A MODELING PROCEDURE FOR THE PUBLIC POLICY SCENE. EXPERIENCES FROM A SYSTEM DYNAMICS STUDY OF THE SCANDINAVIAN FORESTRY AND FOREST INDUSTRY

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ABSTRACT

The basic assumption of this paper is that system dynamics in its original form was developed to suit policy-making in small organizations and that application of system dynamics in the field of public policy must be accompanied by change in research methodology and organization. To support this view, the paper describes experiences from a study of the Scandinavian forestry and forest industry.

The model building process, interaction with decision-makers, and the organization of empirical research are analyzed separately. Based on the analysis a procedure for using system dynamics in public policy analysis is recommended. In the recommended procedure a reference group representing various client groups serves as a source of qualitative information and as a channel for implementation. The need to keep model building well focused is stressed. Parallel studies of historical development on the micro- and the macro-level are suggested as a means to speed up modeling. It is finally recommended that the major results from the analysis are presented in a non-technical report.

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INTRODUCTION

The field of application of system dynamics has changed. The technique was initially developed to aid in corporate policy-making. Since then, applications have been extended to various areas of public policy where most of the work is now under way. This means that the system dynamics methodology is used today to deal with problems other than those for which it was developed. The thesis of this paper is that change in problem focus will have to be accompanied by an evolution in methodology.

The situation of analysts working out unrealistic solutions to irrelevant problems is all too common. The original conception of system dynamics tried to assure that analysis and implementation remained integrated into one process. The modeling tools were developed with the clear intention of facilitating the interplay between the managers' mental models and the analysts' formal models. Making the modeling work transparent to the managers reduces the risk of the analyst losing contact with reality and makes it possible for managers to effectively contribute to and learn from the modeling process as it evolves. As long as managers remain in close contact with the model building exercise, the issue of model validity change from the abstract question of how true the model is to a question of whether the model helps the manager understand his situation better.

Unfortunately, there are few detailed accounts of how system dynamics modeling has been integrated in the policy-making process of a company or an organization. In Industrial Dynamics one finds the view that the system dynamics methodology, at that time labeled industrial dynamics, would be most easily employed in small- and medium-size organizations:

> "Last, there is the question of the size of company to which industrial dynamics is most suitable. There is a common first presumption that industrial dynamics is a tool of use primarily to the largest corporations. As the field has thus far been developing, there seems to be little immediate support for this conclusion. In the largest organizations, the functional compartmentalization is apt to be stronger than in smaller companies, making it very much more difficult for any person actually to cut across all activities from research to marketing. It is beginning to appear that the aggressive, rapidly growing, medium- and small-size organizations may be the places where the methods discussed in this book will have their first important impact. Such organizations are often more flexible. They may be more responsive to the wishes of the company officers, so that if the officers want to explore a new management tool, the organization will indeed do so. In the newer companies, the management is often younger, expects to hold office longer, and takes a longer-range view of developing company strength than in more mature companies. The smaller organizations may be more fluid, so that the rigidities of functional sub-divisions are not so much of a handicap. The costs of management systems research are low enough, so that they present no great difficulty in an organization as small as one million dollars per year of business." 1

If policy change is a more complex and inertial process in a larger organization, the complexity and slowness of change is even more marked in the area of public policy. In comparison with the typical case of a single organization there is first of all a difference in size. A large number of people are involved in or affected by a public policy issues. Most problems range across several institutional boundaries. The information relevant to analysis of a given policy is more diverse and consequently require a wider expertise. Secondly, public policy is formed in a different way than corporate policy (single organizations other than companies will normally represent an intermediate case). The main objective of a company is clear: a good economic result. Whether the result need be sustainable; whether one shall make one choice or the other between the long- and the short-term or between one product line and another may be an open question, but this does not change the largely unidimensional objective. A company is usually hierchically organized with clearly defined responsibilities on each level. A fairly small group has the power to change policy as long as the major economic objectives are met. On the public policy scene many interests and objectives meet in a process of give and take. Public policy goals are many-dimensional, and are continuously discussed and redefined. Public policy is formed through bargaining between

1. J.W. Forrester, 1961, p. 365.

a large number of interest groups, each with many members. The policy-makers, if they can be identified, are dependent upon support of an electorate or special interest group. Significant policy change is preceded by public discussions.

The described differences between corporate and public policy-making do not apply in all cases, but appear as a clear tendency. Frequent complaints that decisions are made over people's heads suggest that there are variations and that public policy is not always formed in a participatory manner. Likewise, there are signs that corporate policy-making in several countries is moving in the direction of public policy-making. The concentration of business activity to fewer and bigger units increases the influence that an individual company exerts on people's lives. This, and other tendencies, seem to make it increasingly necessary for the companies to supplement the purely economic objectives with objectives in the area of work environment, pollution, job security, etc. There seems also to be a gradual erosion of the hierarchal decision structure in favour of more democratic forms of organization.

One can begin to identify the differences between the corporate setting and the public policy scene as environments for policy analysis. An attempt to describe the environment in the two cases is made in Figure 1.

