ACHIEVING IMPLEMENTED RESULTS FROM SYSTEM DYNAMICS PROJECTS:

THE EVOLUTION OF AN APPROACH

By

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Abstract

This paper documents a series of lessons that the author and his colleagues have learned about how to achieve implemented results from system dynamics projects. Through a series of three case studies, the paper illustrates the evolution of their approach to implementation over the period 1966 to 1975. These case studies focus on: client involvement in projects; the process of model development; the nature of the models developed; and the end-products of the projects. The paper draws upon the case studies and earlier writing on the subject by Roberts to generalize about the factors that are most critical in achieving successful implementation. These factors include: the sharpness of the project's problem focus; the urgency of the problem addressed; the organizational position of the client; the degree and nature of client involvement; the size of the model developed; the demonstrable validity of the model; and the nature of the project's end-products.

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I. A Review of the Implementation Problem

Fifteen years ago, when I first began building system dynamics models, I thought very little about implementation. The approach was quite new then, and I was preoccupied with its compelling intellectual appeal and its technical facility. Now, it is fair to say, I am most concerned with the problem of achieving implemented results from system dynamics projects. Moreover, It has become a problem of critical importance to everyone in the field.

First of all, the sponsors of system dynamics projects deserve their money's worth, both as a matter of professional ethics and a basic tenet of good business. A private corporation that hires a consultant generally expects results of immediate value which can and will be implemented. Public policy analysis is admittedly a less clear-cut case, but here, too, projects which have a definite impact on people's thinking and actions are more valuable than those which don't. It is naive to think that sponsors are not aware of the implementation problem. On the contrary, they are increasingly demanding evidence of prior success in this regard.

In addition, work which leads to implementated results is far more satisfying. I can really speak only for myself and my close associates, but I would be surprised if many others did not share this sentiment. We think of ourselves as <u>effective</u> professionals, because we can see the impact of our work. "Being effective" and "having impact" is an absolutely essential part of our concept of professionalism. It is depressing when, for whatever reasons, a project fails to produce meaningful implementation.

Furthermore, success at implementation is necessary to preserve and enhance the credibility of the system dynamics methodology. People all too

easily reject an approach that does not seem to be producing results of immediate value. This tendency may be unfortunately short-sighted, but then short-sightedness is not a new trait of the human animal. In some quarters, system dynamics may already be stereotyped as only good for taking a very long-term view of very aggregate problems, and not capable of producing anything sufficiently detailed, specific, and practical to be usable in the short-run. Of course, nothing could be farther from the truth. But the only persuasive way to answer such criticism is with an ever-growing number of clear examples to the contrary.

Despite its importance, meaningful implementation is an elusive goal. Success occurs only when all of the essential ingredients are present. First, the results of a project must, in fact, be implementable. This statement may sound obvious, but many projects offer recommendations which are technically "right", but at the same time too extreme, or too unconventional, or too inconsistent with established social/political structures to stand a realistic chance of being implemented. This shortcoming is an easy trap for a model builder to fall into. He is, after all, an outside technician who may well lack the perspective and sensitivity to properly determine what is implementable.

Furthermore, those who will have to take action must have a clear desire to implement. The sponsors need to understand, accept, and have confidence in the results before they will advocate implementation. They must attach a sufficient priority to the problems being addressed to justify the time and attention, the disruption, and the risks inherent in attempting to implement the results. In other words, there must be a significant client commitment.

And the environment must be properly receptive. Rarely are the sponsors the only people involved in implementation. In public policy analysis, the sponsors are often quite separate from the people who actually make and carry out policy. The policy-makers who have to be sold on project results are strongly influenced by their constituents and rivals, as well as by their advisors. If the political environment is not right, implementation will not take place, even though officials may agree privately that the recommendations are "theoretically correct." The same holds true in a private corporation. Management can accept your recommendations and direct that they be implemented, but resistance at lower levels or in parallel groups can easily defeat implementation.

