region or a state to adjust to economic change would need to be considered in making forecasts for that particular area. I thought it was significant, too, when he went on to say that this sort of thing cannot be pinned down in a model. Chinitz also made a significant statement when he pointed out that in the field of transportation, model building has been successful in some directions and not so successful in others.

Mr. Darmstadter cited a point that is of importance to all forecasters when he commented that the relative accuracy or inaccuracy of a given forecast will depend on the purposes for which it was made. Thus, if a forecast value falls at a point where significant changes would appear to be required in a long-range plan it becomes very important that the forecast be essentially accurate. For example, if a forecast of the traffic to use a certain facility would fall exactly at the point where the design would need to be changed to provide additional lane capacity, that forecast immediately becomes a key factor in the overall plan. If the forecast is too high the resulting facility will have been overdesigned. On the other hand, if the forecast is conservative the probability is that the built-in capacity of the new facility will be sufficient to absorb the additional requirement.

Mr. Frechtling appeared to agree with this conclusion, although his interests in forecasting are, in general, considerably different from those of Darmstadter. The market analyst is, as he pointed out, primarily interested in the short-range forecast; the margin of error that can be tolerated in estimating future demand for his company's product is small indeed.

I noted that Mr. Schlager also emphasized [in his oral comments] the importance assumed by forecasts and forecasters when a major planning position depends on their predictions. I thought it particularly significant when he cited the desirability of having two forecasts made independently under such circumstances. He would apparently favor having one of these made by the best mathematical and automated means available, involving the use of both models and computers, while the other would be made using traditional forecasting procedures in which the experience and good judgment of the forecasters would be of prime importance.

Mr. Schlager's frankness in admitting [also in his oral comments] that his group had made errors in forecasting was comforting. He also made what appeared to me to be a very significant statement when he said that some forecasters err in attempting to obtain and utilize too much data, thereby allowing themselves to become unnecessarily involved in the procedures of forecasting and usually ending up far behind their deadline dates. It is important that every forecaster, and every researcher for that matter, have a real "sense of closure." This is something that I am afraid many of us badly lack.

On the basis of his long experience in planning, traffic, and related studies, Mr. Wynn stated that he has little faith in the long-range forecasting of peoples' behavior. On the basis of my own experience in research relating to consumer demand for transportation I am inclined to agree wholeheartedly. Although Mr. Wynn pointed out the possibility—of which all of us are well aware—that technological changes may invalidate all or some of our present travel modes within the period of our long-range forecasts, he does not, I am sure, intend to imply that forecasts relating to future demand for transportation should not be made. These are essential, and the economic forecaster must do the best he can with the tools and the facts that he has at hand.

I could not help chuckling when Dr. Paterson said that the computer has now become a status symbol—that every business organization, college or university, and governmental agency of any stature is now expected to have one. His note of warning, however, was timely; after all, the computer is only a tool and forecasters and others should not give it any more authority than a good tool deserves. I thought it was significant when he stated that in his opinion the computer has proved very good for forecasting some "micro" items, but that for forecasting "macro" items it has not proved so satisfactory.

Closing Remarks

SIDNEY GOLDSTEIN

I was particularly impressed with the diverse subject matter to which our panelists directed their remarks. Some spoke from the point of view of industrial and market forecasting and the need to have immediate answers; in such an operation short-term forecasts are needed. Others spoke of the forecasting requirements in economic development activities, in regional planning, in travel forecasting, and in goal testing and planning.

What was most impressive was that each speaker was cautious in his appraisal of utilization of computers and models in economic forecasting. All recognized the values in terms of quick testing of alternative formulations, rapid computation, handling of many variables, etc. But each expressed some reservation in complete acceptance of any mechanical framework.

All research and planning organizations have a tug between the new and the newer, between those oriented toward trend analysis, time series analysis, cross-section analysis, versus those who believe that computer models can actually do forecasting in a mechanical sense. Some are aware of the subjective features that must exist in any such mechanical approach but believe that these can be spelled out more precisely and in an organized manner in a model. In addition to this, every organization has representation of deductive and inductive thinking. This is a tug-of-war between those who assume regularities and probabilities and proceed from there as compared with those who believe in a cumulation of demonstrated relationships from which generalizations may be induced.

Ever since Adam Smith developed his classical descriptive model in economics (and in the field of human relations this was far from the first model—and, of course, in the sciences abstractions have always been used) economists have sought to mathematize it and its assumptions and to improve upon it in terms of various types of equilibrium constructs, in terms of partial analysis, aggregate analysis, etc. The theories that have been spawned in this process are legion. The computer allows some test of these theories, but perhaps in too regular, logical and sanitary a world, leaving too little room for subjective inputs.

The concept of "model" has been used in political science, management, sociology, law, other behavioral sciences, natural sciences and engineering. But to some "model" has meant a mental construct; to others there was no such concept unless it could be given rigorous mathematical and not only logical form. Because of the dependence upon manual methods in the past, there was little possibility for dealing with many variables, much data, testing sensitivities of variables, or testing alternative hypotheses.

But with the computer, giving mathematical or statistical form to logical ideas was accelerated. Giant strides were made possible in terms of specificity of assumptions, speed of computation, evaluation of alternatives, and dreams of large simulation systems even extending to individual decision units became reality. Such systems were to be used to arrive at present and future choices under various assumptions.

As a result we find models and the computer being used in areas such as studies of social communications, psychiatric, medical, psychological, labor relations, in addition to those with which this panel was concerned. The belief is that in some of these other fields we may learn to evaluate certain intangibles that are more predictive of economic behavior than the ordinary sources used in economic forecasting.

But all models inferentially depend upon current knowledge and relationships in response to certain outside stimuli, governmental or private.

Some of the complaints that have been voiced against use of computers and models in economic forecasting include of course:

1. The necessity of dealing with intangibles or non-priced quantities in truly forecasting such items as transportation demand, let alone the total demand for which it is derived.
2. Human behavioral variables are too uncertain.
3. Most such variables suffer from the bane of interrelationship.
4. Sensitivity analyses when applied to forecasting problems deal with the sensitivity of individual items to the total forecast but are not indicative of basic data quality.
5. Data used in many forecasts are spurious, indefinite, etc.

Our speakers have made clear to me, at least, that a combination of methods, and skills are required. For certain problems, our conventional techniques will be applicable; for others experimentation is worthwhile, for we may be able to predict behavior in an economic sense at certain levels. But no computer program will help us unless we understand what to ask the computer, and the frantic search for complete and predictable explanations by some has to be combined with approximations to reality and decision-making.

The cautions to be exercised in predictions can best be illustrated by my opening remarks. I had anticipated that the speakers would exhibit widely disparate opinions because of their own interests and backgrounds. I find, however, that most of our speakers described similar hopes and fears and there was more agreement than disagreement. This is a healthy sign.

A Regional Economic Simulation Model for Urban Transportation Planning

DAVID E. BOYCE and SEYMOUR E. GOLDSTONE, Battelle Memorial Institute, Columbus, Ohio

Forecasts of population and employment for urban transportation planning regions can be prepared using the regional economic simulation model described. The model consists of a set of recursive difference equations describing the demographic and employment sectors of a metropolitan region and its growth. Computer simulation studies on the model enable the testing of alternative assumptions and hypotheses concerning a region's future.

•A BASIC requirement for the preparation of land-use forecasts in urban transportation studies is a set of population and economic forecasts for the planning region. These regional forecasts provide control totals for the small analysis zone forecasts of land use, population, income, and employment. In addition, the regional population and economic analysis provides information on the economic vitality of the metropolitan region that bears directly on the region's need and capability for improving transportation facilities (2; 3, Chap. 2; 12, Chap. 2-3).

During the past 10 years regional forecasts in urban transportation studies have been based mainly on extrapolation of trends or on available forecasts that were adapted for the study. One recent study report (12) states that the land-use forecasting procedures are probably somewhat more refined than the regional population and economic forecasts, which are their basic inputs. As this report points out, most transportation studies have allocated much more effort to forecasting land use and urban travel models than to regional economic analysis. Two notable exceptions to this are the economic forecast prepared by Hoch (7) for the Chicago Area Transportation Study, and the forecasting model developed by Artle (1) for the Oahu Transportation Study.

Several reasons for this past underemphasis of the regional population and economic forecasts come to mind. First, the technical skills required to prepare economic analyses and forecasts have been extremely scarce, even more so than transportation planning skills. Second, the methodology required to produce reliable population and economic forecasts was being developed while transportation planning studies were being completed. Isard's work (9) is representative of the state of development of this methodology during this period. Methods available today are in many respects still unsatisfactory for the requirements of urban transportation planning.

This paper describes a regional population and economic forecasting model potentially useful in urban transportation planning. The model was developed as part of a water resources planning study for a large river basin in the eastern United States (6) and is currently being refined and extended. The study was based on the philosophy that existing knowledge of causal forces should be fully exploited in preparing regional forecasts. The structure of the model is, therefore, based on theoretical concepts as well as empirically verified relationships. The relationships are assembled and integrated to achieve a fairly simple operational model of a regional economy. The model equations are solved in a recursive manner over the planning time horizon; the model is run on the IBM 7094 computer using the DYNAMO compiler developed by Forrester (5) and his associates in the Industrial Dynamics Group at M.I.T.

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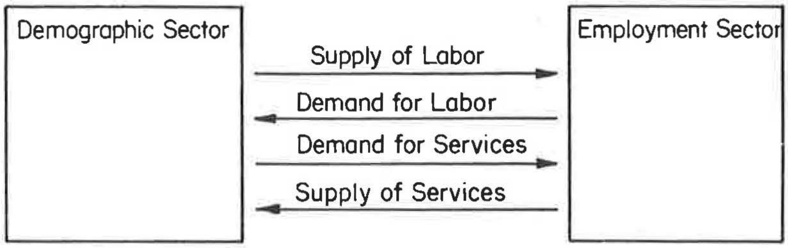

Figure 1. Overview of the model.

The model differs from previous population and economic forecasting procedures used in urban transportation studies in several important respects. First, and possibly most important, the model provides a framework for the planner to test readily the significance of alternative assumptions regarding growth rates and interaction of regional activities without significant model revisions. Second, the model forecasts the path of population and employment growth for the region through time. Most transportation studies have been concerned with a planning horizon 20 to 25 years in the future and have given little attention to the interim period. The model may thus help the transportation planner not only with the question of how much but also the question of when, new facilities should be constructed.

