BRINGING THE RESULTS OF THE BONNEVILLE PROJECT TO THE CLASSROOM

Andrew Ford and Peter Gardiner
Systems Science Department
Institute of Safety and Systems Management
University of Southern California
Los Angeles, California 90089-0021

ABSTRACT

The Institute of Safety and Systems Management of the University of Southern California (USC) operates a Masters of Science Program in Systems Management (MSSM) at the main campus in Los Angeles and at 70 study centers located throughout the United States, Europe and the Pacific Far East. An introductory course in system dynamics is offered as an elective in the program. The students are interested in how managers use system dynamics and in the lessons from previous applications of system dynamics in large organizations.

One such application is the on-going project for the Bonneville Power Administration (Bonneville). System dynamics models are used at Bonneville to assist in the formulation of conservation policies. This paper provides a brief summary of the Bonneville project before turning to the main question of interest: What lessons from the Bonneville project are generally applicable to large organizations and worthy of attention in the MSSM program?

THE MSSM PROGRAM

The current Master of Science in Systems Management program at USC grew out of an early interest in applying the systems approach to aerospace related problems and opportunities in the early 1960s. In response to a request, primarily from the United States Air Force, a master's program in Aerospace Operations Management was created in the mid 1960s which emphasized an interdisciplinary, systems approach to managing the large, complex aerospace and aerospace related system. In the early 1970s it was recognized that this approach could be applied to a wide variety of systems beyond aerospace so the program changed its title and broadened its emphasis to systems management: the science-art of managing in the systems age. The Master of Science in Systems Management is the degree that emerged from the combined interest in management in general and management in the systems age in particular. The current curriculum represents a multidisciplinary blend of management, human factors and systems science designed to teach current and future managers the necessary conceptual, human, and technical skills required to successfully manage the large, complex systems that typify the systems age.

The program is offered in a distributed educational format which recognizes the so called "third wave" of students that are now reported to make up the fastest growing segment of student populations. Third wave students are most often mid career adults (i.e., an average age in the mid thirties) who are returning to education for very specific reasons. Most often they are seeking new knowledge and skills that are of immediate and long term benefit to them in their workplace either through enhancing current job performance or by opening up new opportunities for transfer or promotion.

Third wave students are unlike students that have entered graduate programs directly upon graduating with a bachelor's degree. They differ in a number of ways other than age. First they expect the faculty to be well informed and able to communicate their knowledge. Second, they have a lot of practical, on the job experience so while they tolerate (and often enjoy) theory, they also insist on seeing practical applications associated with theories. They have little tolerance for theory for the sake of theory or theories that have little or no practical application. Third, they are not bashful students. They enter eagerly into discussions with faculty and among themselves in the classroom. The are not reluctant to support or challenge faculty or each other when appropriate. Fourth, they enroll in programs that are convenient. Convenient programs are those that meet at a location and during time periods that are convenient to working adults. This means that such programs are often offered on the job site or close to it and that the classroom hours are either during the evenings or on weekends.

The Master of Science in Systems Management (MSSM) program is clearly a third wave program. Offered since 1972 by the University of Southern California's (USC) Institute of Safety and Systems Management (ISSM) it has grown to become well and widely known. The program has an average enrollment of 2200 students and is offered at the USC home campus as well as over 70 other locations ranging from Germany, across the United States, to around the Pacific Rim. There are now over 11,000 graduates of the program. Originally created in response to a need of the United States Air Force with enrollments heavily consisting of military officers (95%), it has now broadened to a 60% military and 40% defense, aerospace and other large, complex system civilian student base. Students enter with varied background ranging from "latin scholars" to science and engineering with the vast majority of students having a business or engineering undergraduate degree.

Students complete a sequence of courses that combine systems theory, systems science, management, and human factors with electives/options (i.e., minors) in program management, logistics, information systems, or human resource management. The goal is to produce generalists, line managers fully capable to meet the challenges inherent in managing in large, complex systems. They have the conceptual, human, and technical skills to plan, organize, staff, lead and control large, complex systems in the face of uncertainty, ambiguity, turbulence, and in turbulent, competitive or often hostile environments.