Ed Roberts (1972) has outlined a number of factors which influence these key ingredients for implementation success. This paper is intended to more fully document lessons that my colleagues and I have learned about the achievement of implemented results from system dynamics projects. A series of case studies illustrates the evolution of our approach to implementation over the past ten years, and generalizes about the causes of success and failure.

II. Three Implementation Case Studies

Frohman (1970) has correctly remarked that: "failure....is far more common in consulting than is generally recognized and is extremely embarrassing for both the consultant and the client. The mutual face-saving efforts that result often preclude using the experience as a learning situation for either the consultant or the client." A profession has to acquire a necessary maturity and confidence before it can be usefully self-critical. System dynamics has reached this point. My colleagues and

I are not embarrassed to cite the mistakes we made in past years, because we have learned from them and are achieving implemented results much more consistently today.

How our approach to implementation has evolved can be illustrated through a series of three examples. All three were projects for private corporations and all involve development of a system dynamics model. The first occurred in 1966, the second in 1971, and the third in 1975.

Case Study No. 1: Retail Food Chain

Background

The client for this project was a large diversified corporation with activities in the supermarket, department store, food manufacturing, and restaurant fields. The project focused on several issues relating to the firm's Retail Food Division and Manufacturing Division. Management considered the issues to be of significant mid-term importance, but, realistically, they could not be called "urgent".

The first issue was growing conflict between these two major divisions, which together accounted for sales of several hundred million dollars. Each division increasingly blamed the other for its problems. However, no one could articulate a complete and correct picture of how in fact the two divisions affected one another's performance.

The second issue arose out of the first. The Manufacturing Division produced private-label food products that were sold almost exclusively in the company's own stores. These stores were operated by the Retail Food Division. Goods were "bought" and "sold" between divisions at internal transfer prices, and the precise nature of this transfer pricing had an enormous impact on the accounted performance of both divisions. Understandably then, in light of the general interdivisional friction, management was unable to agree on what constituted a proper transfer pricing policy and what measures of divisional performance to use.

The third issue was related to the first two. Over the preceding five years, the company had invested very heavily in manufacturing facilities. A new bakery facility, which represented the largest capital investment ever made by the firm, was about to start operation. Manufacturing Division profits had been lower than expected, and top management was concerned that prevailing policies were somehow causing the division to underachieve.

The model developed during this project has been described by Roberts, Abrams, and Weil (1968). In brief, it centered around two related interdivisional flows: the flow of orders and goods, and the flow of cash. The determinants of sales were represented in considerable detail. The model was, for the most part, conceptually straightforward and easy to understand. The only conceptually advanced part of the formulation had to do with the process of managerial control with respect to multiple conflicting performance criteria. A very small model by our current standards, it contained 110 significant variables.

Outline of the Project Process

The project got off to a fast start. Very little selling was required, nor did we have to prepare a formal written proposal. We had been approached by an M.I.T. alumnus who was well-acquainted with system dynamics and already convinced that it was the proper way to approach his company's problems. He occupied a key staff position in the company (assistant to

the Treasurer, who was the son of the firm's President and founder) and championed our involvement as consultants.

The first step was a series of discussions with top management regarding their perception of the problems. Next we conducted an initial round of "scouting" interviews at many levels in both divisions. The purpose of these interviews was to learn the organization and come to our own conclusions about the problems.

We then adjourned to our offices for about six weeks. During that period, the model was conceptualized, equations were written, and preliminary parameter estimates were developed from company-supplied data and our interview results. We subsequently had a series of lengthy meetings at which the model structure and initial simulation runs were discussed with divisional and top management.

Following these meetings, we again worked independently for a considerable time. We refined the model based on further interviews and data gathering. The model was initialized with year-end 1961 conditions, and a five-year historical simulation was produced for the period 1962-1966. Management reviewed this simulation and pronounced it "reasonable." However, we did not engage in any formal quantitative validation of the model. At this stage of the project, the model was accepted by company management as sufficiently realistic for policy testing.

The final phase involved the analysis of alternative policies. We examined policies in the areas of transfer pricing, divisional performance measurement, goal setting (for production, sales, and profitability), and managerial control. We presented our findings at a meeting with divisional and top management and submitted a reasonably brief (30-40 pages) nontechnical report.

