SCHRIFTEN DER GESELLSCHAFT FÜR WIRTSCHAFTS- UND SOZIALWISSENSCHAFTEN DES LANDBAUES E.V.

Farrel. K.R., Haidacher, R.C.: Development an Use of Police Model System in USDA. In: Henrichsmeyer, W.: Prognose und Prognosekontrolle. Schriften der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e.V., Band 17, Münster-Hiltrup: Landwirtschaftsverlag (1980), S. 39-57.

DEVELOPMENT AND USE OF POLICY MODEL SYSTEMS IN USDA

by

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1. Introduction

The serious application of quantitative models to economic policy analysis in the United States dates to the early 1960's. Members of the Council of Economic Advisers at that time had a strong orientation toward economic modeling and utilized models in their economic analysis and forecasting activities. Subsequent Councils continued this use of models, further stimulating the development of analytical and forecasting

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The authors are grateful to Jim Johnson, Rodney C. Kite, C.E. Overton and Abner Womack for their contribution to this paper and also express their appreciation to J.B. Penn and others in ESCS for their review comments and suggestions. The views expressed in this paper do not necessarily represent those of the USDA,

systems.

The employment of large-scale sectoral models for agriculture is even more recent. The number and complexity of such model systems have increased rapidly in recent years. This development has been paralleled by advances in econometrics, computer technology, and the availability of a greater amount of better quality economic data.

The National Science Foundation (FROMM, et al., 3) inventoried the number of Federally supported models in 1974 and found that there were 274 models in operation or under development; 52 were in Agriculture. The General Accounting Office (U.S. GENERAL ACCOUNTING OFFICE, 16) in 1977 surveyed models specifically for food and agriculture policy analysis. The 78 models it found included econometric, programming, input-output, and simulation models, that treated the very short-run to the very long-run. Moreover, within this decade, several private firms have successfully marketed their models and associated services, some both nationally and internationally. These include the familiar names of Wharton Econometric Forecasting Associates (WEFA), Chase Econometrics (CHASE) and Data Resources, Incorporated (DRI).

The widespread existence and use of models appears evident. Rather than further elaborating this point, it is perhaps more interesting and instructive to explore the reasons for this proliferation in the development and use of models, and their relevance to agricultural policy and program analysis. Subsequently, based on our experience in the Economics, Statistics, and Cooperatives Service (ESCS) of USDA, we briefly describe some of the models we use and then consider some salient aspects of the model development process, the costs, resource requirements, and maintenance. Later, we turn to the implementation and use of models in ESCS and the issue of performance, and conclude with some prescriptive remarks on model development and use.

2. Reasons for Model Proliferation

We propose that the primary reasons for the recent expansion of model development and use are demand oriented, and comprise two interrelated phenomena. The first concerns the expectations of society and its constituent interest groups, and the second relates to the interdependence of economic systems.

The many diverse interest groups of society have certain expectations regarding how our economic system should perform, and various perceptions about how it is performing at any particular time. The difference between expected and actual performance creates the impetus for action and a search for means to narrow the "gap." The result is greater emphasis on managing various aspects of the economic system. This has been neither a recent nor sudden phenomenon, but rather a gradual one that has evolved over time. What is different now as compared to the past two or three decades is that a multiplicity of policy and program instruments have been accumulated, implemented, and tried. The end result has been more widespread management of economic sectors.

The interdependence of economic systems encompasses two aspects. Economic interdependence per se is not new for we have known, at least since the time of Walras, that all elements of an economic system are more or less related. However, the recognition of this aspect seems to wax and wane over time; and it does so in rough concordance with the magnitude and frequency of change in relevant economic variables. Increases in either the frequency or magnitude of change, or both, brings the underlying economic interdependence back into sharp focus. But such changes, more often than not, widen the "gap" between the expectations and realizations of certain interest groups. Furthermore, proposed policies or programs designed to deal with the effects of these circumstances are not the kind that imply "incremental" changes in the various economic sectors.[2] We contend that this combination of factors has been the primary reason for the rapid increase in number, complexity,

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2) For an excellent discussion of this point and related issues in this paper, see (GREENBERGER, 4) especially pages 39-42.

and use of models in forecasting and policy and program analysis.