Third, many procedures forecast population as a first step and then either reconcile this forecast with an independent employment forecast or base the employment forecast on the anticipated population level. This model treats population and employment growth as interacting processes (Fig. 1). For example, the growth of employment opportunities will attract migrants to a region, in turn creating new job opportunities in the household-related businesses and services. These interactions between population and employment are an important part of the dynamics of regional economics. The manner in which they are treated can have a significant effect on forecasts.

THE DEMOGRAPHIC SECTOR

The demographic sector of the model is designed to project the level of population and the supply of labor. Changes in population are the combined result of birth, death, and migration rates. Probably, the most important determinant of these rates, as well as the labor-force participation rate, is age. Thus, to trace these demographic variables through time, it is necessary to keep track of the distribution of age of the region's population.

An important question in modeling this sector is, therefore, what kind and how detailed an age breakdown to use. By examining the behavior of birth, death, migration, and labor-force participation rates by age, it is possible to define a set of age groups which is fairly homogeneous with respect to these age-dependent characteristics. Six age groups appear necessary to achieve effective simulation of the population dynamics:

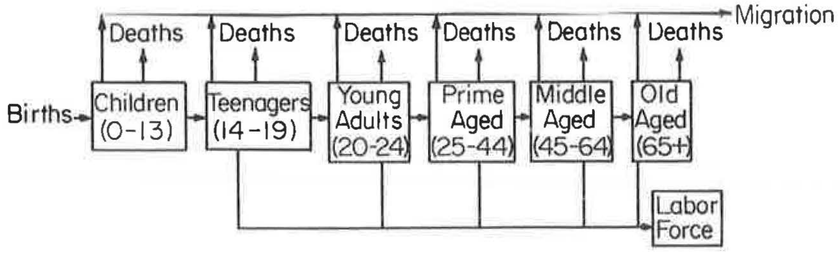

Figure 2. Structure of population flows.

0-13, 14-19, 20-24, 25-44, 45-64, and 65 years and older. Figure 2 shows the basic flows represented in the demographic sector of the model.

Birth and Death Rates

Birth and death rates are fixed for each age group in the current formulation of the model and are based on 1960 regional data. For example, the birth rate for a given age group is estimated as the ratio of live births during 1960 for that age group to total population of the group. There are significant differences, especially for birth rates, among several regions examined. These differences may be explained to some extent by differences in the (a) urban-rural mix, (b) racial composition, and (c) ratio of males to females in the local populations.

Migration

The demographic factor with the greatest potential for wide fluctuation in the short run is migration. In this model, the net migration rate (ratio of in-migration minus out-migration to regional population) for each adult age group is related to relative regional employment opportunities. The regional unemployment rate minus the national rate is used as an index of regional employment opportunities. The migration of children in the model is linked directly to migration of their adult parents.

Figure 3 shows the results of linear regression analyses on net migration between state economic areas in the period 1955 to 1960 (15). These results provide statistical support for the thesis that the 20 to 24 age group is much more responsive to relative employment opportunities than the older age groups. However, all age groups have a net out-migration when employment opportunities are equal.

Coefficients of determination (r^2) also show that relative employment opportunities are more strongly related to net migration for the 20 to 24 age group (0.52) and 24 to 44 age group (0.58) than for the older 45 to 64 age group (0.35). The results for the 15 to 19 age group (0.24) and the retired 65+ group (0.26) are considerably weaker.

Labor-Force Participation Rates

The two important determinants of labor-force participation rates (i.e., rates the labor force to population) are age and sex (17). Since the model does not break down the population by sex, it is assumed as a first approximation that the proportion of

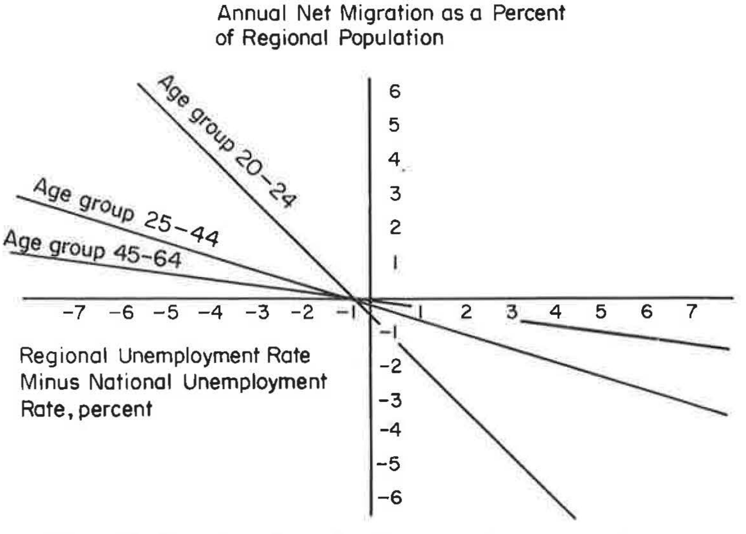

Figure 3. Net migration related to unemployment rate by age.

females in the population will tend to remain relatively constant. This being the case, participation rates are estimated by aggregating over sex for a given age group. Data on participation rates show that age does not explain all the variation in participation rates. In some cases considerable differences exist for given age groups for selected regions. These differences may be attributable to such factors as degree of urbanization, average level of educational attainment, average earning levels, and employment opportunities.

THE EMPLOYMENT SECTOR

Briefly, employment is of two types—provision of goods and services within the region and production for export out of the region. Locally based employment is a function of demand for goods and services by households, local businesses, and manufacturing firms. Employment for export production is a function of the region's competitive advantage or disadvantage with respect to other locations for industry and is measured by comparative indices of wages and access to markets and raw materials outside the region. The employment sector is interrelated with the demographic sector through the regional unemployment rate and population level.

Definition of Employment Types

Export employment is defined as production for sales primarily to nonlocal markets; export producers include both final producers and intermediate producers selling to firms that are producing for sales outside the region. The basis for the export employment forecast is a cost-oriented location model. Therefore, employment in non-cost-oriented industries such as some installations of the Federal Government, higher education, and military service are forecast outside the model framework. Similarly, employment forecasts for resource-oriented industries such as mining and agriculture are prepared outside the model and entered as direct inputs to the model.

The second category of employment is designated "local serving" in the sense that goods and services produced are consumed within the region. This employment group serves both household demands for goods and services in the region and requirements of local firms for goods and services of a generalized type such as transportation, communication, and public utilities.

General knowledge of industry shipment patterns and results obtained in previous research (4, 10, 13) provide a basis for classifying industries into the two types. In general, production of goods and services for sales to the region's households and all types of firms in the region is the criterion used to distinguish local serving from export employment. This definition results in all 2-digit SIC manufacturing industries (Standard Industrial Classification Numbers 20 through 39) being classified as export, with several important exceptions. Those manufacturing industries whose products are produced entirely for local consumption, such as dairy products, newspapers, bakery products, commercial printing, public utilities, and construction materials, are removed from the export classification and designated as local serving employment. All other industries, including SIC Numbers 40 through 89, are classified as local serving.

The Export Employment Model

The forecasting equations for location and growth of export employment in the region may be viewed as a simple adaptation of industrial location theory to the forecasting model. Industrial location theory, as formulated by Isard (8) for example, embodies the concepts of market area, source of raw materials, transportation costs, and local production costs including wages. The procedures for incorporating these concepts into the forecasting model are now described.

Consider a group of manufacturing industries with similar transportation costs, labor requirements, and market-area characteristics. The market area for these industries may be defined from data on shipping characteristics such as is available from the U. S. Census of Transportation (16). For example, a typical market area might be those states east of the Mississippi River for a metropolitan region located in the eastern United States. Industry growth rates for the total market area by 2-digit manufacturing industries are available from the national and state projections to 1976 by the National Planning Association (11).

This market area growth rate is used as a starting point for the computation of a regional growth rate. The region's industry growth rate, as contrasted with that of its market area, is determined by its relative advantage with respect to costs incurred in manufacturing and distributing the product. A cost index is formulated which compares the region's total costs with the costs of other regions serving the same market area. Costs that vary significantly between regions are wage costs and transportation costs for both raw materials and products. Wage costs are adjusted during the operation of the model in response to the local employment conditions. Transportation costs also may be varied during the model operation to incorporate major changes in the transportation system such as the construction of an Interstate highway.

The cost index operates in the following manner. If the region offers lower cost characteristics than competing regions in the market area due to lower labor costs or better access to market and raw materials, then a regional industry growth rate greater than the corresponding market area growth rate is inferred. However, if the access characteristics of the region or its labor costs are higher than in competing areas resulting in a cost index greater than 1.0, then the industry growth rate is adjusted downward accordingly. A cost index equal to 1.0 means that the industry growth rate for the market area also applies to the region.

In the applications of the model to date, export employment is divided into four industry groups with similar labor and transportation cost characteristics; two of the groups are fabricating industries and two are processing industries. Market areas, wage costs, and transportation costs are defined and derived for each of these four industry groups, and regional growth rates are computed for each industry group.

Local Serving Employment

Local serving employment is divided into two subcategories, household serving and business serving. First, household-serving employment, which includes all employment primarily engaged in production of goods and services for sale to households, is forecast as a linear function of regional population. Analysis of the relation between total regional population and household-serving employment in several metropolitan

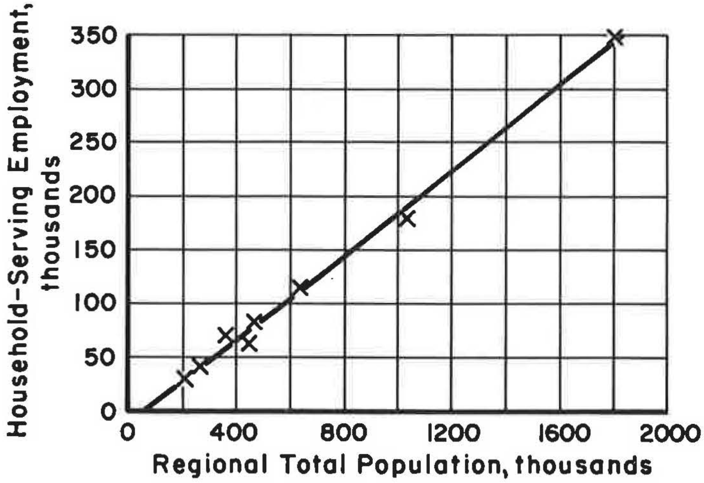

Figure 4. Household-serving employment vs total population for selected regions in eastern United States, 1960.

