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

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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.

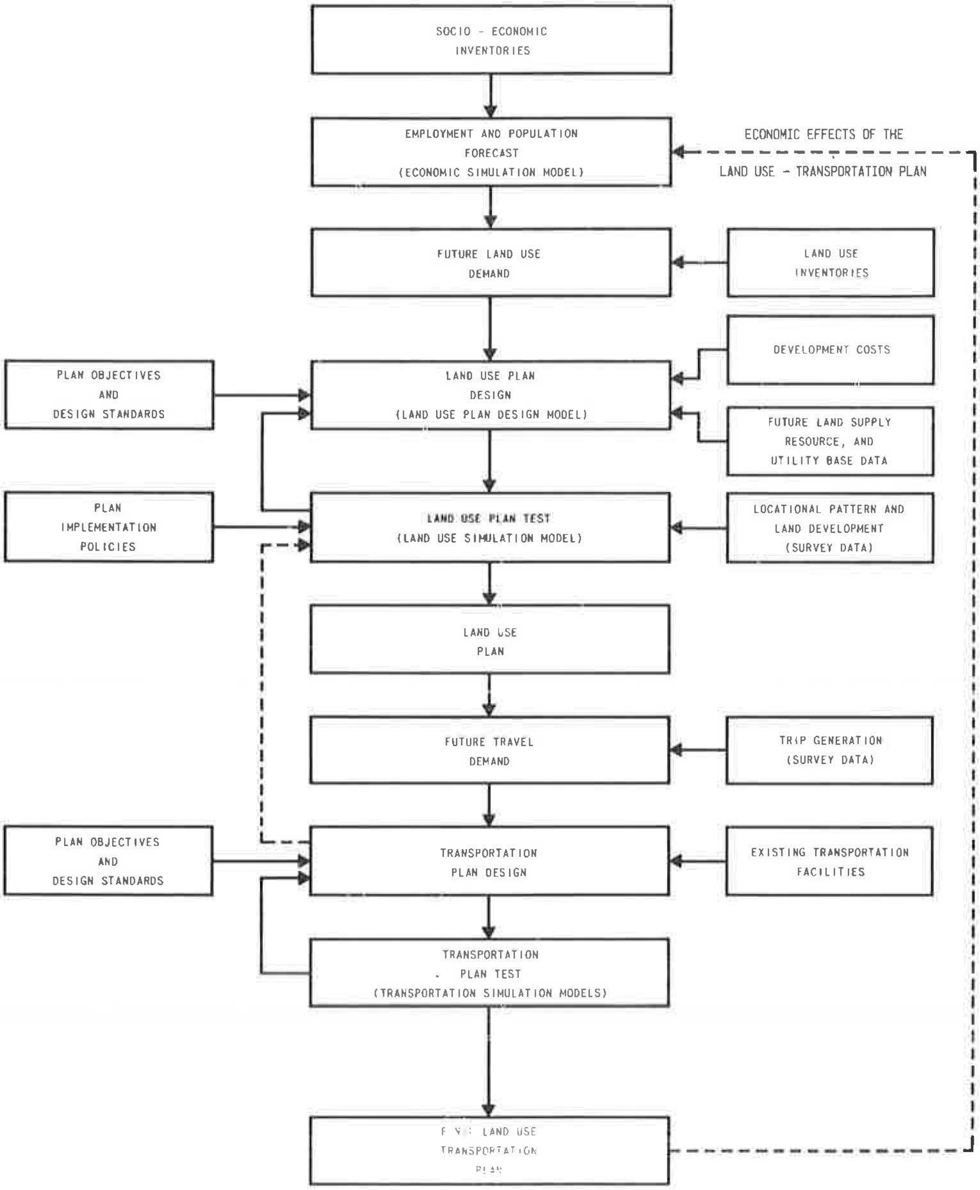

Figure 1. Land use-transportation study planning system diagram.