Most recently, a major impetus for the use of models in agriculture has been the large and frequent changes in commodity and input prices, the effects of which were certainly not limited to a single economic sector. Moreover, these events came on the heels of an extended period of armed conflict and the implementation of vast social progams concerned with issues of human rights and environment. The effects of all these events have served well to reawaken us to the existence and pervasiveness of economic interdependence and to reemphasize the importance of considering the total economy when economic policy is being formulated and implemented.

Public policy for food and agriculture in the United States reflects the attitude of the citizens toward the food system, and the resulting policies and programs are expected to achieve certain goals. Familiar ones include adequate supplies of farm commodities and reasonable prices to consumers, a fair return for farmers, stable markets, food aid for both domestic and foreign poor, and expansion of foreign trade. Invariably, such policies involve compromises among the many competing objectives held by various interest groups that become involved in the policy process.

In the past, farm groups possessed enough political leverage to obtain enactment of the legislation they sought, and were largely responsible for the development of the farm programs. But these programs evolved over time by the incremental approach in which marginal, periodic changes were implemented. Consequently, the formulation and analysis could proceed largely if not entirely on the basis of history, judgment, and experience. And since the observable impacts were relatively small and primarily in agriculture, the underlying economic interdependence with other sectors could largely be ignored. In the present and recent past, however, changes in various economic variables are more frequent and of such magnitude, that many diverse groups are either impacted by economic performance of the food and agricultural system, or they lay competitive claims upon resources such as water and petroleum that are used by agriculture.

The political economy of food and agriculture is no longer the concern of just those in the traditional agricultural establishment. This means that food and agricultural policies are viewed in a much broader and more complex economic, social, and political context than a few years ago. Consequently, the agricultural policy decisionmaking process routinely includes input from representatives of all agencies and branches of Government, as well as input from representatives of farm, environmental, agri-business, consumer, religious, and hunger groups. Politically, this means that before any policy proposal for food and agriculture can be enacted, it is now scrutinized by a broad range of interest groups.

For policy analysts, this means that the scope and magnitude of information needed by the decisionmaker is greatly increased. Analysts must not only consider the direct impact of proposed changes in policy variables on the agricultural sector, but also indirect impacts from the many linkages between agriculture and the domestic and world economies. Furthermore, not only is the scope of analysis extended beyond the traditional boundaries, but the potential impacts often lie outside the realm encompassed by historical experience. Thus, a relatively narrow incremental approach that relies largely on history, judgment, and experience is no longer sufficient.

It is also difficult, if not impossible, to analyze the economic impacts of a policy initiative separate from the manner in which it will be implemented and administered. As discussed earlier, a wide variety of policy variables must now be considered in developing new policy proposals and in administering existing laws. Each year a specific program for agricultural commodities is formulated using some or all of the policy instruments available to the Secretary of Agriculture. For example, the commodity program for wheat includes setting the nonrecourse loan rate, the target price, the amount of any acreage diversion, provisions of natural disaster programs, and the quantity acquisition and release price for grain reserves.[3)] The choice of policy instruments to use is

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3) See (JOHNSON AND ERICKSEN, 9) for a description and explanation of these program features.

conditioned by present and expected economic changes in the U.S. agricultural sector, the domestic economy, and the agricultural and general economies of other exporting and importing nations. Not only must consideration be given to how existing and expected economic conditions may impact supply and prices, but the linkages between the programs designed for each commodity must be analyzed.

Evaluations of a given level for policy instruments that are included in a program require estimates or projections of the magnitudes of economic variables such as farm income or trade, so that tradeoffs between the level of policy instruments and their impacts can be assessed. The complexity arising from the need to handle linkages among commodities within the agricultural sector, between the agricultural sector and the domestic economy, and between the U.S. and the world economy, requires the use of a systematic analytical framework.

3. Policy Models in the United States Department of Agriculture

Within the USDA, ESCS is a major source of economic policy analysis and expertise. The expertise and associated quantitative tools have developed rapidly in recent years so that today our model systems, both short and long term, generally include econometric models, mathematical programming models, input-output models, simulation models, or some combination of these.

In ESCS, simulation and mathematical programming models have been used for both long and short term analyses. We have at least two model systems which we use specifically for long run analyses. One is the National Interregional Agricultural Projections (NIRAP) system, and the other is the World Grain, Oilseeds, Livestock (GOL) model.