Very few of our specific policy recommendations were implemented. General agreement did not exist among the President, Treasurer, Vice-President of Retailing, and Vice-President of Manufacturing that the feedback concepts embodied in the model reflected the essential characteristics of their organization. They attempted to use the new conceptual framework provided by the model as an aid in thinking about the company's problems. Therefore, the principal effect of the project was "consciousness raising". At the time, this outcome seemed perfectly satisfactory. In fact, there was a tendency, then, to think that "greater understanding" was the primary benefit to be expected from a system dynamics project. But, by our current standards, we were not very successful in achieving implementation.

Comments

This project was rather typical of our approach ten years ago. Our principal point of contact in the client organization was not a line manager, but, rather, a sophisticated staff man who was favorably disposed toward system dynamics, understood what we are doing, and readily accepted the emerging analytical results. He was a very "comfortable" person to work with for these reasons. Communication was easy, and he posed few cross-cultural problems; he was sharp, quantitatively-oriented, open-mined, rational -- just like us! Unfortunately, he was not the President, nor the President's son, nor an influential member of line management. For all practical purposes, he was another outsider. The official sponsor of our project was the Treasurer, but we had only intermittent contact with him.

Furthermore, the model was built and exercised almost exclusively by us, with little client involvement. At various points during the project, meetings were conducted with key company executives. These sessions covered the model's structure, the simulation results, and our policy recommendations. In each case, the managers were being asked to react to

a reasonably finished product, not to participate in developing it. Our role in this project was that of systems analyst and researcher; people in the client organization served as information sources and as an audience for our work.

With the benefit of hindsight, clearly we were probing very sensitive areas. The question of transfer pricing policy involved very significant financial stakes for the division affected. The question of proper performance measures involved very strongly entrenched traditions in the retailing industry. The questions of goal setting and control involved the personal styles and values of the President and other key managers. Our recommendations in these areas were viewed as "unconventional" and "controversial". We had a credibility problem. Although management generally accepted the structure of the model, they were not yet ready to accept its analytical implications.

Nor did the end-product of this project allow management to come to terms with the results on their own, later. As noted previously, our only tangible end-product was a non-technical report. We did not deliver the model itself, with the detailed technical documentation required to examine it in depth, test it, and recreate our results. And we did not spend time developing the in-house capability to engage in continuing work with the model.

To summarize the salient characteristics of our approach ten years ago:

1. We tended to work independently as systems analysts and researchers, with relatively little client involvement.
2. The client's role tended to be that of information source and audience.
3. Our closest contacts in the client organization tended to be with sympathetic and sophisticated staff people, rather than line managers.

4. We tended to build small, aggregated models for the purposes of understanding system behavior and testing potential policy changes.
5. We tended to ignore questions of formal model validation and be satisfied with a model whose historical behavior was qualitatively reasonable.
6. The principal end-product of our work tended to be a report.

Case Study No. 2: High-Technology Manufacturer

Background

The second project was conducted for one of the world's leading manufacturers of information-processing equipment. Our specific client was the Senior Vice-President for research and engineering. He had requested our assistance in three areas which, he felt, were important to the mid-term success of his organization.

First of all, he wanted to develop a framework that would help him communicate more effectively with the president and other senior executives. He felt that they did not understand the R&D process. He wanted to be able to show them how his division worked and where his problems came from. He was particularly anxious that they recognize that many problems in the R&D area were caused by people elsewhere in the company.

Second, he wanted to establish within his organization an ongoing strategic analysis process. He had come to his position from outside the company, and was not satisfied with the calibre of analysis he found. He was eager to address resource-allocation and technology-policy issues in a

more sophisticated manner.

Third, he wanted to deal with a problem of erratic workflow through the R&D organization. This "workflow bunching" phenomenon manifested itself in several ways. The whole division went through cycles of overload followed by slack; these cycles were far more severe for individual R&D sections. Furthermore, the R&D process consisted of a sequence of phases, which could be viewed as a "pipeline" of sorts. Workload tended to surge down this R&D pipeline in a series of waves. Consequently, the organization often found itself understaffed in one area and overstaffed in another. Differences in skill requirements could easily produce simultaneous hiring and layoffs.

