Staff Papers Series

P81-9 April 1981

SOCIOECONOMIC MODELS FOR DEVELOPMENT PLANNING.

I. VALIDATION METHODS

Wilbur R. Maki

Department of Agricultural and Applied Economics

University of Minnesota
Institute of Agriculture, Forestry and Home Economics
St Paul, Minnesota 55108

SOCIOECONOMIC MODELS FOR DEVELOPMENT PLANNING.

I. VALIDATION METHODS

Wilbur R. Maki

REIFS Report No. 17

Prepared for Workshop on Model Acceptance, National Science Foundation, 1800 G Street, N.W., Washington, D.C., April 22-23, 1981.

CONTENTS

Acknowledgements

Special thanks are due to the co-organizers of a recent Workshop on Model Acceptance -- John McLeod of Society for Computer Simulation and Siegfried Dickhoven of Gesellschaft für Mathematik und Datenverabeitung -- for their forsight and fortitude in addressing the topic -- Guidelines for Developing Credible Models and Producing Acceptable Information. The key-note address by Don MacRae, East-West Center, on the policy process in global modeling, and the discussion which followed, provided a common ground for exploring model validation strategies in this Workshop. Also acknowledged is the incisive and scholarly analysis of large-scale model validation and assessment criteria by Glenn Johnson in his recent paper entitled, "Some Philosophic Considerations Behind Model Validation and Assessment" (presented at TIMS-ORSA Meeting, Washington, D.C., May 4-7, 1980). The Workshop and the Johnson paper strongly re-enforced earlier perceptions that model validation is a critical, but much neglected, issue in socioeconomic modeling; it must be addressed as a necessary condition for model acceptance.

Abstract

The purpose of this paper is to assess alternate strategies of socio-economic model validation. An extensive literature review provided the delineation of validation methods and, also, brief summaries of each type of validation. Finally, personal experience in the implementation and use of regional economic impact forecasting and simulation systems was used in outlining the structure and the steps of play of a simulation/gaming model for testing the validation methods listed earlier.

Summary and Conclusions

Next to documentation, validation of socioeconomic models is viewed as the most important task in making a model useful. Nearly as important as validation is timeliness. Only when needed information is quickly available will the related modeling activity achieve acceptance among information users. Timeliness, of course, may affect choice of validation methods. Timeliness is also dependent on appropriately trained and competent staff.

Validation is a word of at least two meanings. In the philosophic literature it refers to logical fit. In the system sciences, validation refers to correspondence with reality. In this report, validation includes both verification, or the evaluation of model assumptions and the accuracy of its mathematical representation, and validation as the term is used in the system sciences.

State and regional development planning, which is the decision focus of this paper, is viewed as the information recipient, or model user. Interpreted model output received from the information system, which includes the model, the model-builder and the model-user, is thus one input into the development planning process.

Other information users -- public and private -- can be identified in a paradigm in which model methodology, model structure and model output are the responsibility of the model builder. Supporting the modeling effort are the activities of at least four different functionaries -- the model-builder, the data provider, the model user, and the executive/legislature. The base of this paradigm is a budget, controlled by the executive/legislature, which supports the information system and its related data base and is affected, in varying degree, by the actions of model-builder, model-user and decision-maker (e.g., in development planning).

Three stages of model validation are delineated -- a preliminary stage, an *ex post* stage, and an *ex ante* stage. A preliminary stage includes the initial steps of estimation and statistical verification. The *ex post* stage deals with the "track record" of both model-builder and model-user. The *ex ante* stage is a futuristic assessment of perceived model performance.

One method of *ex post* validation is the recording of model performance and the related contribution of model-builder and model-user. The organizational setting of the two participants may be included, also, in the *ex post* assessment.

An *ex ante* validation is achieved in several ways. A smaller-scale interactive simulation model may be derived from the large-scale computer model. In the interactive mode, the model-user may change selected parameters and initial variables and simulate the effects of these changes by comparing the new and the baseline simulations, thus acquiring personal impressions of model performance.

Also, special purpose socioeconomic models may serve as comparison models for the large-scale and smaller-scale interactive computer models. Indeed, a package of socioeconomic models can be included in each socioeconomic information system for particular planning purposes. The alternative model outputs can be compared by mediating individuals or organizations in a rank validation of individual model performance.