Since most students are mid career adults or at least are working adults studying for advanced education on their own, off time, they collectively insist that the MSSM program relate theory to practice. They are delighted with applications and actual experiences gained in the process of implementing theories in the "real world." Often, students will implement classroom knowledge on the job concurrently while they are in class or after a particular class is completed. For example, students who have taken a course in Decision Support Systems often return to their jobs and purchase hardware and software to bring Decision Support Systems to their work environment in a form and with a function that they have just learned. In once instance, a student cancelled a multi-million computer procurement that, after having had the class, seemed clearly to be heading in the wrong direction. There are numerous other such instances in the MSSM program (and other mid career, working adult oriented programs as well). Such students often save their parent organizations millions of dollars by applying the new knowledge gained in the classroom to on the job situations. This is one reason for the popularity of such programs.

Transnational education of managers in the systems age is made possible by programs such as the MSSM. One of the last large, complex systems to actually go international, education is currently finding academic institutions that are betting on this approach. In such programs with mid career adults as the core of student enrollments, theory and practice must be equally represented in the curriculum. In the MSSM program, with the emphasis on management in the systems age, the program must provide students with practice as well as the theory of managing large, complex systems. This suggests a need for some sort of a hands on approach so that students can grasp and internalize an understanding of how large, complex systems are structured and how they behave. They must understand in a practical way how structure influences behavior and how they as managers can influence system behavior by designing or redesigning systems structure. Such design or redesign is called by many names including policy analysis, planning, decision making, systems analysis, organization/reorganization, managing change, implementing change and so on. Although given different names the process is often the same:

a. Diagnosing current system behavior

b. Establishing desired system behavior over some time horizon

c. Attempting to intervene to cause actual system behavior to conform with desired system behavior.

Practicing managers are not only interested in theories that explain how to accomplish this feat but are also interested in how this can be done in practice. As practicing managers, theories in and of themselves are of little use since there are so many of them and they are so often either mutually contradictory or short on implementation guidelines. Since our MSSM students want above all else to be managers, we have been experimenting with ways to provide both theory and practice in the same learning experience. We have searched for a single vehicle with which we can teach both theory and practice about systems and their behavior as systems to managers. We have recently begun to experiment by adding a course in system dynamics to our curriculum to meet this need. The reaction has been overwhelming enthusiasm for System Dynamics. Since our students wish to be managers, not just analysts, system dynamics is well suited to meet this requirement. Students can learn enough about system dynamics and the programming requirements of Dynamo in a single course to translate their own thoughts about a system into a computer model of that system. They can then conduct "management oriented" experiments with that computer model of their own system. The benefits are enormous. Since System Dynamics minimizes the programming agony and time associated with other software applications, the students can focus on conceptualizing their systems and then experimenting with them once they have completed the relatively easy process of translating from concept to computer model.

Once students understand system dynamics and see how easy it is to build their own computer models of a system of interest to them, they see its immediate relevance to management and managers. They then become very interested in just how system dynamics is actually used in real world systems. They want to know where it has been used. They want to know what the results have been. They want to know what luck managers have had in implementing (i.e., actually getting some organization to use) the technique, and in implementing the results called for by the technique. In other words, the students are very interested in applications which represent the practice component of the theory/practice equation. Although there are many such applications that could be reported here, we report on one such application in which we are directly involved and which we have recently used in our classrooms on an experimental basis. It is our experience with this application and the reception it received by the MSSM students that were exposed to it that form the basis for the rest of this paper. The application involves the electric utility industry in the Pacific Northwest corner of the United States and the Bonneville Power Administration, the Federal Agency which markets power from the regions' vast hydro-electric system.

THE BONNEVILLE PROJECT

Electric utility companies in the U.S. and in Europe have become increasingly interested in programs to encourage their customers to invest in conservation. The programs include general information such as advertising, specific information such as audits, and direct financial incentives such as zero interest loans. The programs are needed to help customers overcome market obstacles that limit their investment in measures which would improve the efficiency of electricity use. Utility conservation programs are frequently a better use of company funds than investment in conventional coal or nuclear power plants.

Conservation is especially critical in the Pacific Northwest region of the U.S. This region, encompassing the states of Washington, Oregon, Idaho and part of Montana is blessed with great rivers and mountainous terrain which provide huge hydro-electric potential. Development of this potential, beginning in 1933 with the Bonneville and Grand Coulee dams, gave the region one of the world's largest hydro-electric systems and, historically, some of the lowest electric rates. Because of the low rates, the region's homes and businesses have not made the same level of investment in conservation as in other parts of the country, and the potential conservation savings are large.