In the small- and medium-size companies the analyst can work closely with a few managers who simultaneously are the users of the study results, the main information sources, and participants in the modeling process. In larger organizations the three functions are divided between an increasing number of people. Policy-makers may be distant from the every-day operations of the company and find it below their dignity to participate actively in a modeling effort. Line managers are likely to be more interested in those problems which fall entirely under their responsibility than those which concerns overall company strategy. And there is no single person who has a detailed

aspects of analysis	corporate setting	public policy scene
1. owners of problem	few; closely tied up with problem	large number; each identifies only partly with problem
2. objectives of concerned social institutions	few; clearly defined	many; diffuse
3. sources of information	interviews with employees; corporate records	close to infinite number of decision-makers and area specialists; historical records; research results
4. depth and scope of analysis	limited to the problems of a specific company assuming the framework of the company as given	includes several "sectors" of society and in each sector several organizations/companies. Long time-horizon forces analysis to deal with fundamental social processes, viewing the current social institutions as subject to change
5. policy options	few; clearly defined	many; in the form of broad strategies
6. participation of policy-makers in analysis	high intensity participation feasible	only limited participation feasible
7. nature of results from analysis	specific policy recommendations	framework for broad policy discussions
8. users of analysis	a few policy-makers and their staff	many policy-makers and their constituency
9. evaluation of analysis	same as users	same as users plus research community
10. implementation of policy change	involves a limited number of key policy-makers and can be carried through fairly rapidly once those have made up their minds	a slow process; policy-makers have to solicit support from an electorate and/or members of several interest groups; institutions must be changed

Figure 1. Typical differences in the policy analysis environment between corporate setting and the public policy scene.

understanding of how the company as a whole works. In the larger organization the analyst therefore has to pay attention to company politics and obtain binding commitments on cooperation in the research effort from several concerned parties if his work shall have any impact.

The problems of integrating information gathering, modeling, and implementation are further emphasized when we move into the area of public policy. Insights from a policy study must be spread to many more people than those who can participate in the modeling process if the study shall have any impact. The analyst can no longer rely exclusively on person-to-person communication with the users of his research findings. Insights gained during the model building must be translated into ordinary language and presented in an easily intelligle form. This requires clarity of concepts and awareness of the reader's way of thinking. The analyst's ability to communicate insights becomes as important as his ability to arrive at them.

Only very few decision-makers can be active in the modeling process. They will serve as representatives, although not in the formal sense, of the very large number of people implicated by any given policy issue. The participation of a selected group of decision-makers ensures that relevant questions are studied, that qualitative information included in the analysis, that some users become so familiar with the research effort that they can make an informed assessment of its quality and finally that channels for implementation are provided.

Finally, the gathering, processing, and interpretation of information will be so extensive a task that it becomes a research activity in its own right. A particular skill is needed to connect empirical research on the micro- and the macro-level. The analyst must be able to converse with a wide range of specialists to obtain the information he needs from historical data categorized according to terminology and theories specific to narrow disciplines.

There are reasons to believe that system dynamics modeling can become a useful tool also in the area of public policy. This will, however, require that the special characteristics of the public policy scene are recognized and allowed to influence the way in which policy studies are organized and carried out.

This paper reports experience from a study of the Scandinavian forestry and forest industry. The study had as its objective to develop a platform for policy discussions between people concerned with and dependent upon the future of the Scandinavian forest sector. There was no clearly defined client, but instead several diffuse client groups. Further, the extent of the problem area made acquisition of empirical information difficult. In the organization of the project special attention was given to the issues of interaction with the client groups and cooperation with area specialists. By reporting the successes and failures of the research methodology and organization employed in the project, this paper contributes to the discussions around the use of system dynamics in public policy analysis.

HISTORY OF THE PROJECT

The stated objective of the study was to identify and clarify problems that the Scandinavian forest sector might encounter during the next thirty years or so. Research Councils in Sweden and Norway financed the project for the purpose of acquiring concrete experience with the usefulness of the system dynamics methodology in development of public policy. The project, covering a two-year period, was carried out by a research team of three persons, all trained in system dynamics and one having some acquaintance with forestry

and the forest industry. A steering committee for financial control and methodological advice was set up. Close contacts with Scandinavian forest economists were established before the project began.

The first two months of the project were devoted to formulating a research plan. Contacts were established with representatives of various interests and researchers in forestry and the forest industry.

The original research plan envisioned a project that would be carried through in three phases. During the first half year researchers in the team would define the problem focus of the project in close cooperation with a selected group of decision-makers. The research staff expected to develop a crude simulation model that would serve to crystallize the defined problem. The model would illustrate the kind of problems expected from adherence to current policies. Examination of this first very tentative model should give rise to questions about the validity of certain model assumptions, and make possible a selection of those topics most in need of detailed research. A whole year was allocated for a substudy phase of detailed research, expected to take various forms such as compilation of statistics, modeling studies, and verbal analysis. During the last half year, results from the substudies would be used to upgrade the original conceptual model and to analyze alternative policies in cooperation with decision-makers. A main thesis already from the beginning was that insights from the project should be presented and defended without reference to formal models, so that they would be intelligible to a wide audience.

The actual progress of the project differed from the plans in two important ways. First, development of the first simulation model proved to be more time-consuming than expected. Second, it was difficult to assign meaningful research tasks to researchers outside the team, partly due to the slow development of the simulation model. As a result, the substudy phase was reduced

and most of the detailed research was carried out by in-house members consulting the outside researchers.

After the initial planning period the research staff approached several high-level decision-makers representing labour unions, corporate management, forest owners, research institutions, and government authorities. The staff succeeded in forming reference groups of approximately eight people each in Finland, Sweden, and Norway. A series of ten bi-weekly meetings with the Norwegian and Swedish groups focused on current problems, concerns for the future, and interpretations of past development in forestry and the forest industry. A parallel series of meetings were held in Finland, but for language reasons they were conducted by a Finnish research team.

Discussions in the reference groups covered a lot of ground and were experienced as fruitful. Though very loose in the beginning, the meeetings became more structured as time went by. Causal loop diagrams used to facilitate communication were the only modeling tools employed at this stage. At the end of this series of meetings, the research staff had arrived at a problem definition deemed relevant by the reference groups: There will be a need to limit forest fellings in Scandinavia in the near future. Increasing labour productivity in forestry and the forest industry combined with non-growing production volume will reduce forest sector employment. Allowing fellings to exceed their sustainable level will be a tempting short-term solution to preserving employment. Its long-term effect will be reduction in production volume and faster reduction in employment than had expansion of the industry beyond the sustainable level been avoided.