Finally, the interactive simulation model can be embedded in an interactive simulation/game and each of the four functionaries identified earlier can be represented with certain desires and attributes, along with the steps of play for simulating the outcomes of the negotiated decisions of each role player. The simulation/game thus can serve as a laboratory for model validation. It may serve also as a learning, or experimental, laboratory in the acquisition and development of socioeconomic information for development planning.

SOCIOECONOMIC MODELS FOR DEVELOPMENT PLANNING.

I. VALIDATION METHODS

Wilbur R. Maki

Validation of socioeconomic models may take the route of "reality-testing" -- comparison of the model forecasts with the actual events being forecast.[1/] Such validation is limited to simple, short-term modeling where statistical indicators of pre-determined accuracy and reliability are quickly available for comparison with the forecasts, which are based on earlier estimates in these series.

Socioeconomic models for development planning, which are not simple nor based on quickly available indicator series of acceptable accuracy and reliability, lack the attributes for timely and adequate validation. The forecasts are long-term, typically based on revised indicator series where the revised estimates become available long after the forecast events have actually occurred. By that time, the forecast sponsors and users often have lost interest in any evaluation of forecast failures and the model builders will have moved to other currently topical research areas.[2/]

The two scenarios of socioeconomic model validation and acceptance characterize a recurring pattern in the use and misuse of modeling in development planning. Yet, as noted by the U.S. General Accounting Office, next to documentation, model validation is the most important task in making a model useful (30).

In this paper, the focus of modeling is on subnational development planning -- state, substate, multi-state -- in the United States, particularly the State of Minnesota. Development planning refers to the efforts of federal, state and local governments to intervene in private industry location and investment processes and, thus, to affect the creation of new jobs and additional income within a particular state or region.

Information Needs

An essential first step in any evaluation of socioeconomic models is to determine the purposes, i.e., uses, for these models. At least four purposes are readily identified, namely, prediction, prescription, description, and exploration and education (11,15). Prediction refers to the preparation of point estimates, oftentimes with statistical measures of variance and reliability. Prescription is concerned with the use of the model in exploring alternative conditions, some of which may be sought by the model user or the public. Description involves use of the model in impact analysis, scenario preparation and computer simulation of alternative futures. Use of socioeconomic models in exploration and education is probably achieved best in gaming simulation exercises in which the model user interacts directly with the computerized program while playing a particular role as a decision maker and a user of socioeconomic information.[3/]

While the forecasting uses (and misuses) of socioeconomic models are most visible and well-known, other uses, especially in education and training, probably are more important to state and regional development planning. Model validation methods which focus only on comparisons of forecasts with corresponding socioeconomic indicators, preliminary or revised, truly misrepresent the initial purposes of socioeconomic modeling. Part of this responsibility rests with model users who emphasize the importance of predictions in planning at the expense of a model's educational value. Part rests also with model builders who neglect their role in identifying the purposes of socioeconomic models for development planning and incorporating these purposes into the model design through active user participation in building an information system in which the model, the model builder/provider, and the model user are important interacting elements (5,8).

In this report, the purposes of socioeconomic modeling are examined from the perspectives of model builder/provider and model user. A public (or third-party) perspective is acknowledged, but not explicitly included.

Model Validation

The operationalizing of model selection procedures starts with a statement of modeling purpose. It includes, also, identification of the type of problem addressed in the modeling purpose(11,15). For example, if the model purpose is state revenue forecasting, a quarterly or annual econometric model which has an agricultural sector and a non-agricultural sector linked to macro economic and environmental variables, like GNP and rainfall, may be quite adequate for generating accurate forecasts of state tax revenues. If the model purpose is prescription, however, an actual and a desired state of the economy or society would be articulated by the model user and the model would provide goal-optimizing simulations of these desired states.

Model validation becomes difficult as model purpose shifts from prediction to prescription and even more difficult with multiple purposes, like prediction and, also, exploration of alternative future scenarios and their regional implications. Thus, the evaluation of model properties -- scope, time horizon, level of detail and problem perspective -- is affected by the model purpose, which, in state and regional development planning, is more often exploratory and educational rather than simply predictive or even prescriptive. One student of model validation has expressed the view that "validation of complex models of complex systems is, at best, an unsolved methodological problem, and, at worst, unsolvable" (16, p. 248).

