D-3736

GENERIC MODELS AS EDUCATIONAL TOOLS: TEACHING ABOUT MANAGING TECHNOLOGY CONVERSIONS

Alan K. Graham
Massachusetts Institute of Technology

D. Neal Scogin
Tufts University

ABSTRACT

"Generic models," as the term is emerging, denotes a model representing the underlying causes of commonly occuring sets of problems, whose purpose is for education, rather than for policy analysis per se. Preliminary uses of generic models have been an exciting and efficient means of transmitting insights. This paper is a status report on the modeling of a company's conversion to a new production or product technology. Based on information sources including in-depth interviews within such companies, the authors' previous experiences, and published surveys and cases, the planned model focuses on management goals, staffing, and acquisitions of the skills necessary to deal with the new technology or product. Although the model does not explain every (complete or partial) implementation failure, it seems relevant to a significant fraction of such failures. The authors intend to develop the model and curriculum materials for management education and portions of university courses on technology management.

INTRODUCTION

1979 is an interesting year for those who deal with system dynamics models. It is interesting not because of events concerning such models, but because of what happened to personal computers. That year, the first mass-marketed word processing program, WordStar, was introduced. With WordStar and other general purpose programs, most notably Visicalc for electronic spreadsheet computations, the use of personal computers entered a new era. Prior to 1979, personal computers were for experts. While nearly anyone could own one, using one required programming. Creating or even modifying a useful program required a skill that took months, if not years, to acquire. Creating a useful program could be a major project by itself.

Introduction of more general purpose programs changed the situation rapidly. With programs such as WordStar and VisiCalc, people could produce useful results with a few days for learning and a few hours for a specific task. As a result, enormous numbers of people began to use personal computers. It is this shift from offering the ability to create something useful to offering something directly useful that commends itself to the system dynamics field, where a similar shift seems to be underway.

System dynamics has a decades-long tradition of models custom-built by experts. Becoming a credible model-builder takes years, and building a credible model for policy analysis for one specific client takes months or years. Models arduously (and expensively) constructed to reflect the needs and idiosyncracies of one particular situation are generally not useful for other clients. Today, at most, a few hundred system dynamics modelers have persisted to become experts. At most, several hundred clients have found the courage and the funds to have their own models constructed. Despite the wide applicability and desirability of system dynamics (at least as perceived by practitioners), the method has reached only a tiny share of its potential applications.

The limitations inherent in the traditional, "hand-crafting" style of modeling have prompted several system dynamicists to adopt a somewhat different modeling style. While most of the experiments with this new style are still under way, its overall character has become clear. The models represent the underlying causes of commonly occurring problems, and are embedded in educational materials able to convey important insights, without extensive efforts by a professional model-builder. For example, many companies in many industries show symptoms that include loss of market share, an ineffective sales program, and fully-utilized production capacity. A simple model can show how a single variable -- product availability -- connects these disparate symptoms, and what can be done about them. (This is from Forrester's "Market Growth" model, which is described in the appendix.) The model results apply to these problems even though they occur in many companies, apparently quite different from one another. The models constructed for this wide applicability are therefore called generic models. Just as general-purpose software packages brought the computational power of the personal computer to the mass market, so it is hoped that generic models will bring the intellectual power of system dynamics into the mainstream of management and education.

GENERIC MODELS

According to a dictionary, "generic" means "applicable to all members of a class." A generic model is a model of all organizations (or whatever) vulnerable to a particular set of problems. (System dynamicists sometimes replace "a particular set of problems" with the more precise medical term "syndrome", meaning a unique set of symptoms.) The purpose of a generic model, as the term is coming to be used, is not policy analysis *per se*, but education, including both formal and informal management education within organizations, as well as school-based education.

Generic models are emerging with a chameleon-like quality. Because a generic model and the educational materials created from it synthesize diverse sources of information, the model will look different, depending on the background with which it is viewed:

> Audiences see a model as the most novel part of an educational package incorporating a variety of media and formats. While there are surprises and plot twists in the course of the presentation, the materials and the model in particular serve merely to demonstrate lessons that will ultimately make sense from the audience's own logic and experience.
>
> To the model builder, the model, like any other system dynamics model, is the fundamental medium for arriving at the insights.
>
> To an executive, the model may create the "Aha!" experience of seeing the common thread that connects several well-known incidents. To an experienced top-level executive, a generic model and its educational

package may offer a means to articulate insights and attitudes to younger, less experienced executives.

To a consultant, the model might be seen as the archetype for more detailed policy analysis models.

To an academic researcher, a generic model is a novel way of organizing research findings in a particular area.

To educators, a generic model offers a framework for "war stories"--a means for students to remember and internalize the riches of anecdotal information.