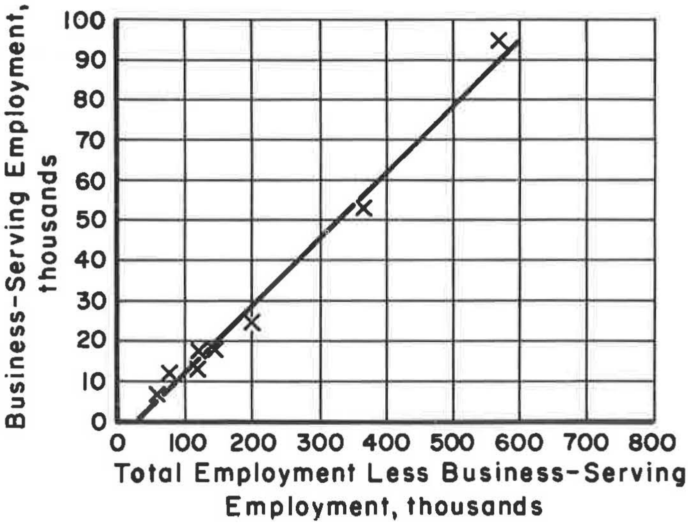

Figure 5. Business-serving employment vs total employment less business-serving employment for selected regions in eastern United States, 1960.

regions in the eastern United States indicates a satisfactory relationship (Fig. 4). Business-serving employment, which includes all employment engaged in the production of goods and services for sale to firms in the region, is related to all other employment in the region in a similar manner (Fig. 5).

INTERRELATIONSHIPS BETWEEN EMPLOYMENT AND DEMOGRAPHIC SECTORS

The key variable in the interaction between the employment and demographic sectors is the local unemployment rate. Unemployment rate is determined by the combined forces of labor supply from the demographic sector and labor demand from the employment sector, and it in turn affects both these sectors. The path of causality is shown

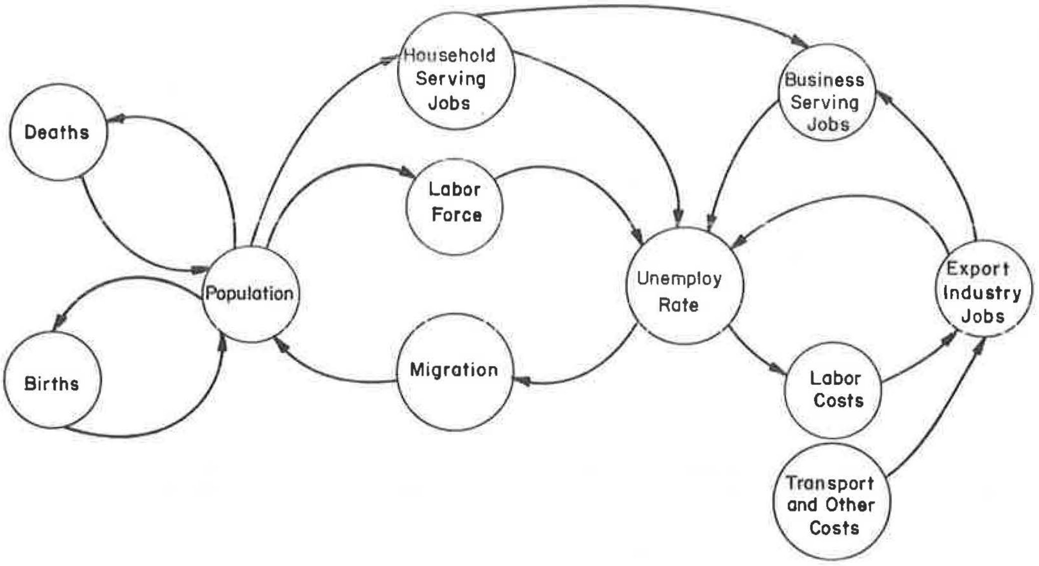

Figure 6. Main feedback loops of the regional economic model.

in Figure 6, depicting the main feedback loops of the model. A second important interrelationship (Fig. 6) concerns the requirements for goods and services in the household-serving industries, which are related directly to population. Employment in this category in turn affects the demand for employment in the business-serving industries. With these interactions in mind, the next section describes how the regional economy evolves over time.

MODEL DYNAMICS: SENSITIVITY ANALYSIS

One of the major advantages of using a computer model for making economic forecasts is that it is a very simple matter to test the effect of changing assumptions. This testing for sensitivity of various parts of the model is important during both the model formation and the model use stages. During the model formation period, various simplifying assumptions are invariably made. The planner will have less supporting evidence for and less confidence in some of these assumptions than others. Therefore, he will vary these assumptions to see if the conclusions are sensitive to them. Sensitive and insensitive parts of models can thereby be pinpointed and the information used for guiding further model refinement.

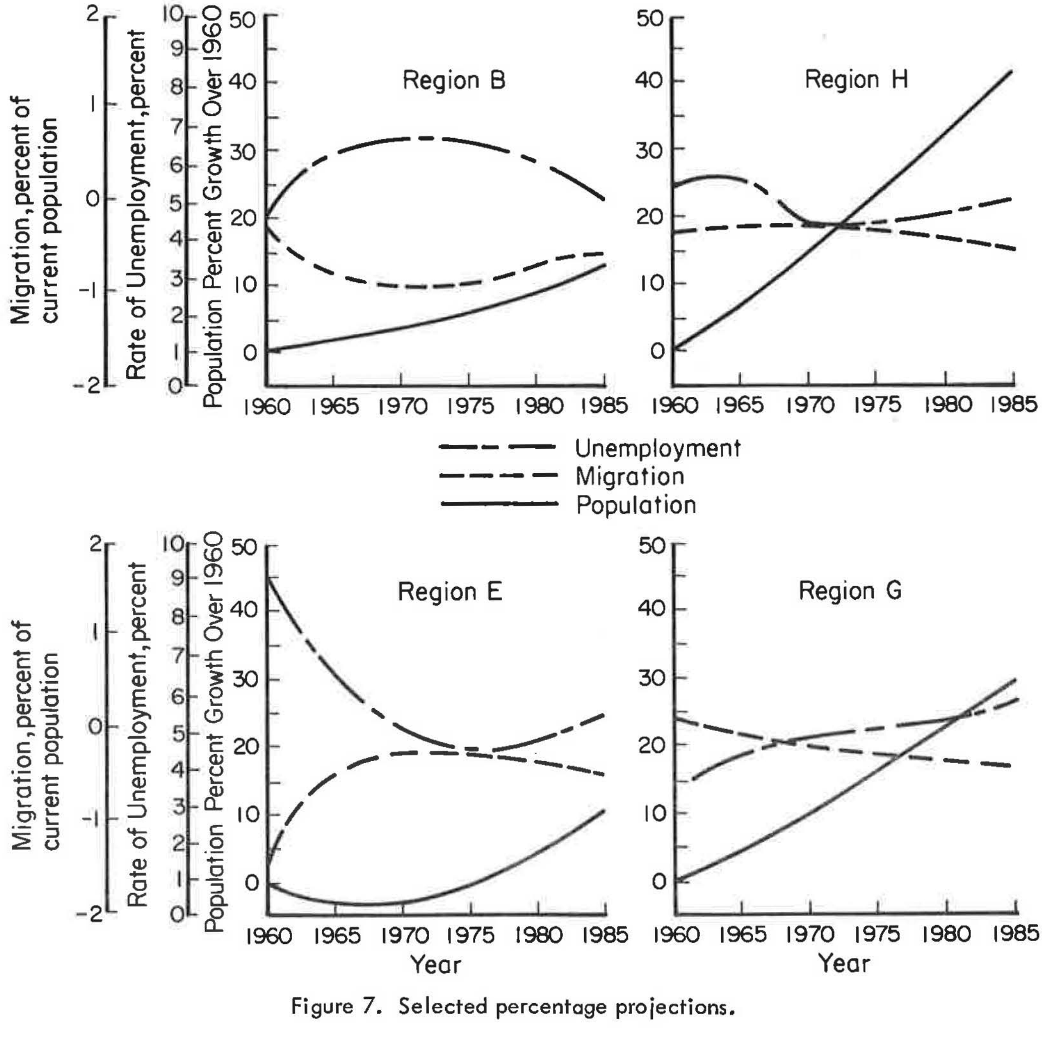

Figure 7. Selected percentage projections.

In keeping with this research strategy, sensitivity experiments are made as a regular part of the research process. Two sets of these experiments, one on migration and the other on skills, are discussed. First, however, it will be helpful to examine several typical model runs. Figure 7 shows typical model output for population, migration, and unemployment rate for selected regions. These graphs show that the model is capable of producing different patterns for different regions. These different patterns arise from differences in initial imbalances between jobs and labor force, differences in the initial mix of export industries, and in enduring differences in competitive advantages due to different locations.

In Region B, because of a failure of jobs to grow fast enough, unemployment rate rises over the first decade. Because of the lack of job opportunities the model generates increased out-migration and reduces pressure for wage increases. This combination of forces results in a decline in labor force growth rate which coincides with increased growth in jobs (because of stable labor costs). A downward correction in the unemployment rate results, slowing out-migration and causing toward the end of the 25-yr period, an increase in the rate of population growth. Examination of the patterns generated for the other regions represented in the diagram will reveal similar forces at work.

Sensitivity Experiments on Migration Formulation

One interesting set of sensitivity experiments concerns tests of various assumptions about the migration formulation. As discussed in the migration section, a statistically significant linear relationship exists between net migration and unemployment rate. We believed that additional research could improve on the accuracy of these results.

However, further expenditures on this part of the model could be justified only if it was sensitive. To determine this, several runs were made in which different relationships between migration and relative unemployment were tried. Figure 8 shows the migration line for the 20-24 age group for three of these runs. The relationships for the other unemployment-dependent migrating groups (14-19, 25-44, 45-64) were changed in similar ways. Run 42 used the relationship drawn directly from the statistical results and thus serves as a basis for comparison against the other runs in this series.