An approach to model validation is outlined here which starts with a decision focus in a listing and assessment of several model validation strategies, including an interactive simulation game. Conversion of a local prototype of a "new generation" of socioeconomic models -- the University of Minnesota Regional Economic Impact Forecasting and Simulation (REIFS) System -- into an interactive simulation game is used, finally, to illustrate an alternative validation strategy (22,24).

Alternate Validation Strategies

Participation of the model user in defining model purpose and, also, in validating the model, ideally would help limit the selection of an appropriate model to one which has properties most compatible with a particular user perspective. Whether or not a more general public perspective is honored in validation strategies depends on prior institutional arrangements as well as the attitudes and perspectives of the principal participants in the modeling process. Alternate validation strategies presented here stem from the more limited, but interacting, perspectives of the model builder and the moder user. Three strategies are outlined -- preliminary validation, _ex post_ validation, and _ex ante_ validation.

Preliminary Validation

Preliminary validation strategies are intended to verify that the model does what it purports to do.[4/] They include both measurement and statistical validation and they are primarily internal to the model building and testing.

Measurement validity deals with questions of the degree to which data correspond with reality, the reconciliation of different estimates of the same phenomena, and the use of final rather than preliminary estimates. For example, the level of expenditure for maintaining standardized employment reporting procedures for individual industries varies from state to state. Evaluation of the effects of these differences on data accuracy is difficult, however, because of the lack of internal measures of accuracy in industry classification. Also, data revisions may occur intermittantly and without prior announcement. A continuous data updating procedure which is an integral part of the socioeconomic information system for development planning would facilitate measurement validation. Such a procedure makes the model timely and capable of responding quickly to questions posed by model-user or decision maker.

Tests of statistical validity are widely exercised in econometric modeling and, also, in the evaluation of games and simulations (9,13). Derivation of model from stated assumptions and calculation of a model's output are essentially problems of model verification (as well as debugging and documentation). The testing of model assumptions and the comparing of model output with the "real world" are usually viewed as more formidable validation problems, especially with long-term forecasting models (15). Included with statistical validation are problems of statistical hypothesis testing, particularly assumptions of error structure and error distribution. Statistical validation is mostly of concern in econometric modeling (4,8,27,29). Models of systems dynamics are less amenable to statistical validation than are econometric models and the more recently developed cross-impact anlaysis models.

Ex post Validation

The comparing of model output with the "real world" can be viewed as a form of *ex post* validation. In this paper, however, *ex post* validation refers to the performance records of the model, the model builder and the model user. An accurate history of model-building and model-using performance would help focus attention on critical questions of performance accountability.

Without standardized procedures for performance (or non-performance) reporting for both model builders/providers and model users, however, the individual model performance resumes would be devoid of critically relevant information affecting its user.[5/]

An alternative approach to individual provider/user performance accounting is the documentation of organizational performance, i.e., the reporting of model-building and model-using activities in various organizations -- academic, business and government. Periodic surveys of this sort have been conducted among state planning agencies in recent years, but these have been limited in scope and only tangentially directed towards the problems of socioeconomic model validation (20). Again, the preparation, testing and acceptance of certain performance accounting criteria is an essential first step in an *ex post* model validation.

Ex ante Validation

Ex ante model validation is an indirect approach to performance evaluation. It depends on surrogate measures of probable model-building and model-using successes and failures. For example, Emshoff and Sisson view the validity of models being tested in a sequence summarized as follows (8):

> First, the model is debugged so that is performs as intended. Second, the model is validated by showing that is predicts reasonably well that its parameters have reasonable values, and that knowledgeable people also pass on its structure and parameters. Third, the use of the model is explored by the decision maker, possibly followed by agreement between model builder and moder user that the model performs reasonably well. Fourth, model performance is monitored over a period of years, with careful records being kept of model forecasts and actual results.