The long period of low electric rates ended in the 1970s when events combined to increase utility spending on new generating capacity. Like many utilities across the country, those in the Pacific Northwest looked to nuclear power plants to meet anticipated growth in demand. And like utilities elsewhere, the Pacific Northwest companies were hit hard by double digit escalation in construction costs and unanticipated reductions in the rate of growth in electric load. The combination of problems led to soaring electric rates, cancellation of several partly constructed plants, major defaults on bonds, and, finally, to the passage of the Pacific Northwest Electric Planning and Conservation Act of 1980 (Bonneville 1981).

The Act created the Northwest Power Planning Council to take responsibility for setting broad policies for the regional development of electricity resources. The Act also created major new responsibilities for Bonneville, the arm of the U.S. Department of Energy with authority to market power from federal resources in the region. The Act calls for Bonneville to take a central role in implementing the best plan for the region and to consider conservation preferentially when determining the resources it should acquire in the future.

Bonneville's response to the new authority in conservation was swift and multi-faceted. Within two years after the passage of the Act, utilities were operating five regionwide Bonneville conservation programs. Conservation planning was upgraded to "Office-Level" status, and the new Office initiated several badly needed evaluation studies to help determine the size of the conservation resource and the likely customer response to different programs. A variety of computer models were developed to help Bonneville assess the possible impact of conservation programs. Conservation "supply curves" were developed for the region based on existing end-use assessments. The "supply curves" were structured for consistency with computer models used elsewhere in Bonneville. The neighboring models included an econometric/end-use load forecasting model and a linear program to determine the optimal mix of new resources.

These initial modeling efforts generated four difficulties for conservation planning. First, the demand models were based on detailed end-use assessments and hence were very cumbersome to use. Also, the existing corporate end-use demand forecasting models were not suited to evaluate the effects of alternative conservation programs and policies. Third, none of the initial conservation modeling had the capability to easily or practically model the effects of Bonneville conservation incentive strategies or program timing decisions. Finally, the desk-top analysis that was done for early program designs was inadequate to answer questions about the programs' ultimate impacts or potential tradeoffs among programs.

Therefore, in 1983, Bonneville's Office of Conservation initiated a project to improve its ability to model the effects of its conservation programs and consumer incentive designs for the Pacific Northwest electric power system. A system dynamics model was designed to provide ready access for program planners and analysts alike, to build from the results of existing models and databases, and to provide quick analysis of many scenarios, while preserving consistency with actual system planning and operations.

Work on the new conservation models began by adapting relevant structure from a simulation model which had proven useful in studies for a major California utility (Ford and Harris 1984). The first step was to design a regional model in which conservation programs, system operation, capacity expansion, and electricity pricing are conducted by a single entity. The next step was to construct a sub-regional model which would distinguish between the loads and resources of the investor-owned utilities (IOUs), the publically owned utilities, and the federal government. The models are known collectively as CPAM or the Conservation Policy Analysis Models.

THE CONSERVATION POLICY ANALYSIS MODELS

CPAM has been used in a variety of analyses and to help Bonneville answer questions such as the following:

1. What are the likely impacts of continuing or expanding conservation programs in the face of a large capacity surplus?

2. What is the likely tradeoff from programs that lower energy service costs but increase electric rates?

3. Which conservation programs present the lowest risk in the face of great uncertainty in loads and resources?

4. What are the likely impacts of incentive programs which aim to reduce the volatility of aluminum industry loads and revenues?

5. What are the relative advantages to the investor-owned utilities, the publics, and the Bonneville of "co-operative" versus "separate" implementation of conservation strategies?

CPAM's greatest strength is its detailed representation of conservation policy options within an integrated model of the region's electric system. CPAM gives the planner considerable flexibility to assemble different combinations of financial incentives and performance standards. When testing utility incentive programs, for example, the analyst may choose from five basic incentive designs and select the parameters within each design. The planner designates the end uses, income groups, and customer classes to receive the incentive and the program startup and completion dates. And finally, the planner may choose from a variety of methods to recover conservation expenditures. These include cost sharing with Bonneville, immediate recovery through expensing, and delayed recovery through capitalization.

CPAM simulates the likely response of different customer groups by showing which of hundreds of specific conservation measures would be purchased with the program. CPAM also keeps track of the costs to the utility, the taxpayer, and the customer to implement the program over time. When all conservation programs are removed, CPAM provides a benchmark projection of conservation investments due to price effects alone. We compare CPAM projections to find a true picture of the net impacts of a conservation program, to distinguish between "programmatic" and "price-induced" conservation and to keep track of utility spending on measures that customers would have purchased without the program.

