A SYSTEM DYNAMICS MODEL FOR LONG-RANGE ELECTRIC UTILITY PLANNING: IMPLEMENTATION EXPERIENCE

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ABSTRACT

The development of a system dynamics model for a long-range planning group in a large electric utility is described. A distinction is drawn between decision-making and decision-preparing models. Some conclusions regarding the implementation process for a decision-preparing model are proposed.

INTRODUCTION

Long-range or strategic planning methods have been developed extensively over the past twenty years and have permitted a characterization of organizations or situations in which the methods can profitably be applied. Among the critical characteristics calling for methods and models adapted to strategic planning issues are 1) long time-horizon, 2) significant changes in the definition of the market for the organization's product or service, and 3) important changes in production technology. The energy industries, for diverse reasons, are having to cope with all three sorts of problems simultaneously since the early 1970's. In particular, electric utilities have now to cope with:

- longer time-horizons due to lengthened procedures for regulatory approval and for lengthened construction schedules
- changes in market definition as an evolution towards greater residential use of electricity runs up against energy conservation programmes of uncertain impact
- changes in production technology as traditional sources are depleted or restricted for environmental reasons.

Having long enjoyed steady growth in demand whether expressed as annual energy or peak power load, electric utilities have been forced to adapt to situations of greater long-term uncertainty. One approach taken to reduce this perceived uncertainty is to enrich the information base on which long-term decisions are made. This paper describes the process by which one electric utility has followed this approach in developing and implementing a system dynamics model for long-range planning purposes.

BACKGROUND

The utility is responsible for supplying electricity to any connected customer in a large geographic area of extremely uneven population and demand- center distribution. A significant trend (until recently, actively encouraged by the company) is the growing use of domestic electric heating. At present almost all generation plant is hydroelectric but further development of this type of source will not likely continue much past the end of the century. Moreover current and future development of this source is characterized by distant, very large multi-reservoir systems requiring longer planning and construction lead-time than heretofore experienced. Thus all three dimensions of the long-range planning problem are present.

In the past, 10-year forecasts of load growth for a mature technology were very successful for fulfilling the utility's mandate to provide abundant electric energy at rates among the lowest in North America. Now it is felt that 25-year projections are needed at least to provide a framework for more detailed planning of new developments using the established technology, or technologies that require innovation, either technical or organizational.

IMPLEMENTATION PROCESS

Some initial informal contact with members of the planning unit attached to the Vice-president in charge of equipment provided the opportunity to discuss some of the advantages, for planning over long time horizons, of including the feedback effects typically developed in System Dynamics Models. As well, the existence of a functioning, long-term model of the national energy-economy system (Rahn 1978) promised to reduce significantly the time and effort necessary to develop a similarly aggregated model for the utility's demand region. Thus, early on, the general direction of development of a *model-based* project was defined, based on i) the perceived need for an overall and integrated approach to determining what kinds of electricity-generation sources would be necessary over the long-term and on ii) the availability of a model that could quite possibly be adapted to the specific situation of the client (Roberts 1978).

The formal development of the model began in a series of biweekly meetings with a small group of planning staff members, all with strong quantitative skills and concurrently engaged on other planning and forecasting studies dealing with different aspects to be included in the model, e.g. demand, supply, new technologies. Although the composition of the group changed somewhat over the development period, one member was involved continuously throughout the study and a second continuing member was involved early enough to participate in the final specification of the issues to be addressed by the model.

The first few meetings were given over to clarifying the System Dynamics approach and some features of DYNAMO at first in the context of the existing national model, but soon after by using a crude form of the new model. The global structure of the regional model (Shown in Figure 1) was relatively quickly developed and differed from the national model in treating hydro-carbons completely exogenously since the region has virtually no indigenous coal, oil or gas industry. Since the national model contained a highly developed electricity production sector, only relatively minor modifications were necessary to adapt the structure to the requirements, expectations and experience of the client group.

A few weeks into the study (which was conducted on a part-time basis by the modeling team), it came time to define more accurately the modeling objectives to be attained. The context of the study was in a sense experimental. The client group already had access to highly sophisticated financial planning and load forecasting models and was in the process of developing complex disaggregated demand models and of doing technology forecasting/assessment studies as well. However it was not clear how these components would eventually be integrated into a coherent view of the utility's long-term future. Thus the System Dynamics study was seen as one among many approaches that had been or were being used to address these questions. However it was not in the mandate of the study to attempt to develop a System Dynamics model that could formally integrate the information developed by other on-going studies and models. Thus the objectives as eventually defined were model-oriented. That is, there was no identifiable, problematic behaviour mode, recognized as such by the organization, and requiring widespread change of the decision-making structure to improve the behaviour. This is true of many long-range planning issues in systems characterized by significant decision-making outside the range of effective control of an organization (e.g. government and regulatory agencies) which is held responsible for the results of these (partly) exogenous decisions. In such situations about the best than can be hoped for is to outline the "region of feasible solutions" (to borrow from the mathematical programming literature) and leave the final choice of programmes or other policy instruments to a process of political negotiation.