To a curriculum developer, a generic model offers an interesting nexus for tying together several educational technologies, including non-mechancial use of personal computers, videotapes, and extensive audience participation.

In each of these roles, a generic model will not be (and indeed cannot be) the perfect vehicle, but will nonetheless make a useful contribution in many of these disparate roles. Although generic models have been applied to areas ranging from individual productivity to macroeconomic cycles, the discussion that follows will focus on corporate applications; this area both supports the largest number of potential applications, and has the greatest amount of previous work in the system dynamics field.

The educational uses of generic models, rather than focusing on presentation of facts, focus on building skill in the use of facts -- an intuition on how the structure of the system comes to determine the behavioral outcome. This skill is what differentiates a new MBA from an experienced manager, or graduate engineer from an experienced engineering project leader. Hands-on work with generic models offers a simulated, controlled environment for improving those skills. Unlike real life, it is possible with a model to find out exactly why something happens, and to experiment again and again until the system is understood -- until it is intuitive.

The educational materials that result from a generic model can be thought of as an extension of the case-study method of business education, as practiced at Harvard. While the case study method focuses on the specific case and attempts to distill generic lessons, the generic model approach focuses on the generic lessons with a number of specific cases to illustrate the common syndrome. The use of a generic model with a number of concomitant case studies retains the vividness and impact that comes from dealing with real-life situations. Several factors, however, add to the impact. Generic models demonstrate the common structure/behavior of several real-life situations. Participants can draw motivation from the focus on important, demonstrably common problems. Counterintuitive model behavior translates into plot twists and surprises in the presentation. Finally, the depth, thoroughness, and clarity of analysis that are possible with generic models far exceeds what can be accomplished through traditional discussion and verbal analysis.

D-3736

CREATING A GENERIC MODEL ON TECHNOLOGY: NARROWING THE FOCUS

There are basically two ways generic models have been built: either one focuses on just one case and then generalizes, or one starts from the beginning to build a generic model. The latter was the path for the research discussed here.

Generic models are created with fundamentally the same process as with any other system dynamics model, with the added constraint that the model must apply to a common syndrome. This creation resembles solving a jigsaw puzzle. In the end, all the pieces must mesh tightly, each with several others. The model structure must match what each of many information sources say about cause and effect. The problem definition must mesh with both the real problem as viewed by various participants and the problem behavior produced by the model. The results of policy variations in the model must match the corresponding real-life cases. In the end, a model fits the facts together into a consistent story.

When working a jigsaw puzzle, one doesn't know how all the pieces fit together. One experiments with a few pieces, fits them together, and then tries to fit other pieces onto the cluster. Likewise one fits pieces of information together to build a model, except a model builder gets to discard some pieces and seek out new ones. The research here, for example, as with most modeling projects, had an initial phase in which the focus was diffuse. It was clear to both authors that making technological changes were extremely important, both for national economic well-being and corporate competitiveness. But what should be examined? The national educational system for training engineers? Issues within individual companies? Aggregate industry attitudes toward quality control? Eventually, simplicity won out, in favor of first examining technology change issues within the individual corporation. After all, the common wisdom for research and development projects said that the vast majority of failed projects did so, not because of intrinsic characteristics of the technology, but because of management. In the jigsaw puzzle analogy, we discarded (at least for the present research) the pieces of various larger puzzles, and examined pieces within the framework of a single organization.

A number of additional pieces fitted to the single-organization framework. A previous modeling effort had analyzed strategic issues in technology conversion; this was Graham and Kreutzer's technology-timing model, described in the appendix. This model dealt with timing a technology conversion to steer between the twin disasters of early adoption of an immature, unviable technology, and late adoption into an already saturated market. During the building of that model, it had become clear that companies could know that a conversion was strategically necessary, but just not manage to implement the conversion promptly enough to remain competitive. Also, both authors had witnessed technology conversions that clearly made economic and competitive sense, that were prolonged simply because everyone in the organization was too busy to learn a system to save time! In the jigsaw analogy, it appeared that something useful could be made from pieces colored "implementation." The pieces colored "strategic viability" could be discarded for now--they are dealt with in other models and other places.

Finally, continuing literature search revealed substantial research indicating the importance of skills, staff and time allocation, attitudes, training, and other issues under the general heading of "human resources management." This was consistent with the authors' experiences. In the jigsaw puzzle analogy, it looked like a good puzzle could be solved by adding the pieces colored "human resources management" to the collection colored "implementation."