Two additional strategies are presented as alternatives to the Emshoff-Sisson validation sequence. A comparable simple, short-term socioeconomic model may serve as a reference, or comparison, model in a socioeconomic information system. For example, a modified regional shift-share model provides alternate population, employment and income forecasts, and an accompaning rationale for projected year-to-year changes in these variables. This model, though more sophisticated than the simple shift-share model, is much simplier than the REIFS system. National trends in aggregate and industry-specific economic activity are related to projected changes in Minnesota industry earnings and employment in such a model for a particular state (12). Many of the same variables and parameters are present in the two models and the comparison forecasts.

In addition, a disaggregated version of the REIFS model has been built for classroom use. Students prepare computer simulations of alternative regional futures for a region which are based on different assumptions about export markets, migration, commuting, capital expenditures and related variables. An interactive computer simulation program is available which allows the model user to modify parameters and starting variables and, thus, experiment with the regional effects of alternate sets of economic assumptions. Over 100 parameter- and variable-change options are available to the model user as a means of gaining insight into regional socioeconomic structure and process by observation of the related variable changes associated with selected change options.

A final validation strategy builds on the interactive simulation game (12,14). The purpose of the interactive simulation game is to transfer insights about the need for, and use of, socioeconomic information in development planning, the degree to which the socioeconomic modeling meets these decision information needs, the reasons for the successes and failures in socioeconomic modeling, and the consequences of model shortcomings, if any, for development planning.

An interactive simulation game for model validation would be developed in three stages (15). The first stage -- development of the simulation model -- is complete in the Minnesota case (22). The second stage -- embedding the simulation model in an interactive simulation -- is also complete. The third stage -- embedding the interactive model in a game -- is currently being completed. This step depends on the role playing feature of the game in ex ante model validation as illustrated by a particular model validation laboratory.

SIMLAB: A Model Validation Laboratory

The socioeconomic model validation approach presented next is still tentative and only partially tested. It represents a synthesis of computer simulation and gaming simulation model-building and model-using efforts, starting with the large computer models of the Iowa economy built in the 1960's and continuing with similar efforts in Minnesota in the 1970's (20,21,22,24). Since 1974, a series of economic impact studies based on the large-scale computer models have been completed for the Energy Agency, the State Planning Agency, the Department of Natural Resources, the Department of Economic Development and others. Also during this period, a new course -- Community Development Simulation -- was organized around the use of interactive computer simulation and gaming simulation models in the classroom. When taught next year, an interactive computer simulation model -- the University of Minnesota SIMLAB -- will be used as a source of planning information for students and, also, as a laboratory for model evaluation as part of a development planning or land-use planning process. This means, of course, that the interactive computer simulation model must be embedded in a gaming simulation model which has a structure not much different from the one outlined earlier for a decision-focused socioeconomic information system.

Interactive Simulation Model

A smaller-scale interactive computer simulation model -- SIMLAB -- has evolved from the large-scale computer simulation used in the state-supported studies noted earlier (22). Eight individual modules are linked together recursively in SIMLAB, which is linked, in turn, to the export markets of local industries and to the population and labor force of the rest of nation. The eight modules represent export markets (i.e., rest-of-world relationships) and local investments, population, labor force, employment, production, income payments, and final purchases.

Each module and each data series in SIMLAB has been reviewed for conceptual and factual accuracy. In a sense, the internal measurement and statistical validation of individual elements of the model are a continuing activity, although most concentrated in periods of model updating and revision. External *ex post* validation also is a continuing activity and, also, quite informal, without pre-determined guidelines and consequences.

External *ex ante* evaluation is confined to comparison of results with those obtained from other, less complicated socioeconomic models. Lacking in the model validation sequences are clearly-defined, consistently-followed steps, like the ones cited earlier (in Emshoff and Sisson). Finally, model documentation could include an appropriate checklist for the use of the model-builders and each model user, but this step also has been omitted.