Having defined the research problem, the staff began working on a simulation model. Four months were needed to arrive at a fist running model. This time was longer than expected. The delay was partly due to the effort of developing too general a model in the beginning. This was particularly true of that part

of the model which represented the forest industry. Instead of focusing the modeling on those changes in the forest industry which were directly connected to the wood supply, something close to a general production function for an industry was attempted. The modeling progressed rapidly once the research team concentrated on the primary effects of a limited wood supply.

The resulting model covered most aspects of forest sector development that came to be central issues during the rest of the project. Nevertheless, the staff found it difficult to adhere to the original research plan and derive from the model specific questions that would be suited for analysis in other research groups. The research staff felt that model concepts were still in too fluid a state to serve as guidance for detailed empirical research to be carried out by outside specialists. Modeling was therefore continued and the emphasis on substudies was reduced.

The first model version had several weak points. The simulation runs were too sensitive to variations in parameter values. Scenarios generated by the model were unrealistic in important ways. The forest industry would for example in some runs enter into a viscious circle of low profitability reducing investments, insufficient investments further lowering profitability and so on, until the industry was practically wiped out. In the real world this process could be expected to be strongly buffered by corrective actions in the environment of the forest industry through changes in exchange rates, wages, prices, or government subsidies. In the model the buffers were weak and limited to changes within the forest industry. The staff tried to improve the model by adding new structure and making the old structure more detailed. As a result the model grew in size. It became harder to work with and ever less transparent.After a vacation rest, 12 months into the project, the staff tried to sort out the basic ideas represented in the model, and started out from scratch to include the central concepts and mechanisms in a simpler and clearer model.

This second model also had a limited life span. After some months the

staff once again started over on a new model. In this way, modeling was continued through the whole project. The staff developed a number of models, each with a total life of two or three months. The step from one model to the next always seemed drastic. Reviewing the whole process of model development, there appears, however, to have been a high degree of continuity. Each model shift represented a step forward in terms of conceptual clarity.

While building models the staff felt a need to sum up their assumptions and insights verbally, both in order to gain a clearer sense themselves of the research and to be able to get a response from outsiders. To verbalize ideas was time-consuming, however, and therefore required some extra motivation such as being requested to make a presentation at a conference. Summarizing current thoughts in the limited space of a paper forced staff members to decide what elements of the research were most important. This pressure helped keep a tighter focus in the modeling effort.

Parallel to, and in interaction with developing the conceptual model, the research team carried on other activities. Two special modeling studies were undertaken to clarify certain aspects of forest growth and long-term industrial development. One study focused on the growth dynamics of a single forest stand. The second study analyzed the adjustment of pulp and paper production capacity to market development.

A wide variety of sources were consulted throughout the project in order to obtain qualitative and quantitative information about the historical and current situations in forestry and the forest industry. During the first half of the project the empirical work was rather fragmented and directed toward answering the specific questions raised by the modeling. Later on in the project the staff made systematic efforts to acquire a clear picture of how the Scandinavian forest industry historically had ajusted its production capacity to the available forest resources. In this empirical research they consulted other

researchers extensively.

Contacts were maintained with the Norwegian and Swedish reference groups throughout the project. Simulation runs generated by the model were discussed during some ten meetings at various stages of model development. Presentation of scenarios of possible future development patterns turned out to be a very effective way to stimulate the members of the reference groups to put forward and reconsider their theories about the past and the future.

There are two results of different kinds to report from the study. First, the members of the reference groups believed that the group discussions increased their ability to see their own sitation in a larger context and put them in a better position to evaluate the long-term effects of various policies. Second, the staff produced a number of documents of value for future policy discussions. The most important is an essay-like non-technical discussion of problems associated with the transition of the Scandinavian forest sector from ample to scarce wood supply, and suggestions for alleviating those problems. Another paper gives an overview supported by statistics of the development of the Scandinavian forestry and the forest industry during the twentieth century from the point of view of resource-constrained growth. The last version of the system dynamics model is documented equation by equation. A large number of working papers are also available.

The coming years will show to what extent the research effort described here has had any positive influence. Several research institutes have expressed their interest in carrying the research work further. Forest economists in Finland, Norway and Sweden have decided to apply the model to a few small regions and for those study the transition from ample to scarce wood supply in more detail. Corporations, labour unions, government agencies, and other organizations have shown interest in continued consultation with the research team. Such contacts could offer opportunities for the team to conduct further research

relating the long-term perspectives developed in the project to concrete policy-making.

THE MODELING PROCESS

Choice of problem focus

A policy study must focus on a limited number of problems in order to yield non-trivial results. The choice of problem will naturally be a major determinant of the relevance of the whole study. Deciding upon what is an important problem implies both a ranking of goals and an idea about the conflicts and trade-offs between goals. Naturally, goals will tend to differ among different people, and a given development may influence people differently. Research around a specific problem may therefore be more relevant to some people than to others.

When the forest study began, the staff had not yet chosen a specific problem on which to focus their research. They had a list of emerging problems in the Scandinavian forestry and the forest industry, and realized that most of them were interrelated, but only had vague ideas about how.

The staff used the first half year to search for a perspective that would help them choose a problem. They discussed with the members of the reference groups what they thought would become the most important problems during the coming 30 years, and how those problems would be dealt with. The staff, in organizing information, had to sort out temporary changes from persistent trends, attempt to explain the forces behind the trends, and then hypothesize about what kind of future would emerge in the absence of any drastic changes in policy. At subsequent meetings they would present theories for criticism or support, depending on how well the theories conformed to the experiences and in-

terpretations of members of the reference groups.