NIRAP (BOUTWELL, et al., 2) is a computerized representation of the U.S. agriculture sector. The system contains a number of sub-system components including aggregate farm output, commodity production-utilization, energy inputs, and components covering land and water resources, and crop yields. It is used to investigate long run scenarios for American agriculture under alternative assumptions. The assumptions include specifications such as Federal and State research expenditures, input price changes, weather, and environmental controls on the supply side; and domestic population and income growth, changes in consumer preferences, and world trade on the demand side. These assumptions enter as exogenous shifts in demand and supply relationships. NIRAP produces a wide array of projections for both national aggregates and regional breakdowns. Projections for the national level include farm output, prices received and prices paid by farmers, gross and net farm income, and production costs; the production, prices and use for 30 commodities, and the consumer food price index. Projections at the regional level include crop and livestock production, crop yields, land use, fertilizer and fuel requirements, and pesticide use. Thus, NIRAP provides a formal systematic framework within which issues such as the economic viability of the farm sector, domestic food supplies and prices, agriculture and energy, and environmental problems may be examined.

GOL (REGIER, 12; and ROJKO, et al., 13, 14, 15) is a world model of grains, oilseeds, and livestock commodities. The model covers some 14 commodities, 28 regions, and contains 930 equations which include supply, demand, price, trade, and market linkage relationships. It determines aggregate individual commodity supply-demand equilibria using simultaneous, partial equilibrium methods, under assumed exogenous conditions. These conditions include projections of growth rates in population and income, technological factors affecting productivity, economic trends; and elasticities of income, direct and cross price elasticities for demand and supply, and various policy constraints. GOL provides export projections for use with NIRAP, and it is used for special studies related to the world food situation and the U.S. agricultural export market.

Mathematical programming models used for domestic analyses have followed the basic formulations of Heady and have dealt with optimal resource allocation. These models have been used in the analysis of land and water use on farms and for recreation, to investigate questions of rural development and the environment, and to assess the impacts of alternative resource policies and programs. The particular formulations used by the USDA have evolved over a period of 15 years (NICOL and HEADY, 10).

The designation of models specifically as simulation models is not clearcut. Many econometric and mathematical programming models have been used to simulate policy and program impacts. However, among the various simulation models available to us, there are three which are used most frequently for policy analysis. We call these models POLYSIM (RAY and RICHARDSON, 11), WHEATSIM (HOLLAND and SHARPLES, 7) and FEEDSIM (HOLLAND and MEEKHOF, 8).

POLYSIM is used to analyze a wide range of policy questions for a time horizon of up to five years. The model includes eleven commodities: wheat, soybeans, feed grains, cotton, cattle and calves, hogs, sheep and lambs, chicken, turkey, eggs, and milk. The structure of the model contains a large number of equations that relate various demand, supply, price, and farm program variables to their determinants; in addition to a predetermined set of commodity supply and demand elasticities and other response parameters. The model also requires a complete set of baseline projections on commodity supplies, prices, and utilization that incorporate assumptions about demand and supply shifts and a specific set of Government farm programs for the full period being analyzed. Given this structure and baseline projections the model will simulate the effects of alternative loan rates, target prices, acreage set-aside rates and Government and farmheld grain stocks.

FEEDSIM and WHEATSIM are stochastic simulation models that have quite similar structure. FEEDSIM is an annual model of the U.S. corn and soybean markets. The model is specifically designed to assess the broad implications of alternative domestic commodity programs under different economic conditions. It covers five major commodity programs: price support, income support, Commodity Credit Corporation sales and inventory, acreage diversion and/or set-aside and Farmer-Held Reserve. Stochastic elements are incorporated in yield and export relationships. Simulations cover a five-year sequence and up to 500 iterations of this sequence can be obtained. Results include mean levels and dispersion characteristics for annual acreages, carry out levels, domestic use, exports, reserve activity, Government program costs and other variables. Cumulative frequencies for annual production and supply are also obtained. WHEATSIM is specific to the U.S. wheat market and covers similar program alternatives. It simulates over a seven-year sequence, for up to 500 iterations and produces results similar to FEEDSIM.