Guidelines for model validation may start with assessment of measurement and statistical assumptions and procedures. To be fully useful, however, they must also include some assessment of both model builder and model user and the effectiveness of their communication with regard to model purposes and selection of appropriate model type. Thus, a validation strategy sequence for the interactive simulation modeling effort may include the following:

1. Review of prior model-building and model-using experiences of modeling participants, i.e., the model-builder and the model-user. This step would have been taken in the early stages of negotiation between the principal parties in the proposed modeling effort.
2. Review of model data base for accuracy and completeness. This step includes evaluation of data updating procedures and the internal consistency of these procedures. Like Step 1, it would have occurred in the initial stages of socioeconomic modeling, but it would be repeated with reference to any new data introduced in the interactive modeling.
3. Review of parameter estimation procedures and statistical tests, if any, of model structure. This step also would have occurred in the initial modeling and it, too, would be repeated in the assessment of any new parameters and assumptions introduced in the interactive modeling.
4. Acknowledgement of the results of each step in validation sequence. The interactive simulation model may be built to accommodate this step-by-step approach to model validation by a summary listing of findings at the beginning of each new simulation exercise.

This approach to model validation provides an important communication link between model-builder and model-user -- a link otherwise lost in the usual pattern of limited man-model interaction. It also serves as a constant remainder to both the model builder and the model user of their roles in achieving successful uses of socioeconomic modeling.

Alternative Socioeconomic Models

An additional step in model validation is the building of simple comparison models for the various purposes of large-scale socioeconomic modeling. A wide range of special-purpose models have been used for development planning purposes, for example, demographic, input-output, economic base, shift-share and econometric (20,23). Each model favors a particular set of purposes and clientele. Recently, in Minnesota, a demographic model was used as the principal framework for the population forecasting undertaken in the State Planning Agency. Various input-output models have provided income and employment multipliers for the regional impact analyses which were a part of studies in irrigated agriculture and peat and copper-nickel mining. A computerized shift-share model was developed for the Upper Mississippi River Basin Commission for quickly generating employment, earnings and income projections for subareas and subbasins and even single counties. Each model served a particular purpose representing, in each case, a partial approach to socioeconomic impact analyses and forecasting.

Economic and demographic forecasts based on the special purpose models would be available for comparison with the wide range of forecasts stemming from the interactive computer simulation model. Again, guidelines for making these comparisons are lacking. A series of validation steps, similar to the one listed earlier, is also needed for each special-purpose model when it serves as a comparison model in a socioeconomic information system.

While the use of comparison models may add to the cost of socioeconomic information system for development planning, the costs are relatively small. On the other hand, the costs of using and maintaining an already-built socioeconomic information system can be small, also, depending, of course, on its size, structure, management, and other factors which are unique to the system or its setting. Model acceptance, rather than model cost, perhaps still is the decisive factor explaining the use (or lack of use) of large-scale socioeconomic modeling in state and regional development planning. Model acceptance depends, not only on documentation and validation, as noted earlier, but, also, timeliness. A well-documentated model with quick response time often is preferred over one that is highly validated but has long response time.

Interactive Simulation/Game

The interactive simulation/game offers a special environment for testing alternative model validation strategies. A brief outline of the structure of such a game is presented here simply for the purpose of focusing attention on this potential resource for improving model acceptance. The proposed concept conforms generally to the one presented by Richard Duke (6, p. 92-3). Other simulation games may serve equally well.

Four roles are identified in the socioeconomic information system -- model builder, model user, data provider, and chief executive/legislature. The last role could be split into two roles. Additional important elements in the structure are (1) the budget, which supports data provider and modeling effort, (2) the development planning, which presumably is facilitated by the information output, and (3) the model validation system, which is in communication with all elements of the information system. Communication linkages among the role players and other elements of the information system are illustrated in Fig. 1.

Each of the four role players responds to both external influences and internal compulsions, for example, the desire for peer approval, more students and staff, larger budgets and job security. For each role-player, the information system budget is a critical decision variable, influenced in varying degree by each player, but most decisively by the Chief Executive/Legislature. This notion of organizational structure and priorities builds on the growing literature on the functioning of bureaucracies and other decision-making groups (26).