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

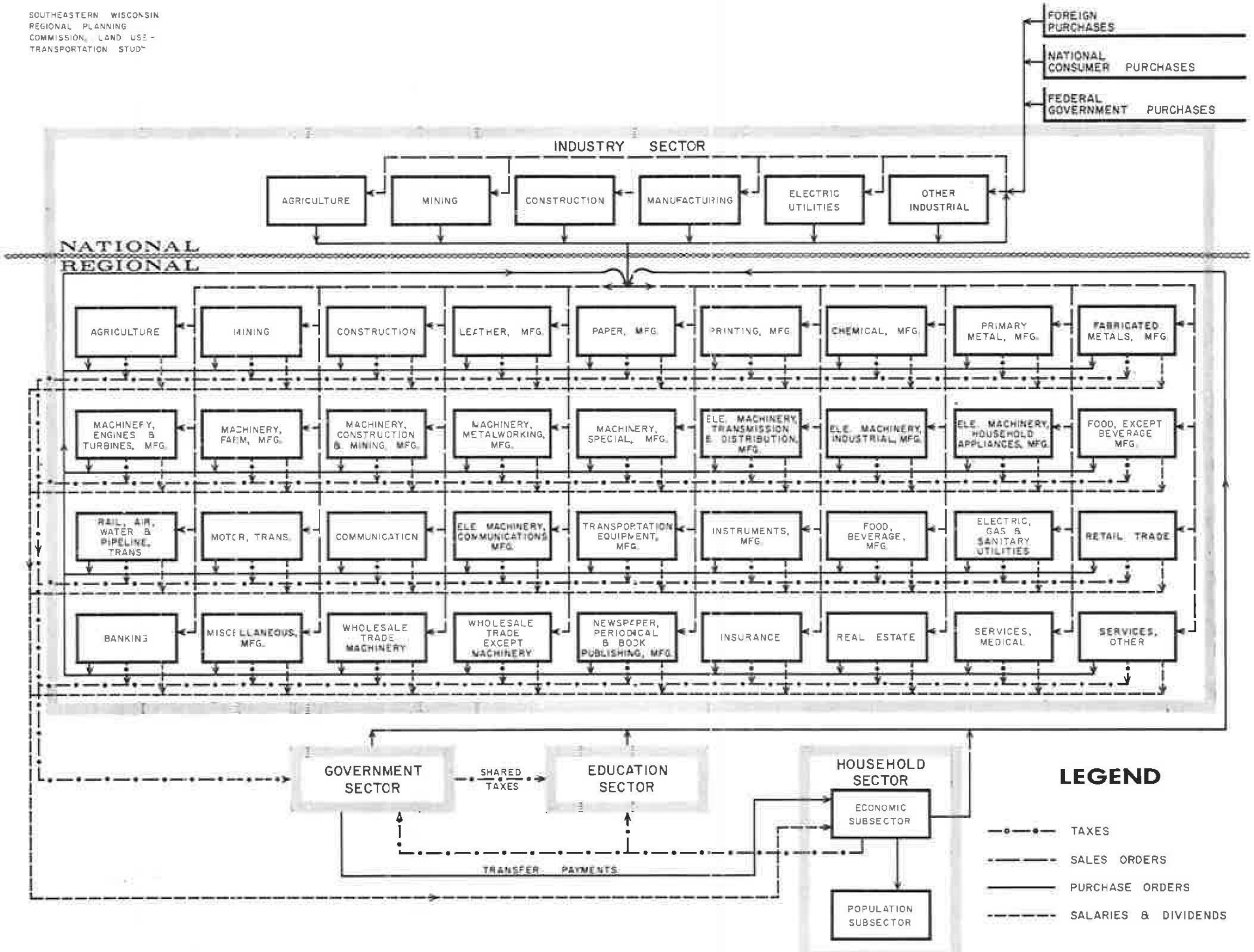

Figure 2. Regional economic simulation model.

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.