A Structured Approach to Knowledge Acquisition in Model Development

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ABSTRACT

Model development for policy purposes often involves consulting one or more experts to acquire knowledge about the system that cannot be found in the literature. This poses a knowledge acquisition problem: how to derive the necessary knowledge from the expert(s). This is particularly acute if the number of potential experts to be consulted is large, as might be the case in public policy making. In this paper we will discuss a structured approach to consult a great number of potential experts. The approach was developed for the construction of a simulation model of a regional health care system. The adopted approach, however, is sufficiently general to be employed in other model development processes as wel.

INTRODUCTION

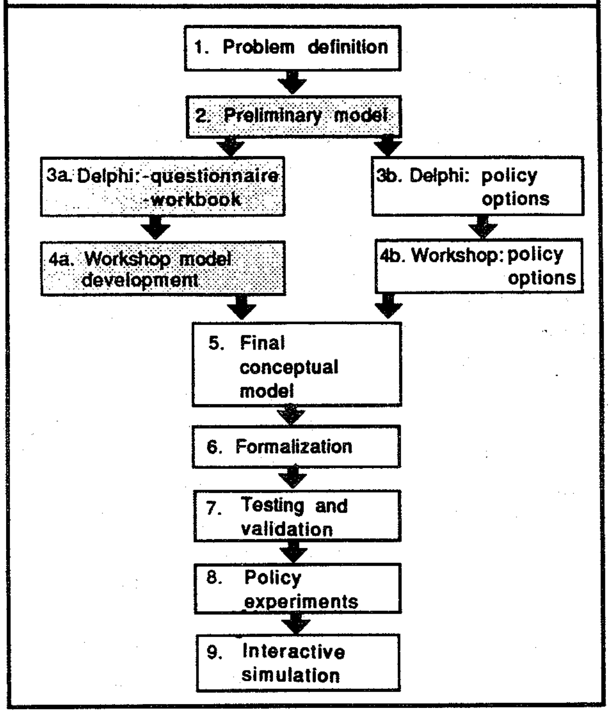
In designing computer simulation models for policy purposes it is important to involve potential users (e.g. policy makers) in the development of the model (Meadows et.al. 1982, Meadows and Robinson 1985, De Greene 1982). There are at least two reasons for this: one relates to knowledge acquisition, the other to knowledge diffusion.

Ideally, the development of a simulation model of a social system should be based on validated theories and empirical data. However, in practice lack of both theories and data is more often the rule than the exception. In those cases the modeler often relies on expert opinion for model development. This poses a knowledge acquisition problem: i.e. finding the most appropriate methodology to extract the expert's knowledge. If the number of experts to be consulted is limited, structured interviews or interactive model building procedures can be applied. This condition, however, is seldom met in public policy making and in the case of ill-defined problems (cf. Stenberg 1980, Dunn 1981, Brewer and De Leon 1983). In the process of developing a computer simulation model of a regional health care system we discovered that the system is quite complex and opaque, and that rather little is known about it. Even experts in the field proved to be often only informed about certain parts of the entire system. In this kind of situation the consultation of a limited number of experts might cause serious difficulties, since they could lack various pieces of essential information and also hold a biased viewpoint. In order to avoid this biased viewpoint effect in model development, we considered it useful to involve a larger number of individuals with different perspectives in the process of modeling. Involving larger numbers of individuals is also a useful strategy from the point of view of knowledge diffusion. In this manner, a greater number of individuals gain familiarity with the model, which in turn increases the chances that the model results will be used in subsequent discussions on policy issues and in policy development. Having various individuals participate in the process of model development also gives them the opportunity to learn effectively about the system's structure and dynamics. This might be one of the most important effects of participation by policy makers (Watt 1977, Smits 1983, Meadows and Robinson 1985, Vennix 1988).