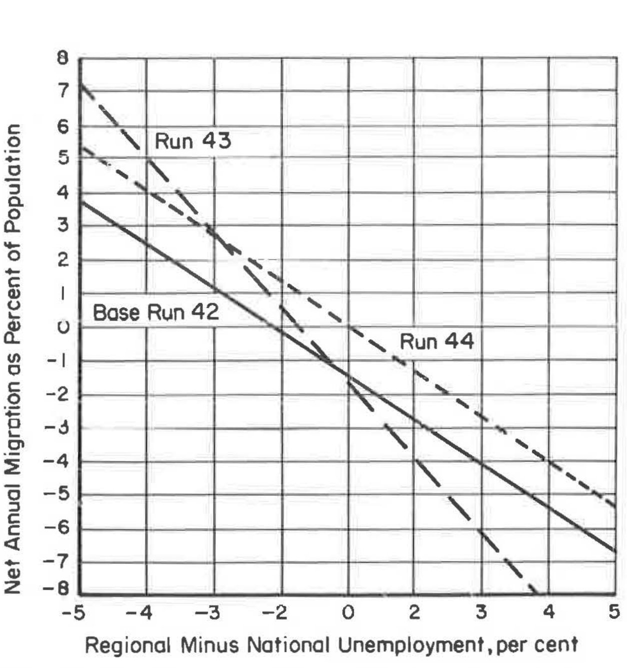

Figure 8. Migration functions assumed in sensitivity analyses (age group 20-24).

TABLE 1

RESULTS OF SENSITIVITY ANALYSES OF MIGRATION FUNCTIONS

Simulation Run[a]	Characteristics of Migration Line	Population Growth Relative to Base Run After 25 Years
42	Migration line based on statistical analysis, so that region has out-migration even when local equals national unemployment	Base Run
43	Slope of migration line doubled	100.3%
44	Migration line shifted upward so that no out-migration occurs when local equals national unemployment	106.8%

[a]Numbers correspond to computer simulation identification system used internally by research group.

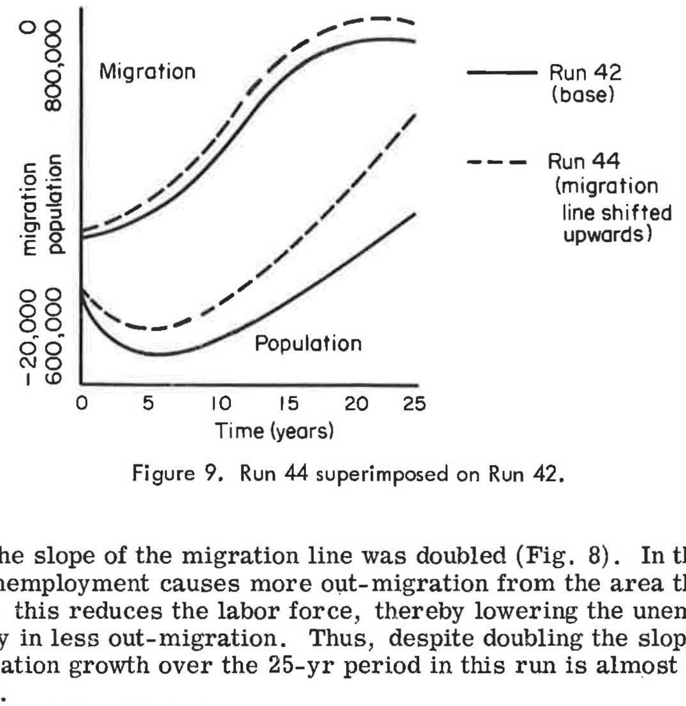

Figure 9. Run 44 superimposed on Run 42.

In Run 43, the slope of the migration line was doubled (Fig. 8). In this run, the initially high unemployment causes more out-migration from the area than in the base run. However, this reduces the labor force, thereby lowering the unemployment rate, resulting finally in less out-migration. Thus, despite doubling the slope of the migration line, population growth over the 25-yr period in this run is almost the same as that in the base run.

Run 44 examined the effect of an upward shift in the migration line (Fig. 8) such that no migration occurs when the local unemployment rate equals the national average. In this case the region grows somewhat more rapidly (Table 1).

Figure 9, a graph of population and net migration of Run 44 superimposed on the base Run 42, illustrates what is happening here. Two factors in particular are combining to cause an increasing divergence in the population projections. First, the migration line is shifted upward, resulting in a reduced net outflow of people. Second, the upward shift in the 4 migration lines to pass through the origin mainly affects the young 20-24 age group (see Fig. 3). Thus, in Run 44 the area is not only losing fewer people but is losing fewer people in the age group which has the highest reproduction rate. Therefore, a higher natural rate of population increase is combined with a higher net migration rate, leading to an increasing divergence in the population projections.

The conclusion drawn from these sensitivity experiments is that the projections are insensitive to changes in the slope, but at the same time somewhat sensitive to changes in the intercept. As a consequence, additional statistical analysis has been undertaken on migration.

Sensitivity Experiments on Skill Level

There is a growing awareness and concern about the effects of education and skill level of labor on regional economic vitality. Unfortunately, in treating a variable such as skill level the investigator is confronted with measurement difficulties. Despite this lack of measurable cause and effect, we introduced several speculative hypotheses involving skill level. The purpose was to determine if regional growth is sensitive enough to this factor to justify the considerable additional exploration that may be needed to refine and test such hypotheses.

After considerable deliberation, despite the recognized limitations, we decided to use educational attainment as a measure of skill level. This is based on the idea that education increases the trainability and thus the potential skill a worker can achieve.

Available data also show that educational level affects the migration rate (Table 2). The migration rate is substantially the same for people who have a high school diploma or less, whereas those with some college education migrate more frequently. The effect is particularly dramatic for the younger 25-44 age group.

TABLE 2

RELATION BETWEEN EDUCATION LEVEL AND MIGRATION RATE BY AGE

Years of School Completed	Migration Rate	
	25-44 Age Group	45-64 Age Group
0-7	5.2	2.9
8	5.7	2.3
9-11	5.8	2.6
12	5.2	3.0
13+	10.7	3.5

Source: U. S. Department of Commerce, Bureau of the Census, Current Population Reports, Series P-20, No. 127 (January 15, 1964): Mobility of the Population of the United States, April 1961 to April 1962, Table B, p 4.

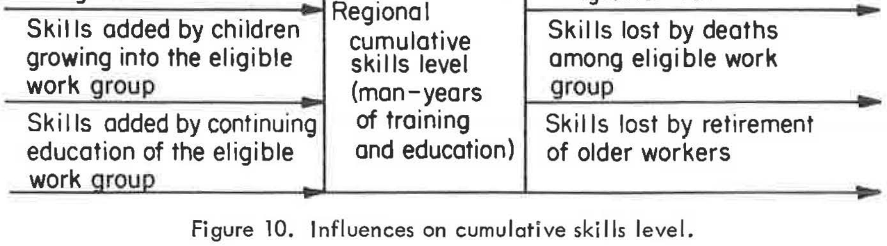

Figure 10. Influences on cumulative skills level.

TABLE 3

SENSITIVITY ANALYSES OF SKILLS EFFECTS ON RELATIVE WAGE COSTS AND MIGRATION

Simulation Run[a]	Characteristics of Skills Effects on Relative Wage Costs	Population Growth Relative to Base Run After 25 Years
47	None	Base Run
62	Relative skills inversely related to relative wage costs	102.6%
63	Same as Run 62, except trend in national skills retarded relative to region	117.1%
76	Migration directly related to skill level	107.1%

[a]Numbers correspond to computer simulation identification system used internally by research group.

Model Formulation of Skills.—In the model, the total skill level of the region's population is represented as the cumulative man-years of education and training of all people in the region in the age range of the labor force (14-64). To the cumulative man-years existing at the beginning of the forecast period are added those brought in by children growing up into the labor-force age group, by migrants into the region and by the continuing education and training of those over 14 years old. Lost from the region's cumulative skills are those withdrawn because of deaths and outward migrations among the "eligible" work group (age 14-64), and retirement of older people from the labor force. The factors modifying the overall cumulative skills level are shown in Figure 10.

In modeling the skills added by entry of the young into the eligible work group, the character of compulsory education is noted so that all youths becoming 14 years old are regarded as having completed 8 years of education. Education beyond the age of 14 is represented in 1960 as adding 3.6 years of education and training to every teenager and trended to 1985 to provide 4.8 years beyond the age of 14. Thus, it is assumed that the average 1960 teenager will receive 11.6 years of education and training, whereas the average 1985 teenager will receive 12.8 years. Such a trend appears reasonable, but variations of this trend have also been tested.

Sensitivity Experiments on Skills Formulation.—Three of the sensitivity experiments conducted on skills are reported here (Table 3).

In Run 76 a relationship between migration and skill level was hypothesized, roughly on the basis of Table 2. According to this hypothesis, as the average skill level in an area increases, the migration rate is modified by an effect of skill index (ratio of regional migration rate to migration rates occurring at average national skill level, Fig. 11). After 25 years this leads to a population projection 7 percent greater than the projection in the base run. This occurs because the region starts out with a relatively low skill level, resulting in a lower rate of out-migration and consequently a greater number of births than in the base run. These two effects combine to produce the higher population projection.

In Run 62 a relationship between relative skills level and relative wage costs was hypothesized. According to this hypothesis, a region with higher average skills level has more productive labor and hence can supply more labor output per dollar wage, thereby cutting total wage costs (Fig. 12). A very small but positive effect occurred due to the growth of skills in the region at a slightly higher rate than the national average.

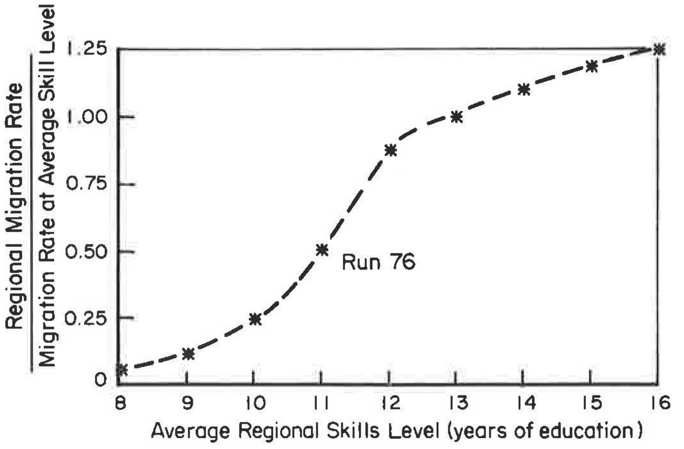

Figure 11. Migration related to average regional skills level.