In the early 1970's, the ESCS initiated development of a comprehensive system of econometric models for the U.S. agricultural economy. This Cross-Commodity Model (CCM) system (HAIDACHER, et al., 5, 6) is comprised of annual econometric models which cover the grains-livestock complex. The CCM system currently contains approximately 200 equations, and it has a dual function: one is to aid our commodity analysts with their outlook and situation work, and the other is to aid in policy analysis. Since the system comprises an extensive linkage between the grain and livestock sectors of the U.S. agricultural economy, these analyses provide an overall impact of policy related to both domestic and international matters. For example, the economic impacts of grain exports are analyzed regularly to determine the effects on the U.S. grain and livestock sector and subsequently, on retail food prices. Additionally, models are used to assess the impacts on reserve stocks of grains, the U.S. trade balance, and the availability of grain for food aid.

While the information provided by the analytical systems is comprehensive, it is not used as the sole source of information on policy impacts. The models provide only one input into this decision process. Analyses depend upon a combination of model results and expert judgment. Thus, in our forecasting and policy environment, we draw heavily on information from commodity specialists and econometric models. Information from these sources is merged into a composite statement designed to address the complete agricultural sector.

3.1 Resource Requirements

The time span required to develop an operational model, i.e., one that is continously ready for use, is certainly not insignificant. The time span from initial model design to a functional model that is a reasonable reflection of a particular sector takes about two years. Several of our models have progressed well beyond this stage toward operational status. But, even these models require further development. Many modifications, however, involve minor refinements of specification and normal updating techniques.

The development of a policy model system of this type requires several distinct but related kinds of expertise. For example, if the objective is to maintain an operational system that is responsive to the wide range of policy issues, special staff requests, and forecasting questions; then close attention must be given to separating out responsibilities for maintaining the accuracy and timeliness of data, computer software support, model development, model applications, report writing, and liaison with key policy analysts and other major users.

Liaison or staff analysts are the front end of this activity. These individuals receive requests and utilize a wide range of inputs including the econometric modeling system in preparing reports, speeches, staff analyses, and responses to other outlook and policy related questions. Also, since the preparation of the final reports is a very time consuming task, part of this burden is removed from the ongoing program analysis and research activities.

A comprehensive, modern data management system is crucial to the development and maintenance of an operational model system for forecasting and policy analysis. Top priority must be given to providing accurate timely data and historical files. The success of a model system in complementing the complete policy-outlook function depends heavily on a system that can provide quick analytical response to priority issues. Interaction with high speed computers to maintain data banks and models, and to generate model output, requires a carefully planned, integrated system with sophisticated software. The system we are developing for this purpose is called OASIS (BELL, et al., 1).

Both model development and application require personnel with strong backgrounds in quantitative economic analysis. These individuals generally have expertise in economic theory, mathematics, statistics, econometrics, and a knowledge of the structure of agriculture. They must also possess, or have ready access to personnel with in depth knowledge of specific commodities and/or economic sectors. This is one reason why the development and maintenance of an operational policy analysis system is an expensive undertaking. Unlike the typical model developed in a university environment, which is often written up in a thesis or journal article and then relegated to a boookshelf, an operational model system must be continously ready for use on short notice. This implies that the model is under constant refinement and validation, and that the data necessary to solve the model are always current.

Thus, not only is there a large initial investment in model development, there are also continuing expenditures to keep the model, data base, and supporting computer software current. For example, the ESCS's cross-commodity model referred to earlier, required an investment of roughly 50 man-years in model specification, data assembly, model estimation, simulation, and related software development, as well as over $250,000 of associated computer costs. And, it requires a continuing investment of roughly 10 man-years annually for data maintenance, model refinement, and operation.

Few institutions, whether public or private, can justify the resources necessary to develop and maintain such models.

This has given rise to the several private firms who specialize in the development and operation of econometric models and who sell access to the models, data, and related computer software, thereby distributing the cost of development and maintenance among the firm's clients. While the subscription fees to these private models appear high, they are much less expensive than developing and maintaining one's own model; and analytical tools are made available to organizations that could not otherwise afford them.