A very simple model was built to represent aggregate skill acquisition, the perception of the adequacy of present employees, and management goals for the productivity of the new technology, interacting as an organization converts to a new technology. With a few interesting model results and further (now more focussed) literature search, one of the authors (DNS) went out to real organizations engaged in technology conversions. These organizations provided several firsthand, in-depth, ongoing case studies. Gradually, cases accumulated that were not easily discussed in the framework of the initial model. In the jigsaw analogy, it became clear that the pieces did not quite fit together; the pieces used for the first model would have to be used in a different location in the puzzle. A new model has been planned, and this paper reports those plans; at the time of writing, the new model has not yet been built.

The need for a new model is far from a setback. It was only in the process of questioning the older model and the accumulating case studies that the authors realized that the same human resource issues applied to conversions from one product to another. A product technology implementation, however, can fail for other than human-resource reasons; the appendix describes models of such failures. Also, in the process of planning the new model, the authors articulated a classification scheme for causes of unsuccessful technology conversions. This classification (which will be described in a later section) encompasses a surprising proportion of known technology conversion implementation failures, in addition to providing fruitful insights into the firsthand case studies.

A GENERIC MODEL OF IMPLEMENTING TECHNOLOGY CONVERSIONS

The planned model represents an organization faced with the task of converting to a new technology. The organization can be any of the primary functions of a firm: design, manufacturing, marketing, distribution, or service. The technology can be a process technology that improves the operation of whatever function is being addressed. The technology can be a new product which the organization has to acquire skills to develop and produce. Examples of a process technology include a computer-driven automation system for manufacturing, a computer-aided design (CAD) system for a design phase, or a computer-based planning system for manufacturing planning. The new product technology could be almost anything, provided the organization needs to acquire new skills or procedures to manufacture/design/plan for it.

The model represents such a wide range of technology conversions because it represents the fundamental learning processes by which a new technology and an organization come to fit one another. The organization acquires knowledge and skills with the new technology; examples include learning to operate and maintain new equipment, reorganizing work flows, learning the intricacies of a new product's design, converting old databases and routines to a new computer system, or creating a way of using existing production equipment to make a radically new product. Similarly, a technology must "learn" about the organization. Products must be redesigned for producability. Vendors must tailor computerized systems to fit the organization's needs. Computer users will set up their own time-saving programs, fit to their own work patterns.

To provide a simple, aggregate representation of these various learning processes, the planned model will include:

A representation of the number of people and, separately, the level of their skills and knowledge relative to the new technology.

Management of human resource flows depending on perceived productivity with the new technology, and time alloted for learning and conversion activities. The policies can include biases for or against allocating time toward continually upgrading skills and therefore productivity.

Perception of productivity with the new technology depending on past productivity. (The true maximum productivity is usually unknown.)

An explicit rate of acquiring skills and knowledge, depending on: The availability of time for learning; availability of experts from whom to learn (including experts within the immediate organization, experts from elsewhere within the company, and experts outside the company such as consultants and employees of equipment vendors); and the availability of equipment with which to learn the skills (either the new production equipment or the new product being produced).

The planned model is to be evaluated on its ability to represent the events in a number of specific cases of process and product technology conversions. The cases of a conversion in process technology include:

1) An aircraft manufacturer converting from standard sheet-metal production techniques to an automated facility.

2) An expert system for planning the detailed steps of aircraft manufacturing.

3) The conversion in the color printing industry from manual color composition (ultimately producing printing plates) to production via electronic workstation (described in Graham and Kreutzer 1983).

4) Small businesses changing over from manual systems to electronic word processing and accounting.

Conversion of a product technology within a firm is the transfer of a technology between design phases or from design to manufacturing. Thomas Peters, a co-author of the well-known <u>In Search of Excellence</u>, asserted that "the 'pass-off' interfaces...account for 75% of the delays in the developments of new products and new sevices" (Peters and Austin 1985). The most publicized examples are:

5) Defense contractors, especially those making products using state-of-the-art technology (as so many weapons systems do).

6) Microcomputer software and hardware developers, where even product delays

of a few months can mean success or failure in the marketplace.

Finally, there are also situations where both product and process technology are changing simultaneously:

7) An electronics manufacturer starting to produce products based on very large-scale integration (VLSI), and using the new production equipment necessary for VLSI.

8) A product development team for an electronics firm converting to new computer-aided engineering (CAE) systems to deal with a complex new product. Another goal of the CAE system is strategic: to turn out products of higher quality and sooner relative to the competition.

For the planned model, some cases come from the business press (item 6). Other cases come from the modelers' previous personal involvement with technology conversions (items 3, 4, and 5). Published case studies and surveys from academic publications provide dozens of case, although with less detailed knowledge (several examples will be cited later).