After some months, the staff had developed a perspective on the forest sector within which the connections among a number of problems, deemed important by the reference groups, could be seen fairly clearly. The staff's hypothesis was that the Scandinavian forest industry is approaching a resource ceiling, but current policies inside and outside the forest sector are still geared to an abundance of wood. As a consequence the policies threaten to cause serious unemployment when the industry reaches the wood ceiling and its growth in capacity must level off. As there seemed to be no convincing policy prepared to meet the unemployment problems, the pressure to temporarily overcut the forests could become strong and, if given in to, cause even more severe problems further in the future when the capacity of the industry would inevitably have to be increased. The defined objective of research in the remainder of the project was to examine this hypothesis in detail.

Looking back at the development of the project as a whole, the decision to allocate the first four to five months to exploratory problem definition, as described above, appears very wise. It gave the necessary direction for the rest of the project. And such direction is particularly needed in a modeling project. The model builder much too easily loses sight of the objectives of his work, and begins to develop a general purpose model that aspires to answer all questions, but in the end yields disappointingly few insights.

The problem focus was cast in the form of a "dynamic hypothesis." [2] This implied hypothesizing simultaneously the future mode of behaviour of key variables (the reference mode) and the driving forces (the basic mechanism) behind this behaviour. The idea of a dynamic hypothesis was useful. In three respects its employment could, however, have been improved. First, more concrete variables should have been selected. "Structure of industry " should for example have been specified to "number of plants", "sawmill production

2. Cf. J. Randers, 1973, p. 54.

as a fraction of total forest industry production" or the like. Second, the dynamic hypothesis should have been verbalized in detail. The causal diagram employed in the project left too many questions unsolved. Third, more attention should have been given to the quantitative aspects of the reference mode. Through simple hand calculations it would have been possible to make order-of-magnitude estimates of the likely development of important variables

Scope of model

During the remaining year and a half of the project, the staff worked out the defined problem in more detail. That is, they developed a theory explaining aspects of the transition of the Scandinavian forest sector from ample to scarce supply of wood.

Most of the work centered around the development of a system dynamics model to bring together a conceptual structure and empirical information about the order of magnitude of relevant parameters and relationships.

The modeling work to some extent distracted the research team from analyzing the defined problem. They started out with the intention of building two models. One would focus on the internal dynamics of the forest sector and have assumed trends in the overall economy as inputs. The other would on a high level of aggregation deal with the general tendency toward concentration of industry into fewer and bigger production units. The decision to build the second model was based on the assumption that geographical concentration of the activities in the forest sector could be adequately explained only in terms of the overall national social and economic development and that policies on this level were the only effective means for influencing the rate of concentration.

The staff's committment to the forest sector model was strongest, so that when time pressures developed the more general study was phased out. Although the staff

intended to analyze the process of concentration of industry verbally, modeling absorbed so much energy that analysis of the interface between the forest sector and the rest of the economy was neglected.

After more than half a year of modeling, the staff recognized the difficulty of analyzing the forest sector in isolation. They began to consider feedbacks through exchange rates, government subsidies, and local resistance to close-down of industrial plants, but so late in the project that these issues were given less than due attention.

Conceptualizing a problem implies moving from symptoms to deeper causes. To succeed in this task, the analyst must have courage to think outside conventional boundaries. In practice it is very difficult to do so. To make connections which are not usually made, the analyst must have experience and confidence. In the forest study, the staff soon felt comfortable discussing the internal problems of the Scandinavian forest sector. By comparison, other areas such as international monetary institutions and foreign trade, seemed like very deep water.

Conceptualization and empirical research

The staff created many models in the course of the project. The first very general and abstract models were never carried to the stage of simulation experiments. In the first running model, the staff had lowered their ambitions of the general applicability of their theories and chosen very concrete concepts. Transition problems were identified as unemployment etc. Later, they once again moved toward more encompassing concepts, with the effect that it became difficult to parametrize the model and for other people to assess the validity of the model assumptions. After further iterations the model had concepts which were concrete and could easily be related to real-world entities, but at the same time were not as narrow as the components of the first running model.

Many of the model-building problems arose from attempts to conceptualize on too scanty empirical ground. Lacking empirical information, the staff often unconsciously moved their conceptualization to a more abstract level where the particular detailed characteristics of the analyzed topic became less significant. They could then proceed with analysis, but reached few insights of value for policy-making. Since the concepts lacked specific empirical content, the analysis had too much the character of the pure mathematics of dynamic systems. Sooner or later, the staff intended to acquire the information necessary to develop more concrete concepts. In the meantime they could, however, waste considerable efforts on modeling when they should have been conducting some field work to find out what actually happens in the real world.

According to the initial project plan empirical research on specific topics should be carried out by outside researchers. As this idea was gradually de-emphasized, as described earlier, the in-house staff should have intensified its own empirical research to provide a firmer basis for the modeling.[3]

Important insights can be gained from comparing development on the micro and the macro level (relative terms, of course). In the forest study the research staff had a tendency to remain on the macro level and deal exclusively with aggregates. For example, they often confused the dynamics of a single production plant with that of the whole industry. They did not complement aggregate statistics with enough plant studies. They had a similar situation in analyzing forest growth, although a study of the growth dynamics of an individual stand in the beginning of the project did provide some basis for aggregate analysis.

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3. Cf. Randers 1973, p. 244: "However, when encountering modeling problems, one is easily trapped into believing that the obstacle is the limited capability of the modeling tools to represent reality. Unending, futile attempts at formulating some part of the model is symptomatic of a lack of knowledge of the real system".