3.2 Experience with Model Systems

Implementation and use of models in the USDA revolves around outlook, policy analysis, and the requests for special studies associated with the food and fiber sector. One activity conducted by the ESCS, is a monthly assessment of the U.S. agriculture sector. This is a sequenced process that begins with an examination of the international markets and proceeds to the domestic markets, food prices, and farm income. Several of the previously mentioned models are involved in this process. The International Economics Division's GOL model is used in the development of export estimates. The National Economics Division uses industry specific models-livestock, feed grains, oilseeds, wheat--and a linked model that contains all major commodity sectors in a single system.

A general theme is addressed each month. For example, in the spring of the year the outlook process will address several alternative levels of crop production with corresponding market implications. These variations are associated with planted acreage, which currently depends on farmer participation in the acreage set-aside programs for grains. Thus, econometric models used to support the outlook and forecasting process also provide information necessary to the analysis of various assumed conditions relevant to the policy process. For example, USDA program decisions for the coming year are dependent on a reasonable statement of commodity utilization two years in the future. While a "most likely" scenario is the end result of this process, it is desirable to ask numerous "what if" questions to examine alternative possibilities.

Models that reasonably reflect the structure of the industry have been extremely useful in these exercises. For example, consider the sequence of events leading up to a decision on program acreage for the coming crop year. In the fall of the year, after crop production is knowen, a complete assessment of utilization is required. Major uncertainties arise from the U.S. livestock cycle and commodity exports. Modelers are asked to analyze several combinations of livestock production and export trade. A key to this analysis is the expected level of grain carryover. Since we have a desired stock level as a cornerstone of the current program, anticipated levels of future reserves in conjunction with desired reserves must be placed in balance. This cross-check mechanism in the farm program provides a release valve for unanticipated conditions-normally weather. If we are below the stocks objective, an attempt to increase acreage or production to make up the gap will be analyzed and vice versa. We may use the commodity modeling system to generate several scenarios to give policymakers a feel for the appropriate amount of inducement (loan rate, target price, diversion payment, and deficiency payments) to bring about the production that keeps the industry in balance around the stated objectives.

Another critical part of this process relates to the demand side of the market. Reserves are held by the commercial sector and the Government. However, the private sector (mainly producers) has been given economic inducement to hold the majority of desired reserves. Producers are paid storage costs plus additional incentives to hold grain off the markets until certain price levels are reached.

At that time, the economic incentives are withdrawn with the expectation that the grains will flow back into the market. We have had very few observations on this release mechanism, but this obviously places the producer in a speculative environment. Our research activity centers around the rational decision process associated with this form of market activity and we use the model system to generate several impact statements on the possible producer reaction to the release price or trigger levels.

3.3 Performance

The ultimate test of a model's performance in the policy process is the acceptability, by policy decisionmakers, of the model's results as an adequate representation of the outcome of the real world system. Pure model solutions are generally unacceptable to policymakers, as they should be. We have not reached the stage where models are so refined that pure model solutions can be used alone. Instead, results must be thoroughly evaluated and used by analysts, who incorporate into the final analysis, information not accounted for in the model.

The question of performance, particularly for policy models, is a difficult one to answer. Most evaluations have been done on the basis of a model's ability to forecast variation in levels, percentage changes, or turning points. Several of these analyses have been published by others, but each has encountered difficulty in comparing different models. In the USDA, we monitor and evaluate our forecasting models on a regular basis and compare our results with those of the private forecasting services. We have encountered similar difficulties in comparing systems which deal with different variables, modeling philosophies and time periods. The tests of forecast performance do not provide a strong test of a model's worth as a policy tool, and we must still rely heavily on an evaluation of model response via expert knowledge.

However, these forecast evaluations do provide a means for identifying major problem areas within a model system. Models require constant monitoring to identify specific weaknesses and to provide measures of performance relative to other models and methods. For this reason, we regularly save our forecasts, as well as those of commercial firms, for evaluation when actual numbers become available. Among the more traditional criteria we consider, are mean error, mean absolute error, root mean square error, Theil's U, and mean square error decomposition. In addition, we examine the rankings by absolute deviations, Kendall's coefficient of concordance, the Wilcoxon matched pairs signed-ranks test, as well as graphs of predicted and realized values. Such evaluations indicate where a model is relatively weak and help establish research priorities for model refinement.

We are not now satisfied with the total performance of our model systems. Model development is never completed. We must continue to search for improvements in both econometric technique and sound application of relevant economic theory. To date, the question about the true value of policy models and policy model research has not been answered. Much remains to be done in development of models adapted to the needs of policymakers. If we approach this work seriously and persistently, we will succeed in providing tools which policymakers and analysts can use with reasonable confidence.