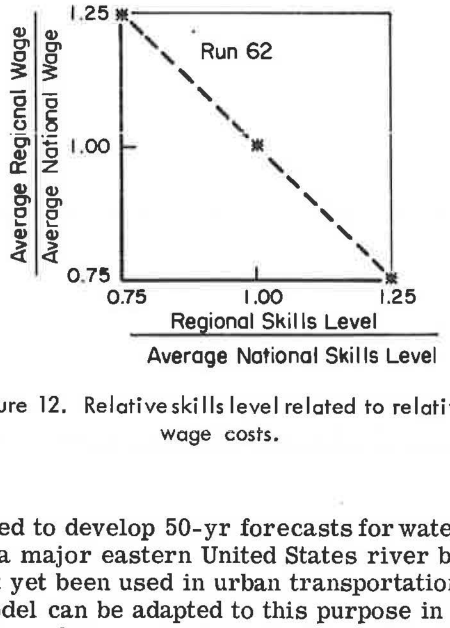

Figure 12. Relative skills level related to relative wage costs.

Run 63 shows the potential of increasing regional growth by accelerating skills development. In this run the region was allowed to outstrip the national average in the education and training of its population. The impact was quite large in 25 years (17%). Moreover, the effects of such skills buildup are cumulative and ever-increasing. These sensitivity experiments clearly indicate that skills level may have extremely important effects on regional economies. Assumptions made about skills do, therefore, significantly affect medium- and long-run projections.

CONCLUSIONS

The regional economic forecasting model described above has been successfully applied to develop 50-yr forecasts for water-resources planning for 8 contiguous regions in a major eastern United States river basin. Although this forecasting technique has not yet been used in urban transportation studies, ongoing research indicates that the model can be adapted to this purpose in a straightforward manner. Several characteristics of the model indicate the utility of this approach for regional forecasting:

1. The explicit form of the forecasting methodology facilitates evaluation and use of the forecasts.
2. The use of a simulation compiler in the computer operation of the model essentially eliminates computer programming and facilitates experimentation with the model.
3. Low computer operating cost makes feasible the testing of alternative growth rates, parameters, and formulations so that an entire set of forecasts based on alternative assumptions and submodels may be prepared.
4. Updating the forecast as the model is revised or new data becomes available requires only a rerun of the model.

As with many operational forecasting techniques, model development is never entirely completed. Ongoing research studies are revising and extending the model described in this paper. Of particular importance for transportation planning is the incorporation of a regional income forecast into the model, from which may be derived the vehicle ownership forecast. The export employment sector is being reformulated in an attempt to incorporate recent research findings on the movement of investment capital among regions. The problems of migration rates and labor force participation rates are being restudied in light of recent developments in this research area. These model improvements may be expected to provide, overtime, a forecasting capability at least commensurate with the status of land use and trip forecasting models for urban transportation planning.

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Direct and Indirect Economic Impacts of Highway Interchange Development

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•THE Keystone Shortway (I-80) now under construction will cross Pennsylvania from Youngstown, Ohio, in the west, to Stroudsburg, Pa., in the east. The four-lane, limited access, toll-free highway will open many parts of the state now relatively inaccessible and will introduce economic and social changes in many areas through which it passes. Economists, planners and others concerned with these changes are well aware that a new highway may increase the demand for goods and services in a region, and that new firms will come into being as a consequence. Furthermore, expenditures by highway users can have a significant indirect economic impact on local communities. The extent and nature of this impact, however, is not well known. It is the purpose of this paper to explore the indirect as well as the direct economic impacts of a new highway in a given community, and to shed some new light on this subject.

It may be well to begin by distinguishing between two kinds of economic effects or benefits of new highways, both of which are substantial and important. First, there are the primary benefits. These values or benefits may or may not register in the commerce of the region or even in the commerce of the nation. Their measurement in monetary terms can be extremely difficult. These benefits are germane to welfare considerations of society as a whole, and must be considered in the decision-making processes that concern choices between alternative uses of scarce resources. As large sums of money are involved in new highway construction, questions concerning the allocation of limited government funds are relevant. Should there be more highways or more aid to education? Should highway A or highway B be built? What kind of highway is it to be?

The second type of benefit involves the local returns or the economic impact on an area as a result of the expenditures for new highway construction and the new expenditures generated by users of the highway. In addition, there are changes in the cost structure of transportation. (For example, there is the comparative advantage one community may realize as compared to another as a result of a reduction in trucking costs; in one sense, changes in the cost structure of transportation can also be considered among the primary benefits.) It is with these types of benefits that most communities and local interest groups are concerned as they affect the people most directly. But there are often conflicts between local and national interests in the framework of these two types of benefits. Such matters as highway location, types of highways, or the regulation of land use adjacent to highways often engender bitter disputes. Recognition and a better understanding of these two types of benefits may help resolve some of these conflicts. This paper deals only with the second type of economic effects of new highways and hopefully presents a methodology which permits better estimates to be made of these benefits.

APPROACH

Estimation of the changes taking place in a region as a result of a new highway requires two stages of analysis. First, there must be some means of predicting the

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probable growth that will occur in terms of new firms and other institutions and the increase in demand for goods and services created by the new highway. Identifying and quantitatively describing these factors constitute an important part of a research project now being conducted by the Institute for Research on Land and Water Resources at Pennsylvania State University. This research involves a study of over 100 interchange communities on the Interstate highways in Pennsylvania.

When the forecasts of demand and economic development have been made, it becomes possible to estimate the direct economic impact of the highway in terms of the increased output of goods and services produced in response to the new demand. However, there are further economic consequences arising from this increase in productive activity, and the estimation of this indirect impact comprises the second stage of the analysis. This second stage becomes rather involved, as it requires some knowledge of the economic structure of the community and how the various forms of internal economic activities are interrelated, not only with each other, but with the outside world. This report incorporates these two stages of analysis in estimating the impact of the Keystone Shortway on the level of economic activity in Clinton County. Two independent fields of research at the University were brought together to achieve this synthesis. It is believed that this is the first time the techniques set forth have been used to attempt a quantitative analysis of a highway's economic impact on a region. This approach is viewed primarily as an exploratory attempt in methodology. The authors recognize many shortcomings and weaknesses in the procedure. However, they strongly believe that future research will enhance considerably the predictive capabilities of such an approach.

All of us are cognizant of the direct expenditures in an area by highway users for items such as gasoline, meals, and motel lodging. However, the indirect effects of these expenditures on the economic life of the community are not so apparent. For example, a tourist purchases gasoline from a local service station serving a new highway. This expenditure becomes income to the proprietor of the station. A portion of this money will be paid by the proprietor to his employees as wages. The employees, in turn, will spend a portion of their wages at the local food stores. The food store owners will use a small portion of these receipts to pay for electricity, local taxes, etc. At each transaction, an even smaller portion of the original gasoline bill paid by the tourist will be spent locally, the balance being spent outside the community to supply the goods and services not available locally. The portion spent outside the community is called leakage. Thus, in time, all of the original expenditure by the tourist in the area will filter through the economy until it is all used up, i.e., finds its way back to the outside world. The ratio of the additional income generated in the community by the expenditure of the original tourist dollar is called the multiplier.

Although the foregoing example deals with only a few dollars, the same reasoning applies to all expenditures made within a region by outside firms or individuals. Clearly, it would be almost impossible to go into an area and trace all these dollars from one business place to another. Yet some knowledge or estimation of these indirect economic effects in a community is important if we are to understand and assess the total role new highways play in generating income and wealth in a region.

The estimation or measurement of just the direct portion of these expenditures is difficult, but with properly designed sampling techniques it can be accomplished with a reasonable degree of accuracy. However, without some methodology or tool strikingly different from sampling, estimation of the indirect effects is virtually impossible. Fortunately, the regional scientists have been provided with such a tool: the input-output technique.

THE INPUT-OUTPUT MODEL

An input-output model is an analytical procedure which systematically portrays the interrelationships of all economic activities in a given region over a period of time, usually one year. A form of the static Leontief input-output model was developed for Clinton County by the Pennsylvania Regional Analysis Group (1). The data used to construct the model were collected in 1964 from primary sources using interview, questionnaire, and sampling techniques.

The model, in a systematic way, shows the total flow-of-funds through the region. The local economy is subdivided into a number of economic sectors, each sector representing some specific type of business activity: for example, all gas stations form one sector; all food stores another. In total, there are 54 different kinds of sectors or economic activities in the Clinton County model. These sectors are arranged in the form of a matrix which shows, in rows and columns, the total value in dollars of all the purchases of one sector from each and every other sector. In addition, it shows the total amount of money flowing into each sector from the outside world, as well as the total amount of money flowing from each sector back to the outside world. In this way, it is possible to depict the interrelationships or interdependencies of any one sector on all the other sectors; that is, it shows how the region, as an economic system, operates, and the role that each sector of activity plays in the economic life of the community. The community is viewed as an integrated economic unit which, of course, it really is.

The monetary input from the rest of the world to the region consists of all the payments from outside the region made to the various economic sectors of the region. These payments include such items as income from the sale of goods by a local manufacturer to a customer outside the region, income from the sale of goods and services by local businessmen to nonresidents coming into the area to shop or who may be passing through on a highway, state funds given to support local schools, and federal payments for social security. This income from the rest of the world then passes from one sector of the region to another. Some of it, of course, passes to the outside world in the form of purchases for raw materials and manufactured goods not produced locally, some in the form of state and federal taxes, etc. This money comprises the monetary output of the model. It is a mathematical characteristic of this model that the total money flow into the region equals, for the time period under consideration, the total money flow from the region to the outside world. The model was constructed by determining all the actual money flows of the types just described that occurred in Clinton County during 1963.

A transactions matrix showing the flows from one economic sector to all the others was constructed. From this matrix, a matrix of technical coefficients was constructed. A given sector's technical coefficients represent, for that sector's total income, the proportions paid to the respective economic sectors of the region and to the rest of the world. Thus, a set of technical coefficients for a given economic sector gives the proportionate distribution of income, as expenditures, to the other sectors of the region. With a set of external incomes to the various sectors of the region and a set of technical coefficients relating one sector to another, the economy of the region can be simulated.

Through the development in recent years of high-speed large-capacity digital computers, it is possible to program or simulate this regional economic system in a computer. Then by feeding into the computer a model of the economy changes in external demand, such as the additional expenditures within the region of a tourist using a new highway, it is possible to trace the manner in which these expenditures are dissipated throughout the entire system, there being no other changes. These changes in external demand will change the levels of activity of all the economic sectors of the region. Because the changes are due entirely to an increase in external demand, their effects can be estimated by comparing the levels of activity the increase induces in the input-output model with the actual levels of activity in the base year. Such estimates should be considered no more than first approximations of the indirect effects of the given change in external demand. However, these estimates should be superior to others not derived from measures of the interrelationships among the economic sectors of the region.