There are special difficulties in establishing facts about historical development. The following is just one example. Concepts which are useful today may present a distorted picture of past development as well as of future potentials. For example, it is practically impossible to find a simple conceptualization of forest growth that would be adequate for a wide range of forest management practices. Most discussions of forest development are today based on the assumption that forests consist of even-aged stands. The trends are clearly in this direction. Limiting oneself to the stand-concept, however, makes it difficult to understand the transition from various earlier forms of forest management to stand management, which has been a main characteristic of the development of the last fifty years, and also makes it very hard to think about alternative ways of managing forests in the future. The staff took some time to realize how the stand-concept limited their views, and then had too little time left to make real use of that insight.

Verbal analysis: the basis of model building

When using a formal modeling technique, such as system dynamics, a modeler is tempted to substitute modeling for verbal analysis. This tendency generates a lot of unproductive modeling. Fruitful concepts are created through verbal analysis. Representation in a formal model can help to identify inconsistencies, incompleteness, or ambiguities, but can not in itself create fruitful concepts. Conceptual analysis can be carried out in purely verbal form. Formal analysis, however, should be used to complement verbal analysis. In this capacity, model building can speed up conceptualization.

In the forest study the staff did not spend enough time on verbal analysis. As a consequence, they occasionally lost control of model concepts, which began to live their own lives. Too often, they found themselves shuffling around abstract concepts where the ties with reality had become obscure. Once

a concept has been positioned in a formal structure, it becomes frozen, and its further use becomes very inflexible. This inflexibility may be an advantage once fruitful concepts have been developed and the modeler wants to preserve their meaning to facilitate analysis and communications. But not until then!

Transparency of model

A conceptualization is more valuable the simpler it is as long as it remains true to the essence of the problem under investigation. The initial decision to view a non-technical report rather than a simulation model as the major product output from the project motivated the research team to keep the model simple and transparent. Simplicity was achieved in several ways. First, the model building had a clear purpose: specification and formal representation of the dynamic hypothesis developed during the problem definition phase. Second, only those processes which had a time constant relevant to the dynamics of the transition from ample to scarce wood supply were analyzed. Fluctuations in capacity utilization and wood prices connected with the regular business cycle were, for example, considered to be too fast processes and were smoothed over. Similarly, selection and mutation of tree genes were assumed to have an effect on wood production only in the very long term and were therefore ignored in the analysis. Third, variables with the same "dynamic function" were in many cases aggregated into one variable. The scale of production, for example, influences the cost of production and distribution through its effects on energy losses, labour productivity, timber catch area, distance to market, design of pollution abatement equipment, cost-effectiveness of control systems and so on. In the forest study it was possible to divide all these effects of scale of production into two categories: the effect on unit operating costs and the effect on unit investment cost.

REFERENCE GROUPS

Only a very small part of all information is available in written form; a still smaller part has the form of quantitative data. Most information can be found in people's heads. A large part of the empirical research carried out in connection with the development of a conceptual framework will therefore consist in communication with other people. This communication will serve two purposes. First, it will contribute to the empirical basis of the analysis. Second, it will open up channels for diffusion of the insights gained through the analysis. The first purpose will dominate in the beginning. As the analysis begins to yield substantial insights, diffusion of research results becomes possible and desirable.

Reference groups consisting of decision-makers in the forest sector were an important feature of the forest study. The reference groups serves as a kind of mini-universe of that part of the real world which the research team studied. The main reasons for bringing people together in groups rather than consulting them on an individual basis were:

1. interaction in groups would bring out problems in communication, as well as actual and potential conflicts of interest;
2. group interaction would also make apparent any consensus or disagreement about the nature of past and current development;
3. to the extent that improved communication among interest groups would be an important element in solving the studied problems, group interactions would serve as a foundation for this process;
4. institutionalized contacts with respected decision-makers would add to the project's status and credibility.

The reference groups consisted mainly of people with experience from forestry and the forest industry. If a majority of the group members had been active outside the forest sector, the research would probably have concentrated more on the interface between the forest sector and the rest of society. Such a concentration might have been desirable in fact.

After the staff had begun building models they often worried about how to keep up the interest of members of the reference groups enough so that they would continue to come to the meetings. The strong focus on model development helped to make contacts with the groups unnecessarily irregular. The staff was constantly waiting for the next week or month when they expected to have a much improved simulation model running. As the discussions in the reference groups were planned to center around model experiments, contacts with the reference groups became difficult to plan well. The staff did hold a number of meetings where simulation runs were discussed. Those meetings were as a rule very stimulating for all parties involed. They could, however, have been even more effective if there had been a higher degree of continuity from meeting to meeting. After outputs from a given model had been discussed at two or three consecutive meetings, there was a break either in the sense that the model was changed drastically or that the next meeting was scheduled for a much later occasion in order to give enough time for the research team to process new ideas that had come up.

Interaction with the reference groups during the second half of the project could have been organized more effectively. Following the problem definition phase a year's time should have been allocated to model building and empirical research. This would give the staff a period of uninterrupted work and make the unpredictability of model development less hard to accept. Necessary contacts with decision-makers would be arranged on an individual basis. Toward the end of the project the reference groups would once again become the center of attention. Through a series of meetings the members of the reference groups would go through an intensive learning process. Their mental models would be confronted with outputs from simulation runs and in the dissonance between the two, the former would become explicit. Continuity between meetings would be a major concern for the staff so that insight generation

in the reference groups became cumulative.

In practice policies are seldom formulated explicitly. They often have the character of fairly simple rules of thumb. Policies may be very hard to state explicitly, since they only appear implicitly in individual decisions, each of which is embedded in complex situations where the particular is hard to distinguish from the general. A prime purpose of the reference groups was to clarify actually operative policies. Success would provide the necessary basis for a critical examination of current policies, and discussions of alternative future policies. Some decisions, like close-down of plants, were so rare in each company that each instance appeared as unique and consequently there did not seem to be any common policy behind the individual decisions. In this and similar cases the policies would have stood out more clearly if cross-section analysis of recent events had been complemented by discussions of the history of some individual companies, forest holdings, and the like. A comparison of strategies outlined in policy documents ten or twenty years ago with the development that has actually taken place would probably also have added to an understanding of what factors influence various decisions.