The detailed representation of conservation and electricity demand interacts automatically over time with the remaining sectors needed for an integrated model. These include hydro-thermal system operation, capacity expansion planning, price regulation, and construction financing (see Figure 1). The integrated representation allows one to rapidly reassess the impacts of conservation strategies with changes in planning assumptions. Of special interest in recent sensitivity testing were the changes in simulated impacts of conservation with changes in Bonneville's assumptions on regional economic growth, nuclear construction, coal plants' attributes, aluminum industry profitability, transmission intertie expansion, and the California utilities' appetite for secondary power. The sensitivity tests focused on changes in CPAM projects over the 20-30 year planning period of the following "figures of merit":

1. Wholesale and retail electric rates,
2. utility revenues,

3. energy service costs,
4. conservation and construction budgets, and
5. key financial ratios.

Energy service costs is often viewed as the most important "figure of merit" because it combines the customers' spending on electricity with their spending on conservation to show the true cost of electric services.

Additional information on CPAM is available from the annual system dynamics conferences (Barton and Bull 1986; Bull, Ford and Naill 1985) and from Bonneville technical reports (Ford and Geinzer 1986; Ford and Naill 1985).

LESSONS FROM THE BONNEVILLE PROJECT

The Bonneville project offers many important lessons for prospective managers wondering about the problems of model implementation in a large organization. The best description of the actual implementation and use of CPAM from Bonneville's perspective is given in Barton and Bull's (1986) decision support paper at the Seville conference. For the 1987 conference, we turn our attention to the two main lessons which generated the most interest from system dynamics students in the MSSM program. The students learned the system dynamics approach explained by Richardson and Pugh (1985). They learned the seven stages of approaching a problem from the system dynamics perspective with particular emphasis on the early stages of conceptualization and model formulation. By the end of the course, they were comfortable with the new set of terms used in discussing system dynamics modeling: reference modes, time horizons, causual loop diagrams, negative feedback, endogenous variables, etc. The first, and perhaps the most important, lesson from the Bonneville project, however, is that other managers are not likely to understand discussions of system dynamics analyses which rely heavily on the students' newly acquired vocabulary. The students were warned that fellow managers are not likely to appreciate distinctions between endogenous and exogenous variables or between positive and negative feedback. Rather, fellow managers appreciate a focused discussion of the organization's problem and an account of how model based analysis can illuminate the likely effects of the various proposals under consideration. Once the discussions reach deeply into the complexity of the system, fellow managers will appreciate the structural design of system dynamics models that support the analysis.

But We Already Have Plenty of Computer Models!

MSSM students learn a variety of system science methods including decision analysis, optimization, and simulation. With this emphasis on quantitative techniques, it is only natural that the students are particularly interested in how one responds to a fellow manager's concern that the organization already has plenty of computer models. These models are usually scattered around the various departments, rely on different computer languages and data bases, and are mantained by analysts who may not have much contact with their counterparts in other departments. When the merits of initiating a system dynamics analysis are discussed, managers quite naturally wonder why another model is needed and how the new model would differ from the collection of models already used at the company.

In the Bonneville project, for example, CPAM was designed as an integrated combination of the five sectors shown in Figure 1 even though Bonneville already had quite sophisticated computer models which provide highly detailed representations of each of these five sectors. The special feature of CPAM is that the five sectors in Figure 1 work together to provide an integrated representation of the region's electric system. Information generated in each sector is available during each time step of the simulation as needed in the remaining sectors. The utility cost from conservation incentive programs, for example, are made available to the price regulation sector where the expenditures are either capitalized or expensed in the rate-making calculations. Electric rates, in turn, are recalculated after the appropriate regulatory lags, and the rates for the next time step are used in the demand sector.

The system dynamics approach to model integration used in CPAM might be constrasted with a more common utility approach in which several different models are designed to operate together as shown in Figure 2. (These models are often constructed in different departments and often use different computer languages.) In this illustration, one begins with a set of electric rates needed as input for an electricity demand model. The output of the demand model takes the form of electric load projected for each of 20 years in the future, and the load projections are used as input for a capacity expansion model. The output of the capacity planning model is a plan for new power plant construction during the 20 years, and this plan is used to drive a costing model which generates a set of electric rates needed to provide adequate revenues. The electric rates emerging from this sequence of model projections are compared with the electric rates used to start the calculations. If the two sets of rates are significantly different, the starting rates are adjusted, and the sequence is repeated. Through artful manipulation of the starting rates, one hopes to obtain a consistent set of projections within a reasonable number of iterations.