The model is used, therefore, to determine for a particular set of external incomes (and technical coefficients) what the levels of economic activity would be in each of the 54 economic sectors. The determination of these activity levels was accomplished by treating the model as a linear programming problem in which the objective function to be maximized was the total economic activity of all the sectors of the region. The problem was solved using the simplex algorithm programmed for a digital computer.

There are a number of assumptions inherent in the structure of the internal producing sectors of the input-output model, as follows:

1. The factors required to produce any good must be used in fixed proportions.
2. Returns to scale are constant at unity, i.e., the activity operates with a homogeneous production function. These two assumptions, taken together, give the fixed inputs coefficients restriction.
3. There is no joint production; each activity is assumed to make a single product.
4. The economic system is in equilibrium.
5. There is no scarcity of inputs. For a model of a small region, exceeding the present supply of an input factor (such as labor) by a small amount may present no severe problem, since in all likelihood, there would be a reserve of that factor in the surrounding areas.

An assumption inherent in the exogenous or final demand sectors of the model is that price elasticities of demand are zero and income elasticities of demand are unity. This implies that regardless of the quantity produced, and the price asked, the entire output will find a ready market. For a small region, this assumption is not too restrictive in the short run, since output from a small region makes up such a small proportion of the total output to the national market.

The following basic relationships are inherent in the model used in this study:

1. The total quantity of output of an activity is either consumed locally (becomes a factor input to some other local activity) or is sold to final demand. The model, therefore, is not of any inventory changes.
2. Capital expenditures for producer's goods, consumer durables, maintenance of plant and equipment, replacement of capital equipment, and new construction are included in the production functions of the business sectors and consumption functions of the households; thus, the model is gross of investment expenditures.
3. The model is not of any capital consumption allowances.
4. The household consumption functions are gross of saving. Saving occurs, but is reflected as a factor payment to the financial sector.
5. The total value of a sector's output, whether sold (consumed) internally or externally, is equal to the total payments made by that sector for factor inputs, whether purchased internally or externally.

The input-output methodology has been used in the past mostly as a macroeconomic descriptive tool. Perhaps its most intriguing use, however, rests with its ability to trace throughout an entire system a given change in any part of the system. This use is called "impact analysis." The model may be altered by: (a) changing the level of outside sales or export demand, (b) changing the internal technical coefficients of some sector, and (c) adding new sectors to reflect the introduction of new businesses into the economy. The new pattern of the flow-of-funds that will be given by the model will be an estimate of the impact of the corresponding changes in the economy being simulated. The primary value of the model, therefore, lies in its ability to estimate the indirect effects of changes in the economy of a region. Such a model can lead to more complete and realistic estimates than have been possible previously. The model mathematically depicts the interdependence of all economic activities of the region. This property of the model should be of considerable value to groups charged with the responsibilities of guiding the future growth and development of local communities.

PREDICTION OF DEVELOPMENT OF INTERCHANGES

The research being conducted by the Institute for Research on Land and Water Resources has, so far, been able to identify a number of exogenous and endogenous factors influencing the degree and type of development that takes place at interchange sites. The exogenous factors include such variables as (a) topography, (b) distance from large or key cities, (c) distances from adjacent interchanges, (d) age of interchange, and (e) volume of through traffic on the limited-access highway. Endogenous factors include (a) population at the interchange, (b) public utilities at the interchange, (c) volume of traffic on the intersecting highway, and (d) existing development at the interchange site or near it.

The aim of the research project is to develop a system of structural equations relating the endogenous variables to each other and to the exogenous variables that have been identified. It will then be possible to make forecasts of the development that will take place at a given interchange after it has been in existence for a specified time. However, the econometric analysis of the data has not progressed sufficiently to provide the systems of equations complete with estimates of coefficients of the interacting variables.

An intermediate step in the development of the full econometric model involved a classification of the observed interchanges according to their degree of economic development. In addition, there was some qualitative analysis of the factors that appear to be related to type and intensity of this development. A pattern of sufficient clarity was observed which made it possible to indicate the development that reasonably may be expected for a group of adjacent interchanges along a section of highway. It was practicable to apply this knowledge to the problem of predicting the economic impact of the Keystone Shortway on Clinton County since the engineering plans indicate the location of the four adjacent interchanges that will be constructed in the county.

Prediction of the economic development that would probably occur at the interchanges was accomplished by adopting the following procedure: (a) engineering plans of the proposed section of the highway through the county were superimposed on a topographic map of the county; (b) data on the factors relevant to economic development were secured from public sources; (c) the sites of the projected interchanges were inspected, and data were secured on such factors as topographic detail and existing state of development in the neighborhood; (d) a projection of average daily traffic for the Shortway and the various intersecting routes at the interchanges in the county was secured from the Department of Highways, and (e) by means of the analysis already made of existing interchanges, the data were synthesized into a picture of development and level of economic output that may be expected in the group of interchanges within five years of the completion of the highway.

Analysis of the foregoing yielded a reasonable expectation that thc following developments would take place: (a) a trucking terminal, (b) one motel of 100 units, (c) four service stations, and (d) two new restaurants.

Insofar as the input-output model is concerned, it does not matter at which particular interchange the foregoing installations would be located. What is of importance is that they will come into existence at some location within the county as a result of the highway.

INCORPORATION OF PREDICTED ECONOMIC DEVELOPMENTS INTO COUNTY MODEL

A number of assumptions were made to ease the burden of analysis and illustrate with more clarity the effects of the highway itself on the local economy. If one knows a priori the true extent and nature of the probable change, relaxing of the assumptions, insofar as the input-output model is concerned, would be feasible. Furthermore, it would add realism to the analysis. The assumptions made were as follows:

1. That portion of the Shortway through Clinton County will be the last constructed. When this portion is completed, the highway will be open for use throughout its entire length.

2. The highway and the attendent facilities predicted as a result of highway demand have been constructed and are in full operation. This abstracts from the impact of local expenditures resulting from the construction costs themselves. In other words, the multiplier effects plus accelerator effects of both the new public and private investment expenditures are not taken into account.

3. There are no significant changes in the levels of activity for both the national economy and the Clinton County economy as compared to the base year of 1963. This yields a comparative static form of analysis in that it compares the county economy as it was in 1963 to what it would have been in that year had the new highway been in existence and operational.

4. The predicted trucking terminal would be one of several already existing in the county and would be merely relocated at an interchange site. Truck transportation

costs were assumed not to change significantly due to the Shortway. The locational advantage of the greater Lock Haven area for industry was assumed not to become more favorable as compared to that of other central Pennsylvania communities. Accordingly, there would be no change in the current cost estimates for transportation and no new industrial sectors would appear in the model.

5. Lock Haven's major competitive retail market is Williamsport, about 27 mi to the east, and outside Clinton County, but the Shortway would not make Williamsport any more accessible to Lock Haven retail shoppers. Hence, there would be no significant increase in external purchasing by Clinton County households because of the Shortway.

6. The Lock Haven retail market area would be more accessible however, to households located to the west, particularly in the northern part of Centre County. Therefore, an increase in retail sales would probably occur in Lock Haven. It was estimated that 300 more families would shop in Lock Haven about six times per year, spending on the average, about $50 per trip. Most of this shopping would be for clothing, household needs, and consumer durables such as are indicated in Table 1.

7. The 100-unit motel would have full occupancy during six months of the year. Total annual external income would be about $455,000. The annual external revenue for the two restaurants would be $850,000. The four gas stations would be under lease arrangements from national oil companies, with external sales of $200,000 per year per station. These data are given in Table 1. The estimated annual cost structures for the operations of these enterprises were based on selected data from existing establishments of the three types in the county.

The three new types of business establishments located at the interchanges were structured into the existing Clinton County model in the form of three new sectors—motels, restaurants, and service stations. Thus the model was expanded to 57 internal sectors of activity instead of the original 54 sectors.

It was recognized that the local pattern of expenditures of these new activities would be a function, in part, of their organizational structure. That is, it seemed reasonable to assume that service stations would operate under lease arrangements with the oil companies, but chain management and local ownership and management were considered alternatives for both restaurants and motels. Local ownership of the motel and restaurants would result in somewhat greater local expenditures for goods and services than those which would result from the chain form of management. A chain restaurant, for example, can be expected to obtain much of its food from a centralized purchasing operation outside the county. In contrast, a locally owned restaurant usually purchases

TABLE 1

INCREASE IN EXTERNAL INCOME DUE TO SHORTWAY
($1,000 units)

Sector	No. of Units	External Income ($)
New activities at interchange		
Service stations	4	800
Motel	1	455
Restaurants	2	850
Increase in retail purchases		
Auto dealers		20
Department and variety stores		25
Furniture and appliances		15
Clothing stores		15
All other retail		15
Total		2,195

much of its food needs from local sources. Such differences in expenditure patterns would result in different values for the expenditure coefficients; thus, expenditure coefficients appropriate to each organizational alternative were computed and structured into the model. The analytical procedure adopted does not imply any value judgment concerning the desirability of one type of ownership as opposed to another. Patterns of ownership that develop in a region normally depend on the source of funds available and on the alternatives open to the local holders of investment funds. Even if local capital is insufficient or unwilling to assume the risk of a new enterprise, the region might still benefit from outside capital investment rather than forego the activity entirely.

ANALYSIS OF PREDICTED IMPACT

The impact analysis is discussed under two different variations:

1. Variation A. Increase in nonlocal retail purchasing plus impact of the three new "highway activity sectors" when the restaurants and motel are under a nonlocal or managerial organizational structure.
2. Variation B. The same as variation A except that the restaurants and motel are locally owned.

The computer analysis provided data on increases in economic activity for each of the 54 internal sectors of the basic model. Because some of these sectors realize little benefit from the highway, only those individual sectors showing appreciable increases in total activity together with totals for sector groups are given in Table 2.

Interpretation of the data in Table 2 is quite straightforward. Because restaurants under Variation B (local ownership) would probably purchase more of their food requirements from local suppliers than from outside vendors, the total returns to the food processing firms in the county will be greater ($186,000 as compared to $150,000). This, in turn, has an indirect effect on the agricultural sector which supplies the local food processing firms. Farmers realize $7,000 more gross income where the new restaurants are under resident rather than nonlocal ownership.