The most telling cases, however, are firsthand cases initiated especially for the present research, where conversions are either recently completed or in process, so that interviews can proceed until all of the needed information has been obtained. Of these examples, numbers 1, 2, 7, and 8 are current firsthand cases studied. Items 1 and 2 are specific projects within an aircraft manufacturer's program to have totally computer-integrated manufacturing (CIM) by the year 2000. Items 7 and 8 both occur within a Route 128 electronics manufacturer, each a part of the company's strategy of internal diversification. The VLSI facility cost $25 million, and is a major new undertaking for the company. In both companies, several interviews have occurred to obtain information for the modeling; no model has yet been used for management education or commentary on the ongoing conversion projects.

SOME GENERIC CAUSES OF CONVERSION FAILURE

The current research suggests that the core process of learning a new technology can go awry in only four fundamentally different ways. In the extreme, each independently is capable of subverting an implementation. The planned model should allow user to experiment with each of these types of failure and policies to avoid them. The ultimate purpose of such an educational tool is to increase the ability to perceive and avoid these pitfalls in real life.

Late User Involvement. Kraus, after studying about 70 implementations of new technology came to see that the failure to involve end-users early was a major reason for failures. (Kraus,1983) End-users includes not only the operators but also everyone who will come in contact with the technology. Kraus refers to the early involvement as a "managed" approach in contrast to the usual "traditional" approach.

In the traditional approach what happens is that there is not much user involvement initially. Only after the implementation is well underway do the end-users become involved. Management is then put into a reactive mode to solve the problems of "resistence" and/or adapting the technology to meet the real needs of the end-users. When a technology is developed secretly and then thrust on the users, then the end-users can prevent the technology from performing up to its potential. The mechanism can be either outright subversion or simply a failure to take initiative to resolve issues.

In the managed approach end-users are involved early in the process. This helps to insure that the technology is designed to meet the needs of the end-users. Furthermore, the end-users come to see the technology as their own, they have emotional attachment to it, i.e., they develop ownership.

One of the firsthand case studies provides an example of successful early involvement. The aircraft manufacturer was implementing a rule-based "expert-system" to automate the planning of production steps. The system developer was offered a location in the plant away from where the process planners worked. He refused the offer and ran a development area. During its development the process planners were invited to "play" with the system. They came to adopt GENPLAN as their own. This basic philosophy of early involvement for this project has been used in a number of other successful implementations of new technologies.

Top management's failure to involve plant manafacturing specialists who knew manafacturing problems was cited by Goldhar and Jelinek as an example of a failure. Even a change in plant management did not bring the hoped for results. (Goldhar, 1983)

There are a few caveats about early user involvement. According to Markus early end-user participation should not be used when:

> It is intended as a symbolic gesture,
>
> Low trust or high conflict exists among the participants,
>
> The outcome has already been defined and participation is as manipulation. (Markus, 1984, p. 201)

If any of these apply then probably the best advice is that the implementer forgo the technology implementation and address more fundamental problems.

It is interesting to note one of the oft-cited major reasons why Japanese management is considered to be so effecive in <u>ringi</u>. This is the traditional Japanese method of participative decision making which, as an institutionalized form of early involvement, would tend to insure psychological "ownership" and adequate preparation of both the new technology and the people who will work with it. (Ouchi, 1981, pp. 42, 45, etc.)

<u>Chronic Learning Shortage.</u> In addition to the ill-timing of the end-user involvement discussed above, we can have management policies that result in a chronic learning shortage. This syndrome applies to management as well as end-users. Training is, or should be, an ongoing process - not only for the operators and maintainers of the technology but for the engineers who design it and for the managers who ultimately make the policy decisions regarding it.

Ettlie provides a number of reasons why there needs to be an on-going, in-house training effort. (Ettlie, 1984, pp 24-25) They range from the need to have refresher courses because by the time a programmable system breaks down the previous training was forgotten to the need to train people because of turnover.

Ettlie, who has looked at around fifty flexible machining system (FMS) implementations, says, "Training and education efforts are hard to overdo or overemphasize." (Ettlie, 1984, p. 25) One would think that companies would realize that they would have to adequately train their employees. However, an official Office of Technology Assessment survey showed that only 22 percent of companies currently using programmable automation provide or sponsor training programs for employees. (Argoff, 1983, p. 98) Programmable automation is defined to be all of the computer-aided technologies - a very broad definition.

In addition to a chronic learning shortage on the part of operators and maintainers of the technologies, there can be management policies that result in a chronic learning shortage on the part of engineers and managers.

To explain we must digress some. Almost everyone agrees that, in most cases, we will be proceeding to the "Factory of the Future" in incremental steps. The recommendation of Abraham is that one should, "Develop a strategic plan that includes a computer-integrated manufacturing system...Develop economic justifications for each subsystem and a phases implementation plan." (Abraham, 1981) This has been referred to a "muddling through with a plan." This implies a continual learning process which brings us back to the subject of chronic learning shortages.