With the iterative approach shown in Figure 2, the output from an early model is not provided to subsequent models until the early model is finished with a full 20 years worth of results. In CPAM, output from the five sectors in Figure 1 are available to other sectors as the model proceeds from one time step to another during the course of a 20 year simulation. The main advantage of the iterative approach is the degree of detail that may be permitted in each individual model in the sequence. Separate models may be coded in different computer languages to allow analysts from different departments to find the best fit with their topic area or to take advantage of existing models. With the CPAM approach, all five sectors from Figure 1 were written in DYNAMO, and the sectors were designed from the outset to work together automatically over time. Each approach has compelling advantages, and Bonneville uses both approaches in the analysis of conservation policies. The idea is to examine a broad range of conservation policies with CPAM before initiating the iterative process for operating and more detailed models.

The distinction between the system dynamics approach (Figure 1) and the iterative approach (Figure 2) is likely to be characteristic of system dynamics analysis in many large organizations. From our discussions with electric utility corporate planning groups across the United States, for example, we notice over and over again that utility planning models (or modeling systems) do not provide a truly integrated picture of the utility

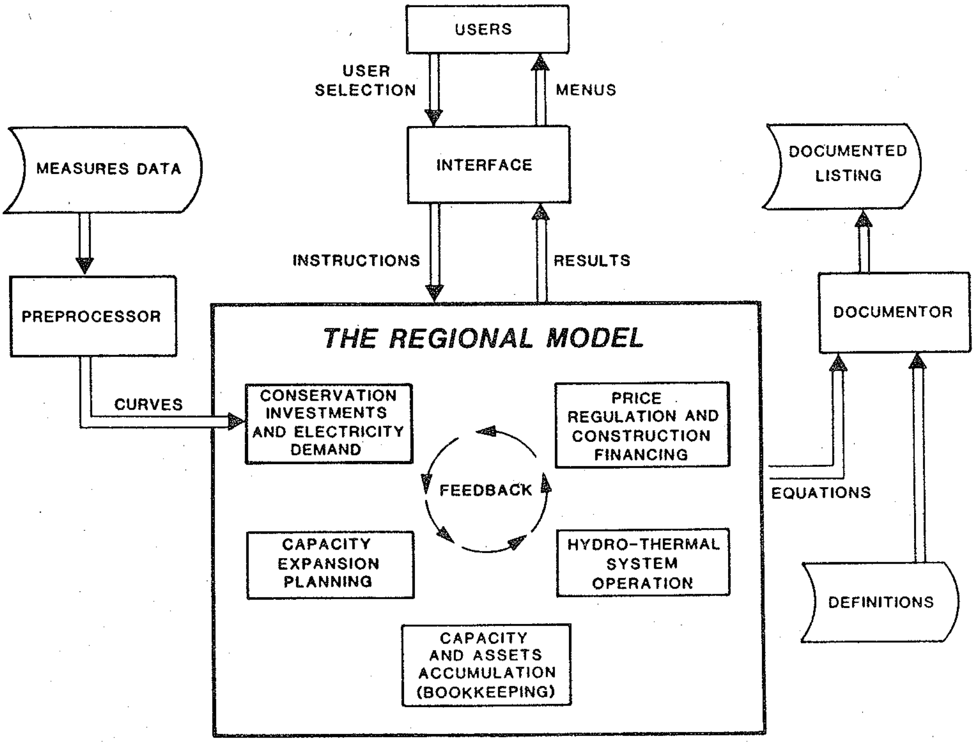

Figure 1. The Regional Modeling System

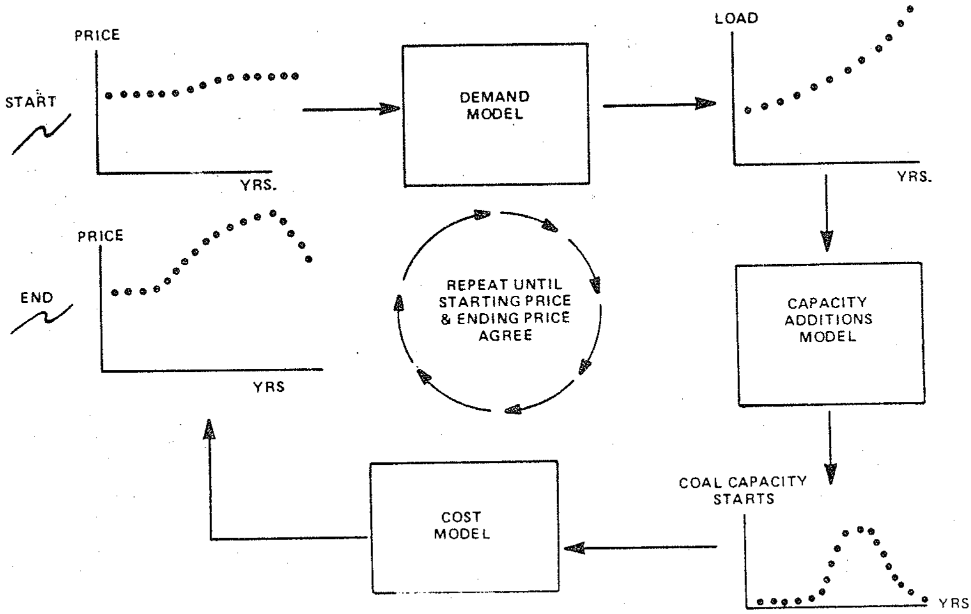

Figure 2. The Iterative Approach Often Used in Utility Analysis of Resource Strategies

system when the model developers are unfamiliar with system dynamics. The reason--most utility planning models do not "close" the key feedback loops that bring a collection of separate calculations into a wholistic picture of the system. Corporate modelers are becoming aware of the value of "closing the loop" from the results of the Electric Power Research Institute (1981) comparison of utility corporate models and the Los Alamos workshop on utility regulatory-financial models (Ford and Mann 1983). The forum and workshop provided information on two dozen utility models (and modeling systems) used across the country. The distinguishing feature of the two system dynamics models in the group was their integrated representation of the utility systems through their representation of information feedback.

CONCLUSIONS

Relating the experiences that occurred in the classroom where the Bonneville application was used as the setting have had enormous classroom benefits to the MSSM students that can be generalized beyond the Bonneville case study experience. As managers or future managers several aspects of translating theory to practice stand out and they stand out glaringly to mid career adults who have already gained considerable savvy in the workplace. Moreover, from the faculty point of view there are additional learning benefits of which the students may not themselves be aware.