The steps of play in the interaction simulation/game which correspond to the steps in the model validation sequences outlined earlier, can be restated now as follows:

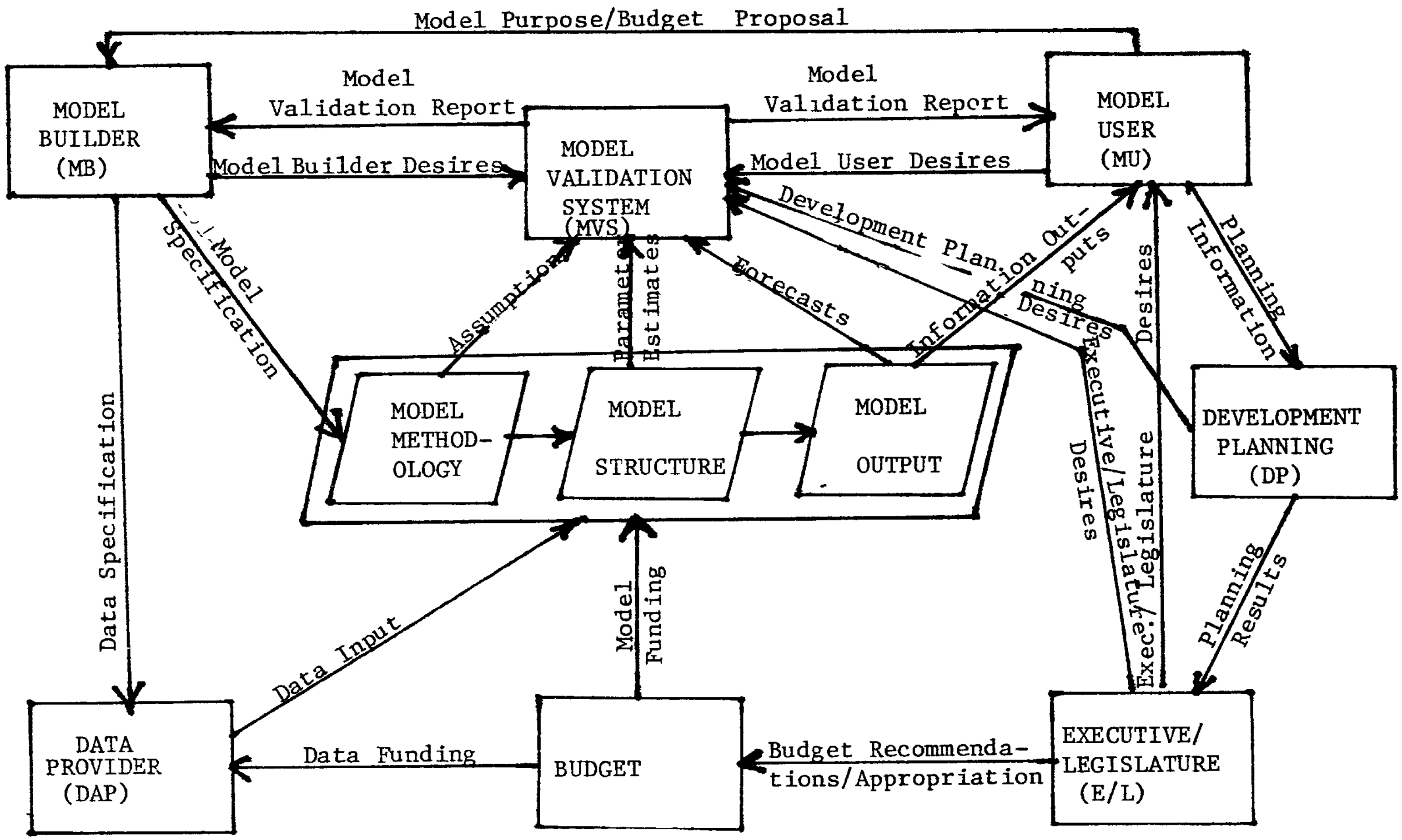

Figure 1. Communication Links and Players in Model Validation Using Interactive Simulation/Game.

1. Model User (MU) communicates with Model Builder (MB) about information needs in Development Planning (DEP). Both consult Model Validation System (MVS) for prior *ex post* validation reports, if any.
2. When, and if, Step 1 is completed to the satisfaction of both parties, MB explores model purposes and budget with MU; eventually a modeling package is proposed, but only after MB has consulted with Data Provider (DAP) and reviewed probable costs against probable budget.
3. When, and if, Step 2 is completed to the satisfaction of both parties, MU reviews modeling proposal; if favorable, MVS is consulted for preliminary model validation reports, if any; proposal changes are negotiated and Step 1 is repeated.
4. When, and if, Step 3 is completed to the satisfaction of both parties, model is built and model output is interpreted by MB, and sent to MU; MVS is consulted for *ex ante* model validation.
5. When, and if, Step 4 is completed successfully to the satisfaction of both parties, the information system output (provided by MB in Step 4) is introduced into DEP.
6. MVS completes *ex post* model validation.