The objectives as finally decided were to develop a Number of scenarios to compare model-system performance under hypothetical policies to the performance under business-as-usual conditions. However 'business-as-usual' in the electricity industry means different things to different people. Hence it was decided to consider two standard scenarios – one based on historic high growth rates of electricity peak power (a relationship with an extremely high R^2) and one based on a price-sensitive– energy source competition model developed especially for the study. These two demand models became known respectively as the 'strong' and 'weak' electricity-growth scenarios. The alternative, purely hypothetical scenaros eventually chosen were

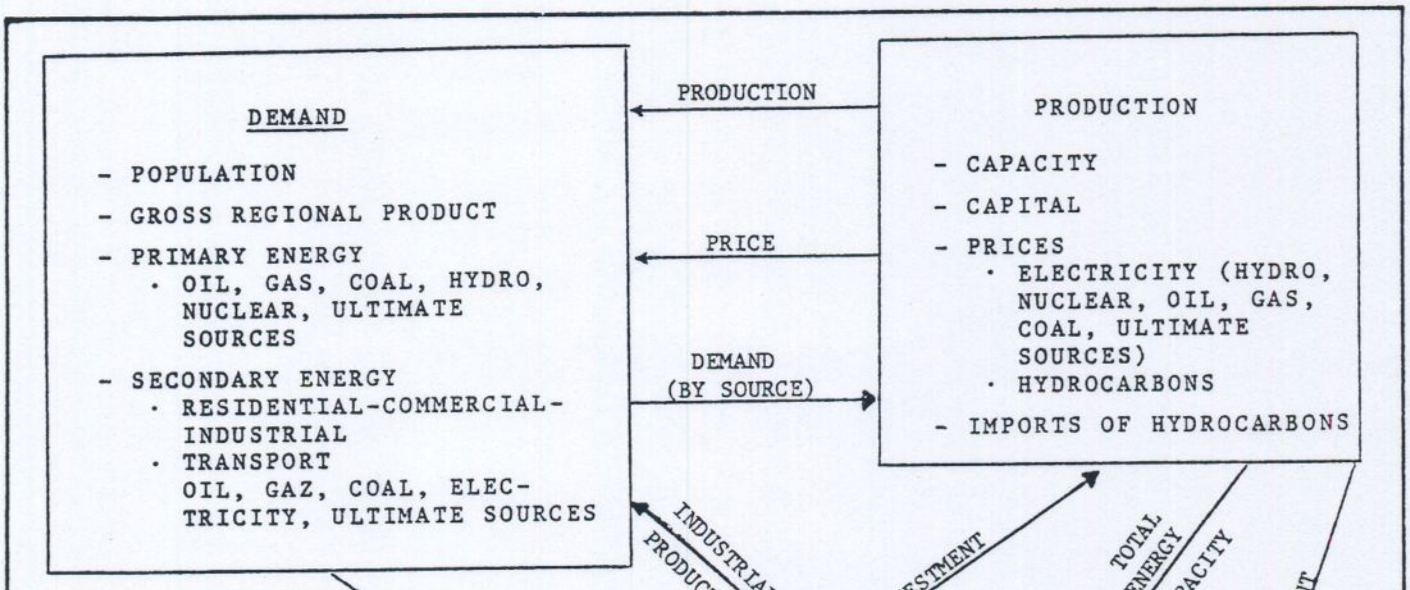

Figure 1: Global Structure of the Regional Model

– energy conservation (reduced elasticity of energy demand with respect to Gross Regional Product)

– no-nuclear (nuclear-electric development eliminated as a future source)

– ultimate sources (development of non-conventional renewable sources was permitted based on the standard economic decision structure in the base model).

Since there were to be two standard scenarios, validation of the model depended on verification of (i) its performance over the historical period 1960-1980 and (ii) certain variable values for the year 2000. The first criterion is typical for models being used for forecasting/planning purposes. No formal measures of error characteristics were developed although the model which was used in the final report gave mean absolute percentage errors for both strong and weak scenarios of 3-10% for total energy demand and electricity production over the historical period. Since it was expected that the model would be modified in-house no great amount of effort was expended to refine its performance once the major variables were in line. However the historical performance even as qualitatively assessed was used in the development of the energy demand sector. It was felt useful to estimate a market-share model for end-use energy sources to justify the 'weak' demand-growth scenario and subsequently it was a simple matter to redo the estimation for the 'strong' scenario. However both models had to be modified somewhat to take account of the special case of natural gas in the region. The modification used was validated largely on the basis of the performance of market-shares over the historical period.

One interesting feature emerged in the process of arriving at the standard scenarios. A very crude depleting-resource-base model was used to represent development of regional hydro-electric potential and the model-system passed through a development phase quite comparable to historical development of a large block of significantly higher-cost power and at about the right time.

The second criterion mentioned above was useful as a means of relating the model to other studies known to the client group. Thus it was possible to develop sufficiently different scenarios which, however, were consistent with the range of possible future developments expected by the client group. This "matching of expectations" is not as conservative a strategy as it sounds since the range of outputs is rather wide. It also appears to be a reasonable criterion when faced with a complex model – if the model generates too-extreme (*not* necessarily counter-intuitive) behaviour, the tendency may be to reject the output as being due to unknown complexities in the model. On the other hand if the model is kept simple and it generates extreme behaviour, the tendency may be to reject the result because excluded complexities (omitted feed back loops) may be the cause of the unexpected result.