General Lessons From the Student Point of View

1. Theory can lead to practice.

   From the student point of view they see that a theory and technique they have just learned can be applied in real world settings. Just having a "hands on" example to illustrate the theory works wonders in terms of student perceptions of the worth and utility of the theory and technique in their own job settings. And the motivation to learn seems to be highly related to perceive worth and on the job utility of what is being presented.

2. Speak English.

   Mid career adults are often well aware of the need to speak in ordinary english about some subject of interest so that listeners don't get lost. A high density of jargon in any presentation can quickly produce yawns or daydreaming in the audience. In the case of system dynamics with its emphasis on tieing model components to real world system components on a one to one basis the opportunity to communicate in ordinary english and in terms familiar to all listeners is greatly enhanced. System dynamics modelers can talk to each other in jargon and then can turn to other managers who have had no exposure to system dynamics and talk to them about the same model in ordinary english. This is an extraordinary advantage in the real world of day to day management where there is little tolerance for models that are full of greek letters and abstractions.

3. Include the whole nine yards.

   Many computer or other analytical models are regarded with disfavor or simply ignored by real world managers because by the time all the assumptions are listed in order to produce the model, the model no longer represents the real world adequately. It just leaves things out that managers know are important or it makes some assumptions that managers know are not realistic. In either case, managers are not going to risk their jobs by implementing the recommendations of models that are incomplete or unrealistic in their view. System dynamics on the other hand can include whatever is thought necessary and places no unrealistic constraints on model construction. The computer model not only mimics the real system, but it looks just like the real system and includes everything that the real system does that is thought necessary. It shows the student of management that it is possible to grapple with large, complex systems as large, complex systems, not merely as unrealistic approximations or in pieces.

4. Find the handle.

System dynamics also shows managers how to intervene in a system in a comprehensive way to move actual system behavior into the desired behavior. Many mid career adults who active in management are familiar with management actions that merely rob Peter to pay Paul. For some, it will be the first time that they see a systems tool that is actually adequate to allow them to find the right "handle" or "handles" in large complex systems so that they may effect overall system behavior in ways desired and not merely suboptimize one subsystem at the expense of another or at the expense of the whole.