For all retail sectors combined, $90,000 of the total gain in economic activity is attributable to the direct purchases by the estimated 300 familes from outside the county expected to patronize this market area. Thus the difference, or $620,000 in the case of Variation B, is the indirect impact. Most of this indirect component originates with purchases by the new facilities connected with the highway. Food stores and auto dealers gain the most under the local ownership variation ($50,000 and $33,000, respectively), reflecting a greater propensity for local patronage.

In the service group, all of the increase in economic activity is indirect. For the finance and insurance sectors it matters considerably whether the new facilities are locally owned or not, but for the professional personal services sector, it matters little.

The wholesale sector, with the second largest percentage increase in activity, derives most of its increase from local distributor sales of gasoline and oil to the new service stations at the highway interchanges.

The local, state, and federal government sectors experienced the largest percentage gain in total economic activity. Most of this ($137,000 of the $142,000 shown under Variation B) was attributable to the state government sector, and is explained by the comparatively heavy purchases of wholesale liquor by the bars at the new restaurants and motels. Local vs nonlocal ownership has no appreciable effect in this case.

Gains by labor are higher under nonlocal than under local ownership. If, at the same time, one considers the proprietary households, which experience considerably higher gains under local ownership, the reason becomes apparent. The local owners themselves undertake the managerial functions of their enterprises. Profits under local ownerships, allocated to the proprietary households sector, therefore remain in the community; but under nonlocally owned arrangements, profits flow out of the community to the head office, reducing proprietary household income. In turn, the head office has to hire managers for its facilities, thus increasing returns to the labor households sector. Under local ownership wages and salaries paid directly by the new motel, service stations, and restaurants amount to $225,000 as compared to 280,000 under

TABLE 2

ABSOLUTE AND PERCENTAGE INCREASE IN ECONOMIC ACTIVITY BY SELECTED SECTORS AND SECTOR GROUPS
($1,000 units)

Sectors	Increase			
	Variation A		Variation B	
	$[a]	%	$[b]	%
Food processing	150	3.5	186	4.4
Printing	15	2.0	21	2.8
All industry	199	0.2	243	0.2
Agriculture	32	1.0	39	1.2
Education	1		1	
Food stores	145	1.5	195	2.0
Auto dealers	105	1.0	138	1.3
Clothing stores	41	1.3	42	1.3
Furniture stores	47	1.4	48	1.4
Hardware stores	59	1.5	61	1.5
Department stores	106	2.0	116	2.2
All other retail stores	22	1.1	24	1.2
Total all retail	608	1.2	710	1.4
Finance	18	0.7	28	1.1
Insurance	39	1.2	49	1.5
Professional personal service	21	0.9	22	1.0
All service	102	0.8	124	1.0
Transportation	10	0.1	11	0.2
Construction	51	1.0	53	1.0
Wholesale	517	4.3	525	4.3
Utilities	100	1.9	103	2.0
Nonprofit	46	0.8	47	0.9
Local government	84	1.4	85	1.4
State & federal government	140	7.3	142	7.5
Labor households	592	1.0	563	1.0
Proprietary households	103	1.2	167	2.0
All households	753	1.0	779	1.0
All other	11	0.4	11	0.4
Motels (new sector)	455		455	
Restaurants (new sector)	850		850	
Service stations (new sector)	800		800	
Total	4,759	1.6	4,978	1.6
Direct only	2,195		2,195	
Indirect only	2,564		2,783	

[a]Multiplier = 2.17. [b]Multiplier = 2.27.

TABLE 3

NET RESIDUAL BENEFITS BY SECTORS
($1,000 units)

Sectors	Variation A		Variation B	
	Absolute Amount	Multi-plier	Absolute Amount	Multi-plier
Households	$753	0.343	$779	0.335
Local governments	84	0.038	85	0.039
Nonprofit organizations	46	0.021	47	0.021
Total	$883	0.402	$911	0.415

nonlocal ownership. Profits to these entrepreneurs under local ownership are $55,000; under nonlocal ownership they are zero to the region. Thus direct payments to all households under both variations amount to $280,000. Subtracting this value from the total increase in economic activity for all households (Table 2) shows that the indirect increase in total household income under Variation A is $473,000 and under Variation B the indirect increase is $499,000.

Total economic activity in the county under local ownership (Variation B) increases by about $5 million, of which approximately $150,000 is due to the increase in purchasing by the 300 nonresident families that use the Lock Haven market area. The total direct increase, i.e., total flow of new money from outside the county as a result of new sales to outside buyers, is about $2,195,000 of which about $2,105,000 is from the facilities at the highway interchanges, and about $90,000 from the new shoppers. This $2,195,000 of new external sales generates an additional $2,783,000 of economic activity internally. This gives a multiplier of 2.27 for the locally owned variation. The multiplier for the nonlocally owned variation is 2.17.

The nearly $5 million increase in total economic activity is a gross gain in the total flow-of-funds through the entire economic system of the region over a period of one year. Much of this gain involves the counting of the same dollar, or a portion thereof, several times, as it passes from one business place to another. A more meaningful measure of the returns, or gains to the community is what could be called net residual benefit or residual county income. This is the sum of the direct and indirect returns to households, local governments, and nonprofit organizations. It is a more accurate reflection of the monetary benefits to the people themselves in the community than the total figure given previously. Multipliers for each of these three sources of net residual benefits can be derived by dividing their direct and indirect increase in activity by the total direct income for each variation. These multipliers and the absolute amounts of the net residual benefits by sectors are given in Table 3.

The multipliers in Table 3 indicate how much of each new dollar of external sales ends up as a return to the indicated sectors. For example, under Variation B, for every dollar of sales to the outside world, $0.355 accrues to households in Clinton County, $0.039 to local governments and $0.21 to nonprofit organizations. When interpreting these results, one point should be borne in mind. The estimates associated with the impact of the new highway are only first approximations of what could be expected to occur. The order of magnitude of these estimates rather than their precise values should be the main consideration.

EXTENSION OF IMPACT PREDICTION—RESPONSE FUNCTIONS

It has been shown how the input-output model can attempt to measure and predict the impact of highway interchanges in a small region. It provides an extremely detailed analysis of both the direct and indirect effects on the various sectors of the region.

However, this descriptive picture applies only to the fixed input levels estimated for the highway after it is finally in operation in Clinton County. The magnitude of these inputs is given in Table 1, in the form of external income into the appropriate economic sectors of the region. Our impact analyses are tied to these fixed external income levels. However, suppose that one or more of these inputs vary from the predicted levels, producing varying impacts on the region. Or, suppose that we wish to examine the impacts on the region over a range of different possible external incomes. Can our model provide such information easily and quickly?

The answer to this question is, of course, yes. We can extend the study of direct and indirect impacts by means of impact response functions. These functions are derived from the input-output impact model of the region. In the case of Clinton County, these functions are of the form:

$$R_i = B_i + M_{iM} X_M + M_{iR} X_R + M_{iS} X_S + M_{iE} X_E \qquad (1)$$

Here, the subscript i refers to a particular sector of the model such as retail or industry. The subscripts R, M, S, and E refer to the sources of external income resulting from the existence of the new highway: R, restaurants; M, motels; S, service stations; and E, increases in retail sector external income. Thus, the symbols of the response function have the following meanings:

R_i = total highway response of the ith sector of region;
B_i = activity level of the ith sector before advent of highway;
X_R = external income to new restaurants;
X_M = external income to new motels;
X_S = external income to new service stations; and
X_E = external income due to new retail sales.

The response coefficients M_{iR}, M_{iM}, M_{iS}, and M_{iE} are, in fact, the multipliers which yield the direct and indirect response of the ith sector to one dollar of external income from the respective income sources. For example, $M_{iS} = 0.45$ would mean that \$0.45 response is generated in the ith sector to meet \$1.00 of external demand at a new interchange service station. These coefficients are given for Variation A and Variation B of the impact study in Tables 4 and 5. Using these coefficients, we can construct an impact response function for any one of the 13 aggregated sectors formed from the original 54-sector model.

This function for the retail sector under Variation A (nonlocal ownership of motel and restaurants) is

$$R = 49{,}097 + 0.2368\, X_M + 0.3368\, X_R + 0.1377\, X_S + 1.1567\, X_E \qquad (2)$$

If this response function works, then the external incomes given in Table 1, when substituted in this equation, should give the response actually recorded by the model for this study. Inserting the amounts (\$1,000 units) given in Table 1,

$$R = 49{,}097 + 0.2368(455) + 0.3368(850) + 0.1377(800) + 1.1567(90)$$

$$= 49{,}907 + 608.3$$

$$= 49{,}705.3$$

(See Table 4).

The response function says that the absolute increase in activity, both direct and indirect, due to the impact of the new highway is \$608,300. This differs from the amount given for the retail sector in Table 2, by only \$300. This error is negligible and pri-

TABLE 4

NEW HIGHWAY IMPACT RESPONSE FUNCTIONS—VARIATION A[a]

Sector	Basic	Motel	Restau-rants	Service Stations	Retail Sales
All industry	$115,674	0.024458	0.198496	0.019735	0.0422
Agriculture	3,210	0.004355	0.029033	0.006792	0.0128
Education	1,862	0.00795	0.000745	0.000429	0.0005
All retail	49,097	0.236835	0.336823	0.137692	1.567
All service	12,093	0.052062	0.059090	0.033620	0.0340
Transportation	6,884	0.006632	0.006123	0.002425	0.0052
Construction	5,123	0.026467	0.031329	0.013686	0.0138
Wholesale	12,114	0.066175	0.046390	0.553322	0.0987
Utilities	5,144	0.111537	0.030240	0.025866	0.0248
Nonprofit	5,494	0.037882	0.020200	0.011838	0.0138
Local government	6,150	0.073578	0.047690	0.010065	0.0133
State - Federal A	1,906	0.004825	0.60359	0.002737	0.0062
Households	75,740	0.430977	0.404479	0.233471	0.2648
Total	$303,223	2.082764	2.377459	2.055047	1.6908

[a]Nonlocal ownership of new enterprises.