After the standard scenarios were developed and accepted as reasonable starting points, it was fairly easy to generate the limited number of scenarios selected earlier. These were reviewed with the client group who happily were sophisticated enought to see these scenarios as "extreme-policy" sensitivity tests of the model. Subsequently a final report was produced describing in detail the causal structure, the equations, the scenarios, the data sources and a brief summary of DYNAMO. In this latter phase of the project the client team acquired a DYNAMO compiler in-house and ran the final-report version of the model to familiarize themselves with its behaviour.

Implementation in the organization is being pursued by the client team with the occasional participation of the author. At the present time an internally-prepared summary of the structure and behaviour of the report-model is in preparation and modification of the model to elaborate the demand sectors is beginning.

It would be rash to conclude that successful implementation has been or can be achieved in the organizational context of the client group. If implementation is restricted to mean in-house development of the model over some limited time-span, then the project promises to be successful. If implementation is taken to mean that the project will result in a complete re-structuring of modeling activities in the client group, then the project is unlikely to achieve this goal. The author would consider the project a success if it lead the client group to undertake other, possibly non-dynamic studies of particular aspects of the regional energy problem as a result of working with some more evolved version of the model. This feature of planning or forecasting-model projects sets them apart from the problem-solving projects (which result in specific recommendations to a responsible, decision-taking client) and from generic-modeling projects (which elucidate structure and behaviour but have no specific client in sight).

IMPLEMENTATION: A divergent view

The implementation of results derived from quantitative analytical studies in large, well-structured organisations has been the subject of many articles and studies, most of which concentrate on implementation in a decision-*making* context (Roberts 1978; Weil 1976; Robinson 1976). That is, they propose implementation guidelines and (self) criticism of implementation efforts where fairly specific organizational changes (new policies) were the objective. These guidelines typically emphasise the aspects of 1) the importance of the problem, 2) the extent and nature of client involvement, 3) the level of disaggregation of the model structure, 4) model validity, 5) the organizational context in which model results will be implemented.

However the use of complex models in a decision-*preparing* context has been less studied. By decision-preparing we mean the period when the organization (or social group) prepares the ground for decision-making by developing information and by elaborating policy alternatives for use by decision-makers. In a large organization most of the planning-modeling activities will be of the decision-preparing type.

The implementation process for decision-preparing models differs from that previously porposed for decision-making studies principally in the aspects 1) the importance of the problems and 5) the organizational context. Decision-preparing ideally is a variety-generating process characterized more by eclecticism than by analytic rigour, by exploration more than controlled experiment, by problem-finding more than by problem-solving. Thus the importance of the problem to be analyzed or modeled may be difficult to establish a priori (except in the trivial sense that the problem area relates more – or less – immediately to the over-all objectives of the organization). One need only reflect on the number of integrated energy demand-supply studies performed by electric utilities before 1970 to appreciate the difficulty at any time of specifying the importance of a potential problem area. It is clear that decision-preparing models and planning activities cannot and perhaps should not always be restricted to problems judged as important by the organization. In terms of implementation strategy, this characteristic of decision-preparing for long-range planning requires that the analytical approach be sufficiently flexible to address at least some of the currently important problems (as seen by the client) in order to gain some credibility, and to suggest other, less immediately evident, possibly counter-intuitive problem areas.

The other component of implementation strategy for which decision-preparing modeling differ from decision-making activities is the organizational context. Since the former sort of model is more investigative and exploratory it will usually be pursued as one-among-many approaches with the results of the work to be synthesized by the organizations planning process. It is important to have insider support for the project – as for the conclusions of a decision-making study. However it must be recognized that this support, because of the tentative nature of the subject, will itself be more tentative and unlikely to be fueled by the do-or-die spirit necessary to make a success of implementation of major strategic decisions.

CONCLUSION

In most respects, the study discussed here paid appropriate attention to points 2) to 4) of the implementation checklist noted above. (Admitted, this is a self-evaluation). When compared with other reported studies it followed more closely the third example of Weil than the first (Weil 1976). However a better comparison perhaps could be made with the project reported by Randers in which many iterations through the "steps-of-modeling" were performed before the end of the study (Randers 1977). Both studies were more decision-preparing rather than decision-making as in the examples reported by Weil. As such, it appears that the current study has followed the first sweep through the steps-of-modeling and is about to return to a redefinition phase in which the emphasis of the model will be on the hitherto underdeveloped demand sector. However unlike the Randers study, it is expected that the global structure of the model as shown in Figure 1 will remain.

This relative structural stability is another manifestation of the difference between decision-preparing and decision-making studies for long-range planning. The former should immediately address generic issues which permit later elaboration in directions deemed useful to the organization; the latter may have to concentrate immediately on specific issues which permit generalizations to be drawn later.

In summary, I have attempted in this paper to draw from an example of a system dynamics modeling project for long-range planning in a large organization some distinctions between decision-making and decision-preparing studies and to show their implications for implementation.

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