Each subsystem implemented can, and should be, thought of as a learning process. The learning done on one subsystem helps to build a knowledge base for insuring the success of the next subsystem. One of the ways that the standard Return-on-Investment (ROI) calculation fails in its use of a criteria for investment is in its inability to consider the benefits of learning for future acquisitions of technology.

Expertise Shortages. The success of an implementation depends, in large measure, on the resources made available to make it a success. This seems so obvious that it is almost embarassing to state it. However, Lowell Steele in "Manager's misconceptions about technology" has written that management's belief that adequate infrastructure to support the new technology exists when it does not is one of the major managerial misconceptions that lead to failure. (Steele, 1983) Infrastructure here is synonymous with resources. We are referring to both expertise and equipment.

Adequate resources helps to insure that the performance of the technology is high so that there is no goal erosion. Also, with adequate expertise available initially there is a realistic perception of what the technology can do and a knowledge of what resources are necessary to insure the success of the implementation. This is related to the previous classification in that adequate on-going learning leads to expertise. It is also possible to purchase expertise via hiring (employees or consultants).

One interesting point about management's expertise as it relates to expectations of new technologies has been made by Hayes and Wheelwright. (Hayes, 1984) They argue that management's perception of the opportunity offered by a new manufacturing process is a saddle shaped function of management's knowledge about that technology. Managers who know very little or a great deal about the technology perceive the potential benefits to be high. Managers who have only a moderate knowledge about the technology often see very little advantage to it.

In addition to the in-house managerial expertise and consultant expertise discussed above, there needs to be internal (designers) and external (vendors) expertise available. Both Ettlie and Leonard-Barton have found that success depends upon building up an expertise on the part of the designers and the vendors. (Ettlie, 1984; Leonard-Barton, 1984) The designers possess the knowledge about the technological needs of the company (assuming that there is early end-user involvement). The vendors know what the range of possibilities from the technology are. Vendor-designer interaction is important because it helps to insure the best match between needs and possibilities.

Ettlie's perspective was that of a user while Leonard-Barton's was that of marketing: what companies had to do to insure success of the implementation, and what vendors had to do to sell their products, respectively.

For the case of the acquisition of the types of technologies we are dealing with, the vendor-user interaction takes on much more importance than what it does in a regular purchase. This importance stems from the fact that, generally speaking, the systems are no longer turnkey systems.

In the early days (a few years ago) of CAD (here the D stands for drafting) purchasing a "turnkey" sysem was one of the primary methods whereby firms started using computer-aided technologies. The same was true for the early days of CAM (where the M stands for manufacturing). Companies purchased a turnkey system that was called a Numerical Control (NC) machine. The days of tyrnkey systems are, for the most part, over.

Most computer-aided technology systems now being acquired are no longer turnkey. This is true for a couple of reasons. First of all, many of the simple drafting or simple machining applications have been done. That is just not where the major action is. Secondly, the advances in the technology are such that, for example, linking drafting with design (analysis/engineering) or design with manufacturing is the state of the art. Developments in material handling and assembly have also paved the way for integration of functions.

Companies cannot expect to purchase a turnkey system that implies a minimal amount of vendor-user interaction compared to the non-turnkey systems. They are going to have to work hard to insure that the system designed meets their specific needs. Management that assumes that because it is spending millions of dollars it will get a turnkey system almost invariably headed for failure. As one of Ettlie's respondents in a study put it, "If you take the "n" out of turnkey, you get turkey - which is how those systems wind up." (Ettlie, 1984, p. 11)

Equipment Shortage. The second type of resource shortage that can lead to failure is to not have equipment available on which to learn. This is related to a chronic learning shortage since without equipment available, generally speaking, not much learning can take place. There really is no substitute for hands-on experience.

Argote, et al., found that employees training to use robots rated working demonstrations as the most effective source of information. (Argote, 1983) Ettlie reported in one of his cases that one manufacturer found that the system went down often and no one could figure out why or what happened. Plans for the next system are that a robot will be available for training. (Ettlie, 1984, p. 15)

Generally, the reason that equipment is not available for learning is that either management does not realize the importance of learning or they are too anxious to get results. This is self-defeating since early failures lead to lowered expectations and demotivation.

One successful implementer reported that he had made the very explicit demand of his top management that the equipment (and concomitant time) be made available for learning. His particular application was a computer-aided design engineering (CADE) system used to design chemical process plants. He reported that he had followed the "Paul Masson Philosophy" - we will produce no design before its time. (Knight, 1984) He credits this philosophy with helping to insure the success of the implementation.