The model that emerged from this project was described by Weil, Bergan, and Roberts (1973). It represented the flow of work through multiple phases of R&D, starting with basic research and ending with major new products ready for large-scale manufacturing. The acquisition and allocation of human resources (scientists and engineers) was modeled in significant detail. Another important sector of the model represented the performance measurement and control process: comparison of actual performance with targets; estimation of future resource requirements; and revision of performance targets.

The model was both large and conceptually subtle. Disaggregation with respect to R&D phase, characteristics of the workflow, types of resources, resource-allocation possibilities, and dimensions of managerial control produced a model with approximately 600 significant variables. The considerable size and complexity of this model was a direct result of an expressed client desire for "realism". Two aspects of the formulation were particularly subtle. First, the actual R&D workflow consisted of a relatively small number of large programs. Therefore, our continuous representation of the flow was a substantial abstraction. Second, it was quite important to model various technical characteristics of the R&D work-flow (for example, how well-mastered was the technology being embodies in new products; how technically advanced were the products in R&D). The technological variables in the model also represented substantial abstractions. These abstractions make the model more difficult to understand.

Outline of the Project Process

Unlike the project described in the first case study, this project started slowly. We had an initial two-day session with the Vice-President and his key staff assistants to discuss the focus of the effort. Based on those discussions, we requested (and received) a small budget to pay for an initial conceptual definition of the system to be modeled and a detailed written proposal describing how we would proceed. These goals were achieved over a two-month period. During this definitional phase, the company made no commitment with respect to continuing the work. That commitment came with the subsequent acceptance of our proposal. We had met several times during the definition phase with the Vice-President's staff. The proposal was a collectively accepted statement of project objectives, focus, process, and end-products.

Once the project has been approved, the next step was selecting a Task Force. The project Task Force consisted of key individuals from the client organization: members of the Vice-President's staff and managers of several of the most important components of the R&D division. In theory, the Vice-President was chairman of the Task Force, but he and the other line managers attended only the major review meetings. The function of the Task Force was to work with us on developing the model, interpreting the results of, and formulating policy recommendations.

Task Force members participated with us in an extensive series of interviews, both inside the R&D division and elsewhere in the company. We refined the conceptualization, presented it to the Task Force, and (based on their critique) refined it further. We then wrote equations and assembled the necessary data to parameterize the model.

The initial simulation runs were reviewed with the Task Force. The historical behavior of the model was examined and deemed "reasonable". No particular effort was made to quantitatively validate the model. We jointly planned refinements in the model and established priorities in that regard. While performing policy analysis simulations, we had frequent meetings with the Task Force to discuss the findings. We produced recommendations with respect to resource-allocation policies and R&D program planning.

At the end of the project, we prepared <u>very</u> complete documentation, consisting of: 1) a management summary; 2) a lengthy discussion of the model's conceptual structure and the simulation results; and 3) detailed technical documentation, which included a write-up of every equation and parameter in the model, all of the important simulation output produced, and instructions for using the model. Furthermore, we "installed" the model on the client's in-house time-sharing system.

No immediate action was taken on any of our specific recommendations. Our conclusions were viewed as something <u>they</u> should study further -- in house, privately. This position was tenable because of the model and the capability to use it had been internalized by our client. A senior staff analyst was assigned to work with the model, and he did so for several years. He called upon us for technical assistance from time to time, but we never learned precisely what he was doing. In this case, we achieved a great deal more than just increasing client understanding of a problem. We created a policy analysis capability that continued to be used. By our current standards, this project was a partial success in terms of implementation.

Comments

This project illustrates the significant evolution of our approach between the mid-1960s and the early 1970s. We had, by then, learned the importance of directly enlisting senior line managers (who generally hold the key to implementation) in our work. They tend to be harder to sell, more skeptical, less analytically-oriented, more frustrating, and less available for work sessions than our in-house counterparts. But none of that matters. Their participation injects important perspectives and considerations that are not available from other sources, and allows them to acquire the understanding and confidence they need to act on our recommendations.

By then, we were consistently employing a project Task Force as the vehicle for securing client involvement in our work. We expected such a Task Force to be much more than a review board. We expected the members to work with us in information gathering, model conceptualization, interpretation of simulation results, and formulation of policy recommendations. Of course, this objective is easier said than done. One problem in the project discussed here was that the Task Force subdivided into two groups. The core group with which we worked quite closely consisted of three members of the vice-president's staff. We met with the full Task Force less frequently. The line managers, themselves, were not sufficiently involved to obtain the requisite understanding of our work. As previously mentioned, the model, while large, contained some significant abstractions that were

not easily grasped.

We had also learned the importance of sufficient preliminaries before a project is launched. As Frohman (1970) points out, the early phases of a project are most critical in determining eventual success or failure in implementation. A formal definitional phase (as took place during this project) allows both the consultant and client to "size one another up". This initial phase is the consultant's principal opportunity to influence the client's view of, and expectations for, the project. The basic "tone" or "climate" of the project is established here. Decisions regarding scope and involvement undertaken at this point generally determine whether there will be a sufficient power base to achieve implementation.

Furthermore, our concept of the end-products of a system dynamics project had evolved substantially. There was much more emphasis on the transfer of know-how, on creating and internalizing in the client organization on on-going capability for analysis. Therefore, we delivered mountains of documentation; we delivered the model itself; and we trained some client personnel to use the model.

To summarize how our approach had evolved by the early 1970s:

1. We actively sought significant client participation in our work. We employed a project Task Force as the vehicle for securing client involvement.
2. The client's role tended to be that of information source, information collector, critic, and trainee.
3. We were particularly anxious to work closely with senior line managers.
4. We tended to build large, complex models which clients would accept as "realistic".

5. We still tended to ignore questions of formal model validation, and to be satisfied with a model whose behavior was qualitatively reasonable.
6. We viewed the end-product of our work as a transfer of know-how and capability.

Case Study No. 3: Insurance Company

Background

The work described in the third case study was performed for a major diversified financial institution. As part of its aggressive growth and diversification strategy, this company had invested over $100 million in a very promising new business area. At the time we became involved, management was increasingly concerned with a series of "growing pains" that the business area was experiencing. They were anxious to review and, if necessary, revise the strategy being followed in that business area. As our work progressed, a clearer perception of the magnitude of the problems and changed circumstances elsewhere in the company heightened the urgency of the situation.

The project focused on several key strategic issues. First of all, management was uncertain of the ramifications of different rates of sales growth in the business area. Among the important considerations were: sales growth/profitability tradeoffs, maintenance of market position and "momentum", adequacy of the "quality" (that is, longer-term profit potential) of sales, dilution of organizational capabilities, requirements for additional capitalization, and vulnerability to adverse economic and/or competitive conditions.

Second, the most effective set of policies for achieving the desired near-term rate of sales growth was unclear. A balanced set of policies had to be defined with respect to product mix, pricing, sales-force compensation, sales-force size, customer service and underwriting (that is, the screening of potential sales). The impacts of changing economic, regulatory, and competitive conditions also had to be properly factored in.

Third, we had to assess the short-run/long-run tradeoffs inherent in each strategic option. The most appealing strategies in the near-term might have significant adverse consequences in later years.

A very large and complex model emerged. Separate major sectors represented: sales-force size, skill, and effort allocation; determinants (both internal and external) of sales-force effectiveness; quality of customer service; performance measurement and managerial control; and accounting relationships. The sales force was disaggregated by skill level and type of organizational affiliation. The determinants of sales were modeled in considerable detail. Managerial concerns, priorities, and reactions were richly represented. The accounting sector was highly complex, disaggregating booked business into five age categories and calculating profits on both a cash and an accrual basis. In total, the model contained over 1250 significant variables. It has been described in detail by Weil, Pugh, Wright and Veit (1974).

Outline of the Project Process

Our client for this project was the Vice-President in charge of operating the business area. He proved to be an extraordinary astute and motivated client. Prior to our first meeting to discuss the possibility of a project, he prepared a paper outlining the issues and a companion causal loop diagram. He assembled for this meeting a group of key managers who, he felt, might be involved if a project went forward. We talked about the issues, the system dynamics methodology, other projects we had conducted (with particular emphasis on implementation success!), the type of model we might develop for them, and how we would proceed. These discussions continued in several meetings over a four-month period before the project was formally launched.

Our project Task Force consisted primarily of people who had participated in the earlier meetings. Therefore, they had been actively involved in defining the project and deciding it was worthwhile. Furthermore, the Vice-President maintained a very high level of personal involvement. He led the Task Force and immersed himself in the project down to the smallest technical details.

We began the project by interviewing each Task Force member to gain general background information. We then devoted several Task Force meetings to familiarization with the techniques that would be used in the project: basic concepts of system dynamics (for example, feedback, rates and levels), the DYNAMO language, and computer timesharing. These sessions prepared the Task Force to participate significantly in model conceptualization.

To begin with, one Task Force meeting was allocated to discussing the project's problem focus and how this focus translated into a necessary set of model boundaries. Then we developed a gross conceptualization of the entire model, which was thoroughly critiqued by the Task Force. Next, we developed the detailed conceptual design for several "core sectors" of the model. This design was critiqued by the Task Force. The Task Force also provided extensive comments on paramater values.

Equations were written for the "core sectors", and initial simulations were performed. At this point, several members of the Task Force

took the time to scrutinize the equations and simulation results. They wanted to satisfy themselves that the model was reasonable on a detailed level and to understand "where the simulation results came from". These people served as a continuing technical working group. Of great importance, though perhaps surprising, the Vice-President and his controller were part of this group.

We then proceeded with an iterative expansion of the core model. One after another, new sectors were conceptualized, critiqued by the Task Force, implemented in DYNAMO, and added to the model. Each time, the new equations and simulation results from the expanded model were reviewed with the technical working group.

When substantially complete, the model was installed on the client's computer system. We intensively tutored several members of the Vice-President's staff in the use of the model. They undertook model testing and some refinements in parallel with our clients.

We devoted a considerable amount of time and attention to improving the historical accuracy of the model. Simulated values for a large number of variables were explicitly compared with historical data for the period 1970-1974. The model generally produced results within $\pm$ 10% of historical values; in some areas, the accuracy was consistently within $\pm$ 5%. We achieved a broad consensus that the base simulation was historically valid and the best existing estimate of what the future held in store. The client has assumed "ownership" of the model (in the psychological sense).

Our policy analyses took place in two separate phases, about six months apart. The first phase focused primarily on questions of growth strategy: sales growth/profitability tradeoffs, investments required to maintain a strong market position in the future, changes in the management control structure to make growth a more orderly process, impact of economic conditions on sales growth. The general conceptual framework provided by the model, the initial analysis results, and our best forecast for 1975 through 1980 became inputs to management's determination of near-term growth targets.

The major company decision was to dramatically slow down sales growth in order to improve profitability. The question then became: What is the best set of policies for achieving this goal? The model was expanded in several sectors where more detailed answers were required. Policies with respect to product mix, pricing, sales-force compensation, sales-force size, customer-service expenditures, and underwriting were analyzed with the model. The results of these analyses significantly influenced key managers' perceptions of the issues and the policy decisions which were ultimately made. We consider this project an implementation success.

Comments

This project typifies our current approach. We now recognize the importance of the project Task Force playing an active role in defining the focus and scope of work to be done. This role requires involvement at a very early stage, while the project is being sold. We regularly request prospective clients to include in preliminary meetings people who would probably participate in any project that might be started. We also regularly request prospective clients to prepare for such meetings papers which define the problems they are concerned about (including causal diagrams). We now believe that a client must participate at a fairly detailed technical level in the process of model development. This technical role means, first of all, more emphasis on familiarizing people with the techniques that will be employed. We encourage Task Force members to read portions

of the system dynamics literature, we devote Task Force meeting time to the methodology, we engage in extensive "on-the-job" tutoring, and we often ask clients to send people to system dynamics courses.

We have also modified our approach to model building to make it easier for clients to keep up with us on a detailed technical level. Now we tend to develop a gross overall conceptualization of the model first, then produce the detailed conceptual design and the DYNAMO equations in several blocks. This approach is not so initially overwhelming, and it produces simulation results earlier in the project. As the model grows more complex, the client grows more sophisticated.

We now routinely build very large models, for several reasons. First of all, clients are more comfortable with and confident in a model which they consider "realistic". Since these attitudes are an absolute prerequisite for successful implementation, we are generally very accommodating to client desires for more detail. Second, both we and our clients are far more confident in models of demonstrable historical validity. We now routinely engage in extensive comparison of simulation results with historical time series and expect a model to be accurate within $\pm 10\%$. To achieve this degree of historical accuracy (except in trivial situations, such as constant exponential growth) requires a very elaborate causal structure.

Furthermore, the detailed implementable recommendations we seek generally necessitate quite disaggregated models. Therefore, we often end up representing multiple product lines, multiple phases of effort, multiple classes of resources, multiple market segments, and/or multiple dimensions of management control in our models. Finally, we have learned that working on high-priority immediate problems greatly increases the likelihood of implementation success. But this kind of problem focus often increases the need for short-term (1-5 years) predictive accuracy, which, in turn, mandates a more elaborate model. The project described in this case study is a good example. An important aspect of policy analysis was determining the impact of various potential actions on 1976 financial results. We needed to accurately judge how strong the actions should be to attain the exact financial results sought by management. Management's confidence in the model was significantly enhanced when the model predictions for 1975 (made in January of that year) turned out to be very accurate.

This project also illustrated a further evolution in the end-product we try to deliver. We now expend more effort creating an in-house capability. This effort is a natural by-product of the greater technical involvement we now demand of our clients. In addition, we have learned that we cannot just deliver our recommendations and ride off into the sunset, in what Frohman (1970) cites as the "Lone Ranger Syndrome". The process of considering and acting upon consultant recommendations takes time. It often necessitates additional analysis to answer unanticipated questions and lengthy meetings to talk through the implications of the various alternatives. Therefore, continuing strategic consultation is generally quite important in the period after the final report has been submitted.

To summarize the further evolution of our approach:

1. We now seek the active involvement of the project Task Force in defining the focus and scope of the work.
2. We now consider it necessary for the client to be a technical contributor to model development and a model user.
3. We now routinely engage in extensive comparison of simulation results with historical time series, applying demanding standards of accuracy.

4. We now consider continuing strategic consultation necessary to assist a client in considering and acting upon our recommendations.

III. Conclusions

From the preceding case studies, our approach has clearly evolved in a significant fashion over the last ten years. As a consequence of these changes, we are consistently more effective in achieving implementation. We still have a lot to learn, but we have made substantial progress in the right direction. Let us review the highlights of the evolution that has occurred.

A. Client Involvement

Ten years ago, we tended to work independently as system analysists and researchers, with relatively little client involvement. A client typically served as a source of information inputs and as an audience for presentation of our work. Furthermore, as Ed Roberts (1972) pointed out, the "client" is not an organization but, rather, an individual. Our closest contacts in those days tended to be sympathetic and sophisticated staff people, not line managers. Consequently, the people who were, in effect, our clients often lacked both the perspectives to make our work "real" and the authority to act on our recommendations.

Today, we actively seek significant client participation in our work. We try to function not as researchers, but as strategic counselors and change agents. We employ a project Task Force as a vehicle for securing client involvement. We expect this Task Force to participate significantly in defining the focus and scope of the project, developing the model, and formulating policy recommendations. We now expect a client to participate at a fairly detailed technical level in the process of model development and use. We are particularly anxious to work closely with senior line managers; we have learned that they are the right people to have as clients if you want to have an impact.