Increasing the number of individuals to be consulted, however, aggravates the knowledge acquisition problem. It thus becomes more difficult to structure the process of knowledge acquisition, especially since this process needs to contain discussions between participants with different viewpoints. In this paper we will present a procedure that can be utilized to consult a large number of experts in the conceptualization phase of the modeling process and that partly circumvents the above-mentioned problem. The approach consists of three stages. The first stage is the development of a preliminary conceptual model by the project group, based on the relevant literature and on general insights within this group. This first stage becomes necessary because, in our opinion, it is easier to confront people with a preliminary model than to start from scratch. In the second stage the actual consultation of experts takes place. The question is what constitutes the best methodological way to accomplish this. A method that has been frequently used when consulting a panel of experts is the Delphi-method (Nutt 1984, 106-110). The Delphi-method generally uses a series of mailed questionnaires. The first questionnaire starts the process. Subsequent questionnaires provide feedback from previous ones, often in order to promote consensus within the panel. The Delphi-approach appears to be a good way to consult a large number of persons mainly because it can be carried out at relatively low costs. In our research, however, two great disadvantages also surfaced. The first relates to the circumstance that a questionnaire does not allow to deal with complex interrelationships between variables. The second is that "Delphi" is not intended for use in situations, that require direct interactions and confrontations between experts. Rather, the confrontation of opinions takes place through the feedback of results from previous questionnaires. This slows down the process of confrontation of opinions tremendously. However, in computer modeling, <u>direct</u> confrontation and discussions between participants with differing viewpoints is very fruitful. To remove the first disadvantage we decided to carry out two Delphi-cycles aimed at improvement of the preliminary model: we used a questionnaire in the first and a workbook in the second cycle. In the workbook we could more easily deal with complex submodels than in the questionnaire. To remove the second disadvantage we replaced the third cycle with a workshop, which enabled the direct confrontation between expert's opinions. These three stages produced a final conceptual model, which, in turn, had to be formalized, tested and validated, before policy analyses could be carried out. The last step in the project involved the design of an interactive simulation that could be used by groups of participants to conduct policy experiments and discuss the results.

Since the model was designed to provide more insight into the development of health care costs, we also decided to make a list of potential policy options aimed at reducing these costs. Here we also used a Delphi and a workshop approach to make an inventory of policy options and to develop criteria which could be considered important in selecting policy options. Discussions in the workshop added valuable information with regard to implementation of policy options in the simulation model. The sequential phases in the modeling project are summarized in figure 1.

Figure 1: Phases in the modeling project.



In this paper, we will concentrate on the three stages in knowledge acquisition, i.e. designing the preliminary model (stage 2), the Delphi-cycles (stage 3a) and the workshop with regard to model development (stage 4a). Before discussing these stages in more detail, we will first describe some typical characteristics of the Dutch health care system and the problem definition for the model study. The next two sections will focus on these subjects. The following three sections will be concerned with the three stages mentioned above. The last section will give a rough sketch of the possibilities for future use of the interactive simulation.

THE DUTCH HEALTH CARE SYSTEM

The organization of the Dutch Health Care System is quite unique. In order to assist the reader in understanding the model presented in the next sections, we will discuss its most important features.
We can roughly characterize the Dutch Health Care System as located somewhere between the British (fully nationalized) and the U.S. systems (market-based). Since 1974, decision making in Dutch Health Care has been based on three characteristics:

- partial competition through price mechanisms and partly regulated competition between non-profit organizations;
- consultations between planning institutions consisting of (among others) representatives of employers, employees and health care insurance companies; and
- guidelines and laws stemming from the federal government.

Within the context of this decision making structure two important decisions were made in the past, that have determined the character of Dutch Health Care. The first is the implementation of a mandatory insurance. Individuals with an annual income below fl. 50.000,- are automatically insured against the costs of medical health care. If married, dependents are insured too. Due to this measure, 60% of the Dutch population is automatically and willy-nilly insured against health care costs. There are two laws regulating this mandatory insurance: the Law on Health Care Insurance and the Law on Special Medical Care costs. The latter is meant for covering the costs emenating from long terms diseases. While the premium for this type of insurance is payed by employers, the premium for the first is payed by employers and employees on a fifty-fifty basis and amounts to about 10% of an employee's gross income. In addition to these two laws there also exist private insurances for the remainder of the Dutch population.

The second important decision, that dates back to 1974, is the division of the Health Care System into echelons. In the first echelon we find the practice- and community nurse, the health care worker and the family physician. The latter usually works individually from his/her own house, sometimes in a community center and only rarely in a health care center staffed by general practitioners, community nurses and/or physiotherapists. None of the family physicians work in a hospital. In the second echelon one finds the medical specialists and the hospitals. Medical specialists can be found in both hospital settings and in facilities for long term patient care. Patients have no direct access to the second echelon for consultation and treatment except in case of emergencies (e.g. car accidents, heart-attacks). Patients have to be referred to the specialist by their family physician. The specialist can refer the patient back to his family physician who might continue the medical treatment if necessary. The specialist can also release the patient from further medical treatment. The general practitioner and the specialist have strictly separated responsibilities.

In sum, the Dutch Health Care system has two important characteristics: a mandatory insurance for the majority of the population and the division of the system into echelons.