TEACHING ABOUT MANAGING TECHNOLOGY CONVERSION

The materials developed for the model described here are intended for use in both corporations and universities. Ideally, the materials for the model here would be supplemented by similar materials for other generic models, most notably Graham and Kreutzer's technology-timing model, whose focus on external competition and technological change complements the focus here on implementation.

Creation of the computer model will be a small fraction of the work needed to create an educational experience. Indeed, the facet of generic modeling that offers the most opportunity for pioneering work is probably the creation of a full-blown educational package. The necessary pieces of such packages have been tried with one model or another, but they have never been developed and used together for a single model. These pieces include:

- Videotapes of well-scripted, interesting lectures on the model.
- Personal computer-based exercises (sometimes competitive games) based on the model.
- Menu-driven facilities for user-directed experiments with the model.
- Journal-length articles on the model results.
- Detailed case histories for discussion and analysis.
- Frequent opportunities for the participants to consider how the results apply to their own organizations.

Follow-up assignments.

Thorough model documentation for modelers who wish to go further.

Availability of consulting or further courses of study for nonmodelers who wish to go further.

Materials for instructors, including lecture notes, solutions and commentary on exercises, and notes for guiding the discussions.

One of the authors (DNS) will be designing a university course on Computer-aided Design and Manufacturing utilizing the planned model and the technology timing model. The generic model of conversion implementation and some of the ancillary materials are being developed in a Ph.D. dissertation. More materials will be evolved as the model and materials are used.

More generally, materials based on the planned model could be used as a one- to five-day module in business courses on personnel or research and development management, or in engineering courses on automation, manufacturing, or design. Universities have begun to recognize the need for interdisciplinary education, especially between engineering and management-oriented programs. This is evidenced by the development of interdisciplinary manufacturing in a number of major universities. The modeling described here, and similar generic models, offer a workable and attractive vehicle for creating such interdisciplinary ties.

In corporations, seminars based on the model could be used for management education or to begin to analyze current issues within the corporation. Generic models are particularly attractive for the engineering manager: someone of exceptional ability who has made the transition from engineering to management. Such people usually do not have extensive management background. Yet, by virtue of their position, they can rarely afford the time for traditional management education. The relatively brief time commitment and the significance of the topics of generic models make them an attractive educational medium.

The use of generic models in general management education is parallel to Morecroft's successful use of "strategy support models" (Morecroft 1984). Just as computer-based information collection supports decision-making, so Morecroft has used a model to support strategy and policy formulation (lets managers make better strategies and policies). He describes the benefits that have been gained from such use:

> The impact of a strategy support model is often intangible. It is an insight generator and, therefore, differs from many common business models such as financial-planning and econometric models. The model does not get implemented in the sense that it is run weekly or monthly to produce a particular report or to execute a particular decision. By its very nature a strategy support model is involved in the amorphous to-and-fro of managerial and political debate. If it generates an insight, the insight can often quickly be absorbed into managerial thinking (mental models are, after all, much more agile than any formal simulation model, which is, by comparison, a rather cumbersome piece of intellectual

> infrastructure). The insight becomes part of intuition, particularly if it was backed with clear simulation analysis. Sometimes the model will form the basis for a specific recommendation but, usually, it will not contain the detail needed to state precisely how the recommendation should be translated into operating procedures. Like any strategic recommendation, it will need to pass through the ususal communication and administrative channels to be fleshed out and receive operational identity. (page 227)

CONCLUSION: THE TECHNOLOGY SKILLS MODEL AS A USEFUL GENERIC MODEL

The changeover from an old technology to a new one is an almost universal problem facing managers. In this era of increased international competition and high rates of change of technology, the challenge is particularly threatening. The cost of failure in many cases reaches the "you bet your company" magnitude. For example, a recent Business Week article on the lateness of a single product development (a telephone exchange) by a major corporation (ITT) was entitled "ITT May Be Putting Its Future On The Line" (Peterson, 1985) Or, as Munson asserts:

> No war...No strike...No depression, can so completely destroy an established business, or its profits, as new and better methods...new and better equipment in the hands of our enlightened competitors. (Munson, 1982)

The lessons to be learned from the research as it has progressed thus far are not new. The lessons are almost platitudes: First, early end-user involvement; secondly, on-going learning about new technologies at all levels; thirdly, cultivate expertise at all levels; and finally, make equipment available to assist learning. But in a corporate setting these issues often do not receive the attention and care they demand - because issues such as skill acquisition, user involvement, and continuous learning are intangible, have low visibility, and are often given little weight in decision-making.

There is a need for curriculum materials in both corporations and universities that make the intangible issues surrounding human resources management more intuitive and compelling. The present research is developing a generic model that should provide just such an educational tool for the critical task of converting to new technologies.