Numerous other steps of play can be introduced into the sequence which involve the budget setting processes of government, i.e., Chief Executive/ Legislature Role, and related communication links. The model validation process is highlighted because of the possibility of adapting the interactive simulation/game as a learning laboratory in model design and use. In this example, various model validation strategies would be available to two principal players in the simulation/game. Game outcomes for the alternate strategies could be compared by the game players in the gradual modification of existing validation methods.

Other steps of play in a development planning simulation/game would include use of the socioeconomic information (i.e., model output which has been reviewed and interpreted by the model-builder) in development planning, which may or may not include actual decision-making. This is not to say, however, that decision makers would be unaware of the model-building and model-using activities, especially when socioeconomic information is deliberately used to rationalize past decisiosn or help clarify problem situations awaiting future decision making. Indeed, the decision maker, however defined, may provide budget support of model-building and model-using functions and yet not be included as a direct participant in the socioeconomic information system.

Different uses of socioeconomic information systems can be introduced into the interactive simulation/game, for example, energy planning, forest and mineral industries development, irrigation agriculture development, and job and skill development. While the structure of the game may remain constant, purposes and desires of individual role players are likely to differ and even to change, as in the case of identical players in successive rounds of play. In energy planning, for example, a mediating organization (like the Energy Modeling Forum at Stanford University) may participate in the model validation process by its assessments of the content and performance of numerous energy models which purport to serve public and private energy planning purposes. Thus, the MVS element in the simulation/game could be represented as an additional role participant in the simulation/game. Energy agency staff and directors also could participate in a second additional focus of role planning, namely, energy planning. Finally, the Executive/Legislature role could be redefined in private sector terms, or expanded to include an amalgamation of boards of directors of energy-producing companies, thus further expanding the size and scope of the interactive simulating/game laboratory.

Footnotes

1. The term "validation" has an inversion of meaning in philosophic literature where it refers to the test of logic rather than reality. The system sciences use the term "verification" for the logic test. Some large-scale social surveys also use the system science definition (19, pp. 43-55).

2. Short response time is a critical model attribute and an important factor in its acceptance, possibly next in importance to validation. Availability of trained and competent personnel in the right places is decisive in achieving a short response time.

3. A decision maker would perform a line rather than a staff function in an organization and he or she would use information more likely provided by the model-user than the model-builder.

4. In the system sciences literature, this step is sometimes differentiated by the term "verification", which refers to the test of logic; it focuses on model assumptions and internal consistency of statements.

5. Competent and dedicated technical staff support for the model building and using activities is also a critical factor in achieving high model performance ratings.

References Cited

1. Ackoff, R.L. Redesigning the Future: A Systems Approach to Societal Problems. Wiley and Sons, New York. 1974.

2. Almon, Clopper and others. 1985: Interindustry Forecasts of the American Economy. Lexington Books, Lexington, Mass. 1974.

3. Ascher, William. Problems of Forecasting and Technology Assessment. Technological Forecasting and Social Change, 13: 149-156. 1979.

4. Christ, J.F. Judging the Performance of Econometric Models of the U.S. Economy. International Economic Review, 16: 54-74. 1975.

5. Dickhoven, Siegfried. Towards Standardization in Socioeconomic Modeling: Concepts for Second Generation of Modeling Tools. Technological Forecasting and Social Change, 13: 34-331. 1979.

6. Duke, Richard D. Gaming: The Future's Language. John Wiley and Sons, New York. 1974.

7. Dutton, John M. and William H. Starbuck (eds.). Computer Simulation of Human Behavior. John Wiley and Sons, New York. 1971.

8. Emshoff, James R. and Roger L. Sisson. Design and Use of Computer Simulation Models. The MacMillan Co., New York. 1970.