Since 1974 several attempts have been made to reduce health care costs. The most conspicious was the attempt to strengthen the first echelon at the cost of the second. Thus far, however, this has not proved to be a very successful initiative. In the United States, the so-called "Health Maintenance Organizations" (HMO), based on a new payment and delivery system, seem to be more successful in reducing health care costs. It has been reported in the literature that, without lowering the quality of health care, cost reductions of 10% to 40% are possible. One of the causes of this cost reduction seems to be the prevention of prolonged hospitalization. There are some indications that it is the structure of the Dutch health care system which prevents effective cost reduction. Within a mandatory insurance system, such as we find in the Netherlands, there are a number of operational constraints that make it difficult for the health care system to function like a HMO. Some of these constraints are (Ven 1987):

- financially speaking, health insurance companies do not operate independently. The premium paid by employers and employees are collected by one central public fund. This in turn pays the costs of the insurance companies.
- insurance companies cannot refuse contracts with a hospital, specialist, physician etc. The contents of contracts are determined by the Federal Government.
- insurance companies are not allowed to operate simultaneously as an insurance company and a caretaker.

Since 1985 there has been considerable discussion in the Netherlands with respect to the possibilities and limitations of reshaping insurance companies into HMO's. As it now stands, it does not appear that the situation will change in the immediate future. Insurance companies are attempting to prepare themselves for this change, however, by strengthening their policy development and implementation capacities. The model discussed in this paper must be seen as the result of these recent developments.

PROBLEM DEFINITION AND PROJECT ORGANIZATION

The background of our study is formed by the problems relating to the increasing costs of public health care in the Netherlands. Total health care costs increased from about 6% of the net National Product in 1968 to about 10% in 1985 (appr. fl. 35 billion). There are several causes for this gradual but persistent increase. Most of the causes that have been identified, however, are more or less exogeneous influences: e.g. increasing wage rates and increasing energy prices (cf. Grünwald 1987). Up to now, very little attention has been devoted to the internal dynamics of the health care system, which could also be held responsible for cost increases. In addition, most policy options aimed at cost reduction do not take these internal dynamics into consideration, though they could possibly neutralize the expected effects of a policy option. Development of a system dynamics computer simulation model could further insight into this phenomenon. To set the process of the construction of the model in motion we defined the problem as follows:

a) What has been responsible for the increase in health care costs in the past?
b) How will health care costs develop in the future?
c) What will be the effects of several kinds of policy options aimed at cost reduction?

Since our client is a regional health care insurance organization, the model is designed for this specific region. In order to increase the chances that the model results would be used in policy development, it was decided to include two persons from the Regional Health Care Insurance Organization in the project team. Together with two experienced system dynamics modelers, this team presently consists of four persons. In addition, some five persons from the Insurance Organization were used as a group to assess the preliminary model, the design of the questionnaire, the workbook and the workshops. In this way, several persons within the organization have been more or less actively participating in the project.

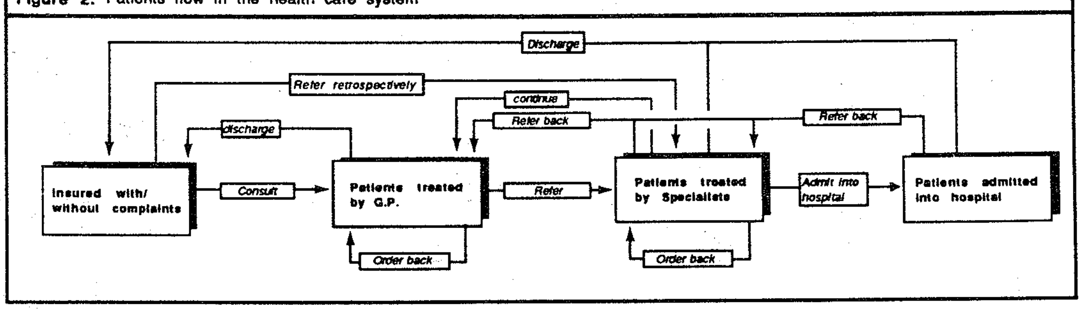
As stated, we started the knowledge acquisition process by developing a preliminary conceptual model.

PRELIMINARY MODEL

To enhance the process of consulting a large number of experts we concluded that, as a first step, it would be useful to develop a preliminary conceptual model. It is easier to ask individuals whether they agree or disagree with (parts of) some model and to add something to it, than to try to have them construct a completely new model themselves. This is especially true when most of those that one has to consult are unfamiliar with modeling procedures.

Because there is a clear patient flow in the health care system which can easily be distinguished from, for instance, information flows, we decided to construct a hybrid diagram as suggested by Richardson and Pugh (1986). Designing the patients' flow is relatively easy, since this process is well known and quite straightforward. People with health complaints in the Netherlands initially consult their general practitioner (g.p.), who decides whether to refer patients to a medical specialist, to discharge them or to perform the required medical treatment himself/herself. The medical specialist, in turn, decides whether his/her patients should be admitted into the hospital or not and when they will be discharged. Figure 2 shows how this process can be envisioned.

Figure 2: Patients flow in the health care system