General Lessons From the Faculty Point of View

1. Systems can be taught.

Many adventures into the world of teaching about systems are based on abstract theories and hand waving. There are also some elaborate programs or programming languages that allow students to explore in detail someone elses system or program their own if they can (a) somehow arrive at a model to program and if they (b) possess considerable programming talents. System Dynamics is unique in our view. It allows students to discuss concepts and then translate those concepts with a minimum amount of programming talent into elegant computer models where those concepts can be experimented with. System Dynamics shows how to conceptualize large, complex systems, or put another way, how to develop mental models. It also provides and orderly and relatively easy way to translate these mental models into computer based models that mimic the behavior of the real systems and permits management experiments to find ways to influence system behavior and gain understanding of the system. From a pedagogical point of view system dynamics represents an ideal way to teach students of management about systems and about how to be better managers of systems.

2. Students love it.

It is hard to convey to the casual reader the extent of the enthusiasm students of management have for system dynamics. With the exception of those few students who show up in any class in a state of continual bewilderment, the vast majority of students quickly become guilty of over enthusiasm if anything. Once they find out that they can model and experiment with their own ideas, they become addicts in a hurry. And faculty are well aware of the advantage of enthusiastic students in the classroom.

3. Quality control

Since students tend to like system dynamics so much they tend to want to use it right away. Faculty should be concerned with the quality control and reinforce these notions in the classroom. Students should be fully aware of the issues of validation of models. They should be warned of what can happen if a model is developed and used and ultimately is found faulty. The resulting loss of credibility can be most damaging.

4. Over enthusiasm.

It is sad but true to state that system dynamics will not solve every problem or be applicable to every situation. Students must be cautioned not to try and fit every situation they face into the system dynamics paradigm. Alas, even though system dynamics works and works well where it is applicable, not all situations are treatable by system dynamics. Students must be taught to distinguish the difference.

5. The time dimension.

Perhaps one of the most understated benefits to exposing students to system dynamics is the awareness they gain of the dimension of time in management. The behavior of systems unfold over time. Managers manage over a time horizon, and the actions they take or fail to take unfold over time. Systems are dynamic, and patterns of behavior over time represent their essential behavior. An understanding of this gives managers a strong advantage over those who see the world as static. What managers do, when they do it and why they do it are very different when managers think in dynamic versus static frames of reference.

It is fair to summarize our conclusions by stating that both faculty and students regard the experiment with system dynamics as a success. We have arranged for additional tests and are evaluating the course as a requirement for all students. Of course, if that occurs, we will require a far larger list of applications that serve the same purpose as the Bonneville application. Toward that end we have begun planning to evaluate the benefits and costs of establishing an information exchange center for system dynamics applications in our system dynamics laboratory. This would be one way to provide a resource for those interested in both the theory and practice of system dynamics.

REFERENCES

Burton, Patrick and Mike Bull, "Planning Conservation Programs: Decision Support with the Conservation Policy Analysis Model," Proceedings of the 1986 International Conference of the System Dynamics Society, Sevilla, Spain October 1986.

Bull, Mike, Andrew Ford and Roger Naill, "The Importance of Feedback in the Pacific Northwest Electric Conservation Planning Model," Proceedings of the 1985 International Conference of the System Dynamics Society, Keystone, Colorado, July 1985.

Bonneville Power Administration, "The BPA Conservation Policy Analysis Models," BPA Technical Report DOE/BP-24760-1, April 1986.

Electric Power Research Institute, "Case Study Comparison of Utility Corporate Models: Utility Modeling Forum Second Working Group," report EA-65, October 1981.

Ford, Andrew and G. Mann, "Summary of the Workshop on Regulatory and Financial Models of the US Electric Utility Industry," Los Alamos National Laboratory report LA-9815-C, June 1983.

Ford, Andrew and Steve Harris, "A Simpler Method for Calculating the Cost of Conservation Subsidies for an Electric Utility," Energy Policy, September 1984.

Ford, Andrew and Roger Naill, "Conservation Policy in the Pacific Northwest," BPA Technical Report DOE/BP-12761-1, May 1985.

Richardson, George P. and Alexander L. Pugh, III, Introduction to System Dynamics Modeling with DYNAMO, MIT Press, Cambridge, Mass., 1985.