The discussions remained on too general a level. To some extent this tendency reflected the early stages of the conceptualization process. Too vague an impression of the daily work situation of the group members on part of the research team was another contributing cause. Contacts with the group members on an individual basis early in the project and focusing on their current work and consulting their special experiences in some detail, would have helped make later discussions more concrete and alive.

On the whole, the members of the reference groups seemed to experience their participation in the project very positively. They got a chance to discuss matters with people who were usually their opponents with a minimum of tactical considerations. The meetings gave an opportunity for the group members to consider their own situation in a larger context and with a longer time perspective than usual. The sessions where simulation runs were discussed were probably the most thought-provoking, even if the insights gained sometimes had a short life due to the lack of sufficient continuity in the series of meetings.

Even if the reference group members shared a wide range of experiences, in many cases the staff had to find information on specific questions elsewhere. Consultations ranged from telephone calls to full-day meetings.

INFORMATION SOURCES

The staff revised their original research plan most thoroughly in the cooperation with other researchers. The research team had ambitious plans that so-called substudies be carried out in other research institutes with the purpose of addressing specific questions that were expected to come up during the development of a first rough conceptual model.

Discussions in the reference groups served as a very important source of information for the research staff, particularly in the beginning of the project.

During the first half year of the project the staff had numerous meetings with research groups working on issues of forestry and the forest industry. Study plans were exchanged and there seemed to be many areas of mutual interest. The initial model building, however, required longer time than expected, and short of a running model, the staff found it difficult to choose a few questions that they would be particularly interested in having answered. During the first year, model concepts were so unprecise and constantly changing that the information most needed could best be obtained through short person-to-person contacts.

The staff derived little benefit from the research projects with which they had established contacts earlier on. This was partly due to a low appreciation of empirical information in the beginning of the project, in turn connected with a committment to the system dynamics dogma teaching reverance for structures as opposed to parameters, which was wrongly taken to mean that empirical studies are unimportant. Collection of high precision data is, indeed, a waste of effort in the early stages of conceptualization. Choice of fruitful concepts requires, however, enough empirical knowledge that one can distinguish crucial factors from those of marginal importance. Later in the project the staff researched in detail aspects of the history of the Scandinavian forestry and the forest industry. In this work much was learnt from other researchers.

In comparison to most current research on forestry and the forest industry the study had a very long time-horizon. Whereas, for example, the research team tried to explain long-term trends in wood prices, studies in other research groups were predominantly concerned with fluctuations in wood prices from one year to another caused by adjustments in timber inventories. Instead of synthesizing from a wealth of available theories and empirical research, the staff therefore had to do a lot of groundwork.

A researcher's total experience and understanding goes far beyond what is recorded in reports of a specific research project. As a consequence, the staff considered personal contacts with other researchers a necessary complement to, and often more rewarding than studying written material. In writing a report, the author would have addressed a specific issues, which might have little in common with the problems the staff was investigating. Research reports were often full of loose ends which the staff wanted to pursue further. For the interaction necessary to obtain this the staff had to talk directly with the authors of the reports. The staff gradually learnt that it is difficult to establish communication beginning on an abstract level. A discussion which started out around some very specific matter and then widened in scope, usually provided more generally applicable insights than one where a general language was used from the very beginning.

To help orient themselves in the research community the research team had a Norwegian forester working with them during large parts of the project. They also frequently consulted with a Swedish professor in forest economics. With these two persons matters which belonged to common knowledge among people active in forestry and the forest industry were discussed. They also provided the team with valuable advice about where to search for specific pieces of information. To the departments of forest economics the study filled a felt need of looking at the forest sector as a whole in a long-term perspective, and this made them willing to contribute some of their researchers' time to the project. Collaboration with the forest economists also produced an institutional basis for continuation of the research. Toward the end of the project it became clear that one researcher from each of the Norwegian, Swedish, and Finnish forest economics departments would start full-time work in the form of detailed studies of the development in a few regions based on the perspectives worked out in the project.

In the beginning the staff studied history through statistics. Successively, increasing attention was given to how people perceived their situation in the past, what they valued as important, and which policies were actually agreed upon and followed. This information could not be extracted from quantitative data. The staff therefore began to study old government reports and read historical monographs. This helped them to a more nuanced picture of both the past and the present. It was, for example, discovered that the limited supply of industrial wood had locally been a major concern also earlier and that temporary over-cut of the forests in some areas had been followed by

massive close-down of sawmills.

The research staff consulted historians too late in the project. They had some contact with a forestry historian throughout the project, but consulted him mainly on current affairs. Historians knoweldgeable about the development of forest industry worked in the regular history departments of the universities. Those historians were therefore outside the network of research contacts the staff established early in the project. This had as a result that the historians were contacted only late in the project. The staff would have saved a lot of energy had they contacted the historians earlier. They could in short time have given the staff a systematic introduction to the literature and helped select the most informative works. And probably more important, the historians could have given the staff concrete images of what the history of forestry and the forest industry had been like.

We have above distinguished between three sources of information: statistical data, descriptive written material, and oral reports given in a discussion. All sources are important, but serve different functions. Statistical data provides quantitative estimates of a few carefully specified phenomena. Written sources brings forth a wide spectrum of qualitative information relevant to a certain issue with a high degree of semantic precision. In a discussion between two persons the level of precision is lower than for the other two sources. On the other hand, it leaves open which issues are to be dealt with, making it possible to decide this as the exchange of information proceeds, allowing for an active learning process. The conclusion is that all three sources should be used while recognizing the proper role of each one.