4. Summary and Conclusions

It appears that certain factors more or less directly influence the success of models developed for use in forecasting and policy and program analysis. From a prescriptive viewpoint, perhaps it would be useful to summarize some of the more salient aspects based on our experience. Among these are the objectives of the modeling effort, the process within which the models are used, the structure of the institution which employs the model, and the initial design of the model system.

The primary objective for constructing a model, or the major role or function it is to perform, must be fairly clearly defined at the outset. This objective, or function, plays a crucial role at various stages in the development process. Initially, it provides an important part of the basis for determining the methods and techniques to be used, the set of determining variables to be included, and in part, the structure of the model itself. At later stages it provides a basis for establishing criteria to evaluate performance.

The necessity for a clear description and comprehension of the process within which the model will operate stems from the simple fact that any model useful in policy analysis must be an integral component, and it is only one component, in the total process or activity. The initial model design must take account of this or the model will probably not be used for more than demonstration exercises. Or, if it is, it will rather quickly be determined to have failed.

The organizational structure of the institution is important for similar reasons. The process, within which the model system is used, exists and operates within a given organizational structure. As a consequence, the institutional structure places certain constraints on the process, and these constraints have implications for the design and operation of the model system.

Another essential element in the model development process is the initial design of the system. It must first of all take the above factors into account, but it must also provide a clear "blueprint" for initial guidance and a basis for decisions at multiple points in the evolutionary development process. This blueprint has three essential elements. It must be well grounded in theory. It must take full cognizance of the existing knowledge of the economic behavior and institutional structure of the sectors being modeled. And it must take fully into account the quality and other characteristics of the data upon which the model must depend.

Given the above, in a very broad sense, a large part of model construction and development can be characterized as an evolutionary process. By analogy, construction of a building follows the specifications of the blueprint; first laying a foundation, then erecting the main structure, and finishing with the roof. In contrast, model construction begins with a foundation based on a blueprint, but the superstructure is continously altered in the construction process and it is never completely finished.

This is partially a result of the continuous evaluation that must be undertaken at various stages in the model construction process. The result of this evaluation activity leads to alteration of the model. But, it also results from the nature of models themselves, in that they continously require substantial care and maintenance if they are to remain fully operational.

Initially, model construction per se follows rather familiar, traditional procedures. For large scale econometric models these procedures are generally applied piece-wise to various parts of the larger model. That is, in a model of commodity subsectors, one might apply the traditional procedures to a beef model, then a pork model, a feedgrain model, and so on. In this process each model undergoes several tests concerning signs and magnitudes of coefficients, simulation over historic and post sample data and consequent evaluation, and examination of internal consistency and stability. In large scale models, these diagnostic exercises are repeated as each of the model components are linked together. At this stage in the development process formal model construction is largely complete, a good deal of evaluation has been conducted, and one might say that a functional model has been obtained, in the sense that the model can be repeatedly used in a simulation exercise to provide "reasonable" results.

It is at this approximate stage that the focus must turn to implementation and use. That is, the model must be integrated into the process in which it was intended to be used. This is a particularly important and difficult step. Timing is an important aspect. If this integration-and-use stage is entered prematurely the model itself will remain undeveloped or be developed poorly or incorrectly. On the other hand, delaying too long runs the risk of developing a model which will not be understood, accepted or used.

Another crucial aspect at this stage concerns the relationship between model developers and the model users. The implementation phase becomes much more difficult if model developers are largely independent of model users, i.e., if the model developers are part of an independent organization. In this case, given that all previous conditions and specifications are met, interaction of developers and users must start at an earlier point in time, and continue for a more extended period, than if the developers are continuing personnel in the operation and use of the model system.

During the implementation and use phase the model undergoes its most stringent performance tests including all of those mentioned previously. In addition, it must be subject to the close scrutiny and judgment of those using the model and those using the end results of analyses in which the model plays a part. Some of these individuals may be adversely predisposed toward most any model use. Should a model be given a somewhat favorable judgment from this process, it can then be said to be an operational model, i.e., one that can be expected to be ready for use on demand and provide useful information.

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