APPENDIX: EXAMPLES OF GENERIC MODELS

Forrester's Market Growth Model. A classic in the field of system dynamics, this model (Forrester 1968) is often used with executives to illustrate both a widespread problem and system principles. The problem arises when capital investment decisions are based on sales volume, or waiting until obvious shortages of production capacity arise. Low product availability results, which depresses sales and market share. The leverage point in the system, the management goal for product availability, is both far removed from the symptoms (sales ineffectiveness and loss of market share), and not very visible or persuasive in a real situation. So the model illustrates the system principle that leverage points can be far from, and not obviously related to, the symptoms they control. The market growth model is often presented to business audiences as an example of system dynamics. It is also included in a commercial management education seminar on systems thinking.

Graham and Kreutzer's Technology Timing Model. A relatively recent model (Graham and Kreutzer 1983), this has a fairly diverse set of educational materials, with a lecture/slide show, journal-length article, and a prototype personal computer-based exercise. The model depicts an industry where the advent of a superior technology eventually causes a shakeout from too much (technology-enhanced) productive capacity. The model explicitly represents both the economic and technological evolution of a market, and an individual firm competing within that market. The central question addressed is when and how the firm should convert to the new technology, relative to its competition. There is a "window of opportunity" for conversion. Converting prior to the "window" allows competitors to convert later, to a more mature technology, and achieve lower production costs. After the "window", most of the industry has already converted and the added capacity has depressed prices and profitability. The firm that converts in this environment experiences great financial pressure just trying to draw even with the average competitor's technology. Early and late conversions are examples of production technology conversions that may be successes in implementation but failures in overall business strategy.

Pugh-Roberts Vest Pocket Model (VPM). This generic model, created by the consulting firm Pugh-Roberts Associates, is a simplified, generalized version of a model of a ship design and construction project. The latter model, described in (Cooper 1980), was originally used in a lawsuit over how much of a cost overrun was due to design changing imposed on the shipbuilder by the Navy. The VPM sprang from the need for a model small and simple enough to demonstrate a model of project management to other clients. The VPM also has probably the most extensive user interface of any system dynamics model. Using proprietary software, non-modellers can choose from menus to alter simulation conditions, and store, recall and display different scenarios. Users can even get simulation results interpreted by written text, identifying in prose the major events of the simulation and what lies behind them. (Naturally, there is a great deal of preparation by the model builder to achieve this capability.) Elaborated versions of the VPM are used as project strategic planning tools by the management of most American shipbuilders. In addition, it is used by the managers at other similar larger projects. The models are used both to computer costs and to provide a facility realistic "what if" testing of many different management policies -- for example, can the project really be completed sooner by adding more people and advancing the schedule, or does the time and cost of bringing new people up to speed undermine the proposition? The model structure revolved around the completion of tasks, creation of errors, and the effort required to discover and correct them. The VPM depicts a major generic cause of "handoff" failures beyond hose described earlier in this paper: financial or scheduling pressure motivates a "handoff" where thorough testing and correction of design errors has been abridge, and the subsequent difficulties with the technology intensify the pressures.

Other generic modeling. There are undoubtedly more generic models than those described below; those that follow here are instructive due either to their subject area or to their educational format. Forrester's Urban Dynamics model (Forrester 1969) portrays the life cycle of an urban area as it matures into a stagnant inner city area. The model has been applied both in the sense of educational use by urban executives and in the sense of being adapted to the parameters of a particular city. (Sterman 1985) describes a very simple model of the fifty-year economic long wave, the so-called Kondratiev cycle, that accounts for both the Great Depression of the 1930s and much of the recent economic malaise. Sterman converted his model into a role-playing game, where a personal computer does the bookkeeping and recording (Sterman and Meadows, 1985). Most players, pretending to manage capital investment decisions in the economy, find it difficult to avoid creating approximately fifty-year cycles. (Kreutzer 1985) describes the use of a model of the arms race (created by Jay Forrester) in a self-paced microcomputer workshop. The software for the workshop including the model, is written in the BASIC language (by far the most common language for personal computers), so the whole package should become available to very large numbers of people. (Homer 1984) describes a model of a "workaholic," job stress, and periodic "burnout." The model has seemed to strike a responsive chord ("I've done that!") among students, academics, and corporate executives alike. (Senge 1985) describes a project aimed at revolutionizing management style and culture; this will entail spreading managerial skills more widely within corporations, which in turn is seen as entailing use of generic models for management education. Thus far, an interesting model of how organizations learn and develop layers of heirarchy has been developed, coming out of workshops given for and with about a dozen chief executive officers. Abdel-Hamid adopted the project management models like the VPM to create a generic model of software development (Abdel-Hamid 1984). Finally, Paich is developing several generic models explicitly from Harvard Business School case studies, both as a means of deeper and more general analysis, and as a means of achieving more educational impact from the cases.