TABLE 5

NEW HIGHWAY IMPACT RESPONSE FUNCTIONS—VARIATION B[a]

Sector	Basic	Motel	Restau-rants	Service Stations	Retail Sales
All industry	$115,674	0.026736	0.248891	0.019735	0.0422
Agriculture	3,210	0.004754	0.037002	0.006792	0.0128
Education	1,862	0.000863	0.000767	0.000429	0.0005
All retail	49,097	0.338823	0.403480	0.137692	1.1567
All service	12,093	0.093192	0.061559	0.033620	0.0340
Transportation	6,884	0.007155	0.066382	0.002425	0.0052
Construction	5,123	0.028236	0.032426	0.013686	0.0138
Wholesale	12,114	0.074791	0.051937	0.553322	0.0987
Utilities	5,144	0.114431	0.032052	0.025866	0.0248
Nonprofit	5,494	0.039934	0.020808	0.011838	0.0138
Local government	6,150	0.075306	0.048544	0.010065	0.0133
State - Federal A	1,906	0.005319	0.160583	0.002737	0.0062
Households	75,740	0.469666	0.415731	0.233471	0.2648
Total	$303,223	2.285863	2.526133	2.055047	1.6908

[a]Local ownership of new enterprises.

marily due to round-off error in computations. Thus, it is obvious that our response functions will yield the study results previously discussed if the given inputs are used.

However, we now have the model expressed in a form which allows a much more flexible use in impact analysis. We can now calculate the predicted response, individually and collectively, for any estimated level of external income into the various highway impact sectors. For example, suppose that under Variation A, it is felt that the original estimate of motel occupancy was too high and we should reduce the expected external income given in Table 1. Further, the subsequent loss of restaurant income, due to this reduction, will be made up by a higher level of expected transient diners, i.e., diners passing through but not stopping at the motel. These new conditions would, of course, also result in an increase in income to the new service stations. Finally, let us assume that another improved road feeding into the new highway would materially improve the access by Centre County residents to the Clinton County shopping area. This might be an improvement of the "Appalachian Throughway," US Route 220, connecting with the new highway in Centre County where they intersect. Thus, our revised input estimates, in $1,000 units might be:

$$X_M = 390 \qquad X_R = 850$$

$$X_S = 885 \qquad X_E = 135$$

Comparing these amounts with those given in Table 1, we find a decrease in motel income (X_M), no change in restaurant income (X_R), an increase in service station income (X_S) and an increase in external retail sector income (X_E). The total here is $2,260,000 compared with $2, 195, 000 of the original set, a net increase of $65, 000 income.

Our response function for the retail sector of the region (Eq. 2) tells us quantitatively the economic response to this new table of highway inputs.

$$\begin{aligned} R &= 49{,}097 + 0.2368(390) + 0.3368(850) + 0.1377(885) + 1.1567(135) \\ &= 49{,}097 + 92.4 + 286.3 + 121.9 + 156.1 \\ &= 49{,}097 + 656.7 \\ &= 49{,}753.7 \end{aligned}$$

The second line above gives the individual response of the retail sector to the four sources of highway income. The total increase due to them was $656, 700, an increase of $48, 400 over the increase of $608, 300 due to the original set of inputs.

If we did not have the response function giving differential responses for the four sources of highway income, we could not have found the magnitude of this response as accurately and as sensitively. For instance, if the response of the retail sector to the net increase of external income of $65, 000 were calculated without regard to the source of the income, the retail response would have come to only $40, 500. The difference can be attributed to the fact that there is a differential in economic response according to the source of external income. Ignoring it does not result in an accurate measurement of a sector's response. The response function, on the other hand, does take these differential response rates into consideration.

Not all sectors respond in the same manner and to the same degree as does the retail sector. For example, the response function for the utilities sector under Variation A is:

$$R = 5144 + 0.1115\,X_M + 0.0302\,X_R + 0.0259\,X_S + 0.0248\,X_E \qquad (3)$$

Examination of the response coefficients shows that utilities reflect only a mild reaction to the new highway activity compared to the retail sector, because the utilities' coefficients are much less than those of the retail sector.

Similarly, one can compare the responses, sector by sector, under the conditions of Variation A and Variation B. The respective response functions can be obtained from Table 4 and Table 5. This comparison can be done independently of the actual external income inputs by means of direct comparison of the response coefficients.

For example, the retail response coefficient for highway motel impact under nonlocal ownership (Variation A) is 0.2368 and under local ownership (Variation B) is 0.3388.

The local ownership coefficient is appreciably larger than that for nonlocal ownership, reflecting the higher level of intraregional expenditures by the motel sector when the economic units are locally owned and run. Although this was pointed out previously, one might wish to make the comparison with respect to actual response in dollars. For instance, one might be interested in knowing, all other things being equal, the additional amount of external motel income under nonlocal ownership necessary to provide the same amount of retail sector response as is provided under local ownership of the highway motel. The retail sector responses to motel income are $107,700 and $154,154 for nonlocal and local ownership, respectively. Since the external incomes to the other highway impact sectors are to remain the same under both variations, we can simplify the respective retail response functions. These then, become

$$R = 49,597.5 + 0.2368\, X_M \text{ (nonlocal)}$$

$$R = 49,654.2 + 0.3388\, X_M \text{ (local)}$$

and if the external motel income remains the same ($455,000) as originally given under local ownership, the total response under local ownership is $49,808,400. To find the external motel income necessary under nonlocal ownership to equal this, we equate it to the foregoing simplified nonlocal response function and solve for X_M, i.e.,

$$49,597.5 + 0.2368\, X_M = 49,808.4$$

$$X_M = \frac{210.9}{0.2368}$$

$$= 890.6$$

Thus, if the retail sector is to realize the same total increase in business as it would under local ownerships, there would have to be an increase in external motel income of from $455,000 to $890,000.

Another application of these response functions demonstrates their flexibility. Suppose the restaurants are nonlocally owned whereas the motel is locally owned. We can construct a new combined response function by using the nonlocal response coefficient for restaurants and the local coefficient for the motel. In this instance, the two response coefficients for service stations and retail sales are the same under Variation A and under Variation B.

[Strictly speaking, combining coefficients from different response functions in this way is not a correct procedure. The coefficients derived from the Variation A model, and the Variation B model, and some model which is a combination of these two will, in general, not be the same. Thus, using a Variation A coefficient and a Variation B coefficient to construct a combined response function equation will result in a function different from the one that would be derived directly from a combined model. However, these differences, in terms of the models used in this study, are negligible from a practical standpoint. Therefore, we can use the simpler combining procedure described in the body of the paper rather than directly derive individual sets of response functions for what could be large numbers of different combinations.]

The retail sector response function would be

$$R = 49,097 + 0.3388\, X_M + 0.3368\, X_R + 0.1377\, X_S + 1.1576\, X_E \tag{4}$$

We evaluate Eq. 4 for the original input conditions given in Table 1:

$$R = 49{,}097 + 0.3388(455) + 0.3368(850) + 0.1733(800) + 1.1567(90)$$

$$= 49{,}097 + 154.2 + 286.3 + 110.2 + 104.1$$

$$= 49{,}097 + 654.7$$

$$= 49{,}751.7$$

This combined retail response function yields an increase in retail economic activity due to impact of the new highway of $654,700. Comparison with the increase under wholly nonlocal ownership (Variation B) shows that this increase lies between the increases of $608,000 and $710,000 for these respective variations. This of course, is what we would expect.

We have not exhausted the various ways in which these response functions can be modified and used to extend and amplify highway impact studies using the Leontief static model. What we have attempted to demonstrate is that the model does provide a much more flexible and useful analytic tool than a first examination would indicate. There is much more information available concerning economic highway impact data than just the impacts of a set of initial inputs of external income. If the technical coefficients of the model are valid, then response function results will tend to be meaningful and can be used by the person who understands them.

SUMMARY

The use of the input-output technique in measuring the economic impact of new highways on a region has been demonstrated. The economy of a microregion was simulated with a Leontief static model. Added to this model were additional sectors to account for the new economic activities due to a new highway. Inputs consisting of new external income to the region were estimated. Their direct and indirect impacts were derived from the input-output model under two variations, nonlocal and local ownership of the new enterprises. These results were discussed in some detail. Impact response functions were also derived from the model. These allowed the examination of highway impacts under a variety of input conditions and under any combinations of operating variations. It is hoped that the efficacy of using this type of approach in new highway impact studies has been demonstrated.

REFERENCE

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The Impact of Modern Highways on American Indian Country

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ABRIDGMENT

•UNIQUE conditions exist where modern highways are constructed through isolated areas. They provide an opportunity to measure highway benefits in a more simplified environment than is ordinarily found. The nature and background of this environment are described, and the opportunity for a new and more productive approach to elusive problems in highway economics and finance is suggested.

The impact of a suddenly built modern highway providing access to the village of Kayenta, Arizona, long the most isolated village in the United States, is described. The income of Indian trading posts and motel accommodations is analyzed before and after access was provided in order to measure the impact and its effect on property values. The effect of the highway improvement on school enrollment, methods of travel by the Indian people and employment, is also delineated.

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Freeways and Residential Neighborhoods

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ABRIDGMENT

•THE study which was conducted in 1964 and 1965 was requested and sponsored by the Automotive Safety Foundation. The purpose of the study is to evaluate the influence freeways have when they traverse rather than circumscribe a neighborhood area. The North Broadway area of Seattle, Washington, was chosen for the study since it was subdivided into three parts by the construction of the Seattle Freeway and the Roanoke Expressway.

The method of making the evaluation was by the collection of data relative to land use, household characteristics, traffic volumes, and accident hazard.

The zoning and land-use portion of the study revealed a strong indication that each of the three areas are being subjected to pressures tending to make them individual sections of the total area.

Household characteristics were collected by means of a questionnaire representing an 11 percent sample. The majority of the residents felt that the neighborhood is now a better place to live, however, access to schools is more difficult. Only the western section, which is mainly commercial and apartments, thought that the property values had increased. Shopping characteristics were also changed for two of the three sections.

Significant relief in traffic volumes was found on the arterials serving and passing through the neighborhood. The number of accidents was also found to have declined significantly. The decrease in traffic has made the northeast and western sections of North Broadway more attractive as "bedroom" communities for the University of Washington. This has encouraged changes such as the construction of new apartment buildings.

The freeway, although not fully completed, already has opened new areas to the North Broadway residents. This is particularly true of the northeast section whose residents find it convenient for short trips such as shopping as well as for the longer work or pleasure trip.

It is difficult to determine whether or not the new areas opened to the North Broadway residents will be better or worse for North Broadway than the present trend now dividing the area. However, the decrease in volumes and accidents was a definite boon to the area.

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