9. Fildes, Robert. Quantitative Forecasting Models: A Survey and an Evaluation. Ch. 5 in Forecasting and Planning, by F. Fildes and D. Wood (eds.), p. 75-103, Farborough, Hants, England. 1978.

10. Gardenfors, Peter. On the Information Provided by Forecasting Models. Technological Forecasting and Social Change, 16: 351-361. 1980.

11. Greenberger, Martin, Matthew A. Crenson, Brian L. Crissey. Models in the Policy Process: Public Decision Making in the Computer Era. Foundation, New York. 1976.

12. Greenblatt, C.S. and R.D. Duke (eds.). Gaming-Simulation: Rationale; Design and Applications, New York, Halsted Press. 1975.

13. Hermann, C. Validation Problems in Games and Simulations. Behavioral Science, 12: 216-30. 1967.

14. Klabbers, Jon, Katy Hoefnagels, Gert Jan Truin and Preter van der Hyden. Development of an Interactive Simulation Game. Simulation and Games, 11(2): 59-86. March 1980.

15. Legasto, Jr. Aligusto. Socioeconomic Modeling - Selecting an Appropriate Strategy. Technological Forecasting and Social Change. 14: 243-257. 1980.

16. Leavitt , M.R. Computer Simulation in International Relations Forecasting, Ch. 16 in: Forecasting in International Relations Theory, Methods, Problems, Prospects by Mazli Choucri and Thomas W. Robinson (eds.), W.H. Freeman and Co., San Francisco. 1978.

17. Lilienfedd, Robert. The Rise of Systems Theory: An Ideological Analysis. John Wiley and Sons, New York. 1978.

18. Little, J.D.C. Models and Managers: The Concept of a Decision Calculus. Management Science, 16: 466-85. 1970.

19. Maclean, Mavis and Hazel Genn. Methodological Issues in Social Surveys. Humanities Press, Atlantic Highlands, N.J. 1979.

20. Maki, W.R., R.J. Dorf and R.W. Lichty. Users' Guide to Economic Forecasting Systems for State Policy Development. Staff Paper Series P77-13, Department of Agricultural and Applied Economics, University of Minnesota, St. Paul. 1977.

21. Maki, W.R., R.A. Barrett and R.J. Brady. Use of Simulation in Planning, pp. 174-192 in Rural Policy Alternatives, Iowa State University Press, Ames, Iowa. 1978.

22. Maki, W.R., P.D. Meagher, L.A. Laulainen, Jr. and M. Chen. Users' Guide to the Minnesota Regional Development Simulation Laboratory. Staff Paper Series P79-28, Department of Agricultural and Applied Economics, University of Minnesota, St. Paul. 1979.

23. Maki, W.R. Regional Economic Forecasts for Water and Land Resources Planning. I. Forecast System. Staff Paper Series P79-33, Department of Agricultural and Applied Economics, University of Minnesota, St. Paul. 1979.

24. Maki, W.R., P.D. Meagher and L.A. Laulainen, Jr. Economic Trade-Off Analysis. Proceedings of the 1980 Summer Computer Simulation Conference, AFIPS Press, 1815 North Lynn Street, Arlington, VA, 22209. 1980.

25. Niskanen, William A. Nonmarket Decision Making: The Peculiar Economics of Bureaucracy. American Economic Review, 58(2): 293-305. May 1968.

26. Nutt, Paul C. On Managed Evaluation Processes. Technological Forecasting and Social Change, 17: 313-328. 1980.

27. Pindyck, R.C. and D.L. Rubinfeld. Econometric Models and Economic Forecasts. McGraw Hill, New York. 1976.

28. Suppes, Patrick. Systems Analysis of Computer-Assisted Instruction, Ch. 11 in: The Challenge to Systems Analysis: Public Policy and Social Change, by Grace J. Kelleher (ed.). John Wiley and Sons, New York. 1970.

29. Treyz, George I. Design of a Multi-Region Policy Analysis Model. Journal of Regional Science, 20(2): 191-206. 1980.

30. U.S. General Accounting Office (GAO). Ways to Improve Management of Federally Funded Computerized Models. Report to the Congress, No. LCD-75-111, Washington, D.C. August 23, 1976.