REFERENCES

Abdel-Hamid, T., "The Dynamics of Software Development Project Management: An Integrated Systems Dynamic Perspective," Cambridge, Massachusetts: MIT Sloan School Ph.D. dissertation, 1984.

Abraham, R.G., "Computer-Integrated Manafacturing" paper presented at the AUTOFACT III Conference, 9-12 November 1981, Sponsored by Computer and Automated Systems Association of SME, Dearborn, Michigan 48128.

Argoff, N.J. "Computerized Manufacturing Automation: Employment, Education, and the Workplace; Volume 11 - Working Papers, Part B: Final Report: Education and Training Case Study Series," Office of Technology Assessment, Washington, D.C. 20510.

Cooper, K.C. "Naval Ship Production: A Claim Settled and a Framework Built," Interfaces, Volume 10, Number 6, 1980, pp. 20-36.

Ettlie, J.E. "Facing the Factory of the Future," August 1984, Unpublished Paper.

Forrester, J.W. Industrial Dynamics, Cambridge, Massachusetts: M.I.T. Press, 1961.

Forrester, J.W. "Market Growth as Influenced by Capital Investment," Industrial Managment Review, Volume IX, Number 2, Winter 1968, pp. 83-105.

Forrester, J.W. Urban Dynamics. Cambridge: M.I.T. Press, 1969.

Goldhar, J.D. and M. Jelinek, "Plan for economics of scope," Harvard Business Review, November-December 1983, pp. 141-148.

Graham, A.K. and D.P. Kreutzer. "Strategies for Converting to New Technologies: Computer Graphics in the Color Printing Industry." Cambridge: M.I.T. Sloan School of Management Working Paper WP-1503-83, 1983.

Hayes, R. and S. Wheelwright Restoring Our Competitive Edge: Competing through Manufacturing, John Wiley, New York, 1984.

Homer, J.B. "Worker Burnout: A Dynamic Model with Implications for Prevention and Control," Proceedings of the 1984 System Dynamics Conference, Oslo, Norway, pp. 454-473.

Knight, R.L. "Computer Aided Design Engineering in Chemical Process Plant Design," Engineering Progress, Vol. 4, No. 1, Spring 1984, pp. 14-17.

Kreutzer, D.P. "A Microcomputer Workshop for Exploring the Dynamics of Arms Races." Cambridge: M.I.T. System Dynamics Working Paper D-3749, 1985.

Kraus, W.A. and N.W. Weiler "Overcoming Human and Organizational Barriers to Implementation of New Technology" in The NTL Manager's Handbook, Edited by R.A. Ritvo and A.G. Sargent, NTL Institute, Arlington, VA 22209, 1983, pp. 357-365.

Leonard-Barton, D. and J. Grogan "Marketing Advanced Manufacturing Processes," to appear in Donald Davis, Ed: Implementing Advanced Technology, Jossey-Bass, San Francisco, 1985.

Markus, M.L. Systems in Organizations, Pitman Publishing Co., Marshfield, Massachusetts, 1984.

Morecroft, J.D.W. "Strategy Support Models," Strategic Management Journal, Volume 5, 1984, pp. 215-229.

Munson, G.E., Preface to "Robots VI Conference Proceedings, 2-4 March 1982, Detroit, Michigan, sponsored by Robotics International of SME, Dearborn, Michigan 48128

Ouchi, W.G., Theory Z: How American Business Can Meet the Japanese Challenge, Addison-Wesley Publishing Co., Reading, Massachusetts, 1981.

Peters, T.J. and Nancy Austin "A Passion for Excellence," Fortune, May 13, 1985, pp. 20-32.

Peterson, T. et al. "ITT May Be Putting Its Future on the Line," Business Week, 13 May 1985, pp. 44-45.

Senge, P.M. "The New Management: Moving from Invention to Innovation." Cambridge: M.I.T. System Dynamics Group Working Paper D-3651-2, 1985.

Steele, L. "Management Misconceptions about Technology," Harvard Business Review, November-December 1983, pp. 133-140.

Sterman, J.D. "A Behavioral Model of the Economic Long Wave," Journal of Economic Behavior and Organization, Volume 6, 1985, pp. 17-53.

Sterman, J.D. and D.L. Meadows "Strategem-2: A Microcomputer Simulation Game of the Kondratiev Cycle," Cambridge, Mass.: MIT Sloan School Working Paper WP-1623-85, 1985.