RECOMMENDATIONS

Based on the experiences from the forest study it is possible to make some recommendations about how system dynamics might be usefully employed in public policy analysis. The recommendations will take the form of an outline of an ideal research procedure for a modeling project. It is assumed that the available research time and manpower resources as well as the scope and complexity of the policy issues are similar to those in the forest sector study. To simplify the presentation the research work is divided into four broad, and in practice overlapping, categories: model building, empirical research, interaction with a reference group,[4] and report writing for wide dissemination. Figure 2 shows the amount of the total effort that goes into each of the four research activities during different phases of the project. The relative importance of the four activities varies with time in the ideal project plan. Accordingly, five different phases of the project can be identified: problem definition; development of initial model; empirical research; model improvement, and report writing.

A first series of meetings with the reference group is intended to give the research staff guidance in selecting a relevant research problem. Both modeling and empirical research are carried on during the whole project period, but with varying emphasis. During the problem definition phase the staff will need to orient themselves in the problem area. Then follows a few months of intense model building. After an initial model has been developed, the staff will allocate most of its efforts during half a year or more to systematic empirical studies that will form the basis for a second period of intense

4. The existence of several reference groups in the forest project was due to the parallel study of Norway, Sweden, and Finland. In most other studies it will be natural to have only one reference group.

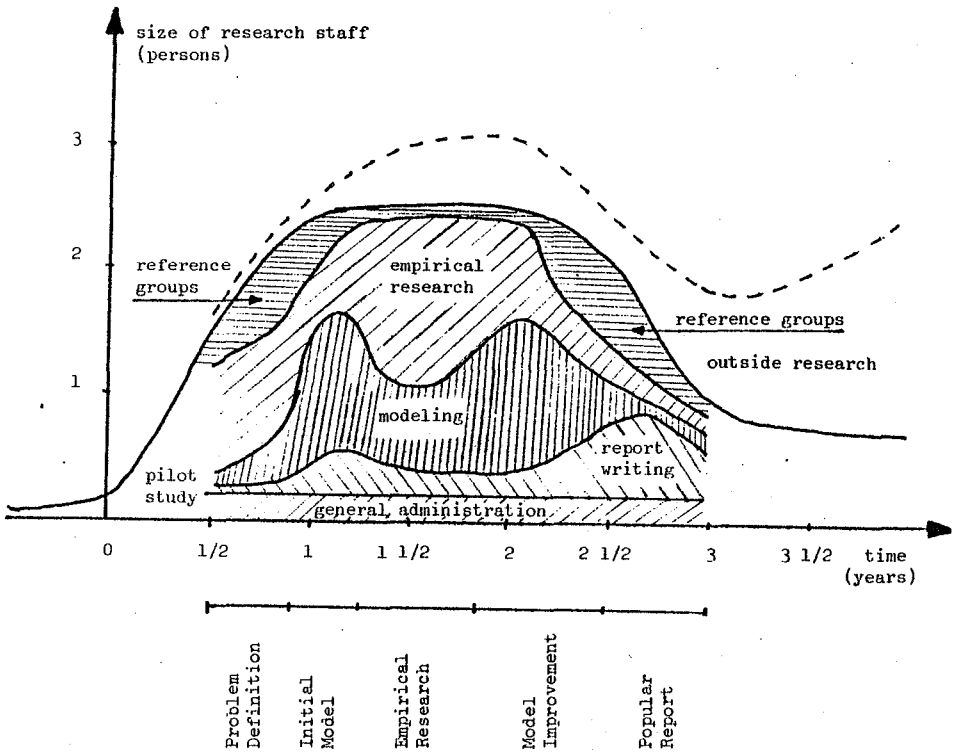

Figure 2. Revised study plan.

modeling during which the initial model is improved to the point where it can generate realistic scenarios. In a second series of meetings with the reference group toward the end of the project, discussion of simulation experiments will help the group members and the research staff to enhance their understanding of the efficacy of various policies. The purpose of the final report writing is to make the main results from the project available to a wide audience.

Below each of the phases of the project are discussed separately.

Problem definition

The purpose of the problem definition phase is to work out a focus for the remainder of the research. It is useful to define the problem in the form of a dynamic hypothesis, i.e. to specify the expected development pattern of central variables and give a causal explanation of why this development is likely.

A series of discussions in a reference group, consisting of people with experience from the problem area will yield a comprehensive picture of concerns about the future, interpretations of the causes of past and current problems, and policy proposals for the future. Individual contacts with decision-makers and researchers and study of written material can be used to complement the information provided by the reference group. People and documents that can present insightful interpretations of the historical development will be particularly helpful at this stage.

When fundamental problems and conflicts can be distinguished from surface symptoms, it is possible to define an appropriate time-horizon for the study and, tentatively, define a set of key variables. Statistics should be processed to obtain time-series for those variables covering a period corresponding to the time-horizon of the study.

Very simple models may be built to illustrate the dynamic effects of feedbacks and delays and to introduce the members of the reference group and others to the basic ideas of modeling.

The output of the problem definition phase should be a written statement of the problem focus, supported by an account of relevant aspects of historical development in the problem area and rough projections of key variables into the future. It is important that the reference group finds the problem relevant and in need of further analysis.

Development of an initial model

When a problem focus has been arrived at, a system dynamics model illustrating the problem should be developed within three or four months. If the problem statement is concrete enough the modeling will be mainly a matter of formalization of a verbal theory. The initial model should be developed fast and the level of detail and conceptual clarity adjusted to this requirement. The success of this phase will depend upon whether the staff can keep the model small and well focused. To avoid falling in the trap of building an ever larger model it may be useful to think of the modeling as nothing but a means of expediting a set of clearly defined calculations too complex to be carried out by hand.