B. The Process of Model Development

Our approach to model building has changed to facilitate greater client involvement and, also (see below), to reflect the different kind of model we produce today. We recognize that it was difficult for a client to keep up with us on a detailed technical level. The larger the model, the worse this problem becomes. Furthermore, we recognized the importance of having preliminary simulation results as early in a project as possible. Producing some early indication of the ultimate payoff is a very important step in building client confidence. In their terms, simulation results are generally viewed as the "first tangible thing coming out of the project."

We now tend to develop a gross overall conceptualization of the model first, then produce the detailed conceptual design and the DYNAMO equations in several blocks. This approach is less overwhelming than our earlier practice of building the whole model at once. Now, the client's sophistication and the models complexity tend to grow together.

Until recently, we tended to ignore questions of formal validation and be satisfied with a model whose historical behavior was qualitatively correct. We now feel that our clients are far more confident in models of demonstrable historical validity and, therefore, more likely to act on recommendations resulting from them. We consider model validity to be a key implementation issue. We now routinely devote a considerably effort to achieving high historical accuracy with our models.

C. Nature of the Models that are Developed

Ten years ago, we tended to build small, aggregated models. They were the minimum size required to understand system behavior and test

potential policy changes. This practice was the conventional wisdom in our field in those days.

We now routinely build rather large models. By "large" I mean models with 1000-2000 significant variables. We have found that models of this size are required to satisfy client standards of "realism" (again, very important in establishing the comfort and confidence prerequisite for implementation), to achieve the desired degree of historical and near-term predictive accuracy, and to produce findings of sufficient detail that they are implementable.

We are increasingly confident in our models as forecasting tools. I now believe that it is unnecessary and counter-productive to make excuses for our methodology with statements such as: "System dynamics models are not developed for forecasting; they are tools for understanding problems". Our models can serve both purposes. We feel that our clients have greater confidence in us because we are confident in our approach. We have found that nothing enhances our credibility more than correct short-term predictions.

D. The End-Products of a Project

A dramatic change has taken place in what we consider to be the appropriate end-products of our work. Ten years ago, the principal end-product tended to be a report. This is no longer true. We now emphasize the transfer of know-how and the creation within a client organization of an on-going analytical capability. As a result, we usually deliver extensive technical documentation, install the model on a client's computer system, and engage in considerable training of client personnel.

We have also learned that we cannot just submit our recommendations, move on to other projects, and expect implementation to occur. The process of considering and acting upon consultant recommendations often gives rise to additional analytical requirements. Clients often want to talk through the implications of the various alternatives open to them, perhaps to probe more deeply or to use us as a "sounding board." Continuing strategic consultation is an important factor in achieving implementation success.

E. Summary

Some of the factors that are most critical in achieving successful implementation are summarized in Figure 1. They include:

1. the sharpness of the project's problem focus;
2. the urgency of the problem addressed;
3. the organizational position of the client;
4. the degree of client involvement;
5. the nature of client involvement;
6. the size of the model developed;
7. the demonstrated validity of the model; and
8. the nature of the project's end products.

As discussed by Roberts (1972) and demonstrated in the case studies presented here, each of these factors contributed importantly to the production of implementable recommendations, to the development of a clear desire to implement on the part of those who have to take action, and to the existence of a properly receptive environment in which implementation can occur. Without these essential ingredients, it is not possible to achieve implemented results from system dynamics projects.

Figure 1: Comparative Summary of Three Projects

	Sharpness of Problem Focus	Urgency of the Problem	Position of Principal Client Contact	Degree of Client Involvement	Nature of Client Involvement	Size of Model	Validity of Model	End-Products	Implementation Success
1. Retail Food Chain	High	Medium	Jr. Staff Person	Low	Information Source	Small	Subjective	Report	Low
2. High-Technology Manufacturer	Low	Medium	Sr. Staff Person	Medium	Information Source, Information Collector, Critic, Trainee	Large	Subjective	Reports, Model, Partially Trained Person	Medium
3. Insurance Company	High	High	Sr. Line Manager	High	Information Source, Information Collector, Technical Contributor, Trainee, Model User	Very Large	+10% of historical values	Reports, Model, Trained People, Counseling	High

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