A modeler who has clear expectations about the behaviour of a model will readily discover and take seriously, surprising effects exhibited by a simulation run. The strange behaviour (explosions, collapses or violent oscillations) often generated by early models can be a sign that important control mechanisms operating in the real world have by-passed the modeler.

The empirical basis for the model will naturally be weak. The process of building and running a model will raise questions of the relative importance of various phenomena and in this way guide the ensuing empirical research.

Although the model is intended primarily for project planning purposes, it should be documented.

Empirical research

A system dynamics model will typically represent the interdependence between a number of "populations." In a study of medical care the populations may, for example, be hospital buildings, equipment, doctors, nurses, patients, and potential patients. The represented characteristics of each population depend on the particular problem under study. Usually, the size of the population, in some sense, is important. In addition, there may be one or more measures of "intensity" such as age of buildings, productivity of equipment, skill of medical personnel and resistance to disease among the population. Changes in one population is tied to the population itself and the other populations through "policies," some of which are given by nature and others which are instituted by humans and subject to change.

In a system dynamics model it is possible to distinguish between the flows and accumulations for each population (the flow structure) and the policy structure that governs the flows. In our revised study plan the initial model will contain a rough outline of a flow structure and policy structure based upon the analyst's general understanding of the structure and bahaviour of social systems and the most readily available opinions and material concerning the studied problem area. In the latter aggregate statistics are likely to dominate over detailed accounts of the "life-lines" of individuals in the various populations. Behavioural relations may have been deduced from observed aggregate behaviour rather than based on a clear understanding of the conditions under which the individual decision-makers are operating.

The purpose of the empirical research following the initial modeling is to give the analyst a richer and more accurate picture of those aspects of the

real world that contribute to the dynamic behaviour of the initial model. Parallel study of the lifecycle of individuals and the dynamics of aggregates of individuals (populations) will indicate useful disaggregations of the populations. Realism in the representation of policies requires that the analyst know what information is available to the various decision-makers and how they use it. Also here micro- and macro-analysis should be combined.

Most of the empirical research will be carried out by the staff. This is necessary because the organizing concepts are fluid and may be frequently changed so that the research strategy may have to be altered as the empirical research yields new insights about system structure and behaviour. If possible, the team should arrange to work closely in this phase with some outside researchers who have contacts with specialists and knowledge about the organization of information in the area.

The empirical research will include such diverse activities as interviews with decision-makers, study of historical records, discussions with outside researchers, and compilation of statistics. Modeling may be used in connection with the empirical research primarily as an accounting device to aid in historical analysis of material flows, population dynamics, etc.

Model improvement

The ultimate objective of this phase is to improve the mental models of the members of the research team and of the members of the reference group. The means for achieving this objective is experimentation with an upgraded version of the initial model which incorporates the findings from the empirical research.

The first three to four months go into building an improved model which can generate scenarios that will serve as a basis for discussions later on in the reference group. If the empirical research has been properly carried

out the staff will approach the modeling with concrete images of the lifelines of typical individuals in the populations to be modeled and furthermore have a fairly accurate idea about the extent of the variations around those typical cases. Particular questions may have to be researched as they come up, but on the whole the model building should be a surveyable and predictable task for which the level of ambition can be adjusted to the available time.

Clarity of model concepts is important if the discussions in the reference group are to be effective. The model should be kept as simple as is possible and still represent the important dynamics. A model with many "decorative variables" will be badly understood by the staff and may confuse issues more than clarify them. If the modeling is focused on the most basic mechanisms, the resulting model will tend to be robust, i.e. it will behave in a reasonable fashion even when extreme changes in policies or parameters are made.

When a robust model is running and well understood by the staff it will be useful to start the second series of meetings with the reference group. The purpose of the discussions in the group is to increase the group members' understanding of the problems they are facing and develop a basis for the popular project report.

The model is used to generate consistent and reasonably realistic scenarios. Simulation runs will show the combined result of growth and decay processes, physical and social limits, information delays, and non-linear relations between system variables. The purpose of the model experiments is to help provide insights into how various policies, due to their position in a complex structure, will tend to alleviate or amplify problems. The purpose is not to produce predictions.

The members of the reference group will compare the behaviour of the model with their intuitive ideas about the functioning of the real world. The

comparison will at least in the beginning be very impressionistic. It will typically concern the relative phasing in time of various phenomena, the amplitude of oscillations or overshoots and the rate at which adjustments are made. When the mental models of the group members yield different results than the model experiments the staff should be able to show why the simulation model behaves the way it does, making it possible for the group members to criticize or accept the assumptions made in the model. In the latter case the group members will have changed their mental models. One simulation run can often be enough to carry productive discussions through a whole meeting.

Between meetings the team will work to clarify issues that were raised at the previous meeting. This may take the form of empirical research, model improvement, or authoring of short memoranda. The criterion for judging whether a specific model change should be introduced or not is the extent to which it will enlighten reference group discussions.

When the group members have become familiar with the model they will be able to suggest policies that might be institutionalized to alleviate undesirable behaviour shown in model runs. Much can be learned from studying the behaviour of the model resulting from incorporating those policies in the model.

Report writing

Along with results from the empirical research the discussions in the reference group form the basis for the major report of the project. This report should address a wide audience and be written in a non-technical manner. It will typically contain an interpretation of past development and present alternative scenarios of the future. It will attempt to explain the connection between emerging problems and the structure underlying them, and show how various proposed policies might alleviate or amplify the problems.

Parallel to writing the report the model should be finished up and documented with an explanation of its rationale equation by equation. The documented model along with working papers from the project will be of value primarily to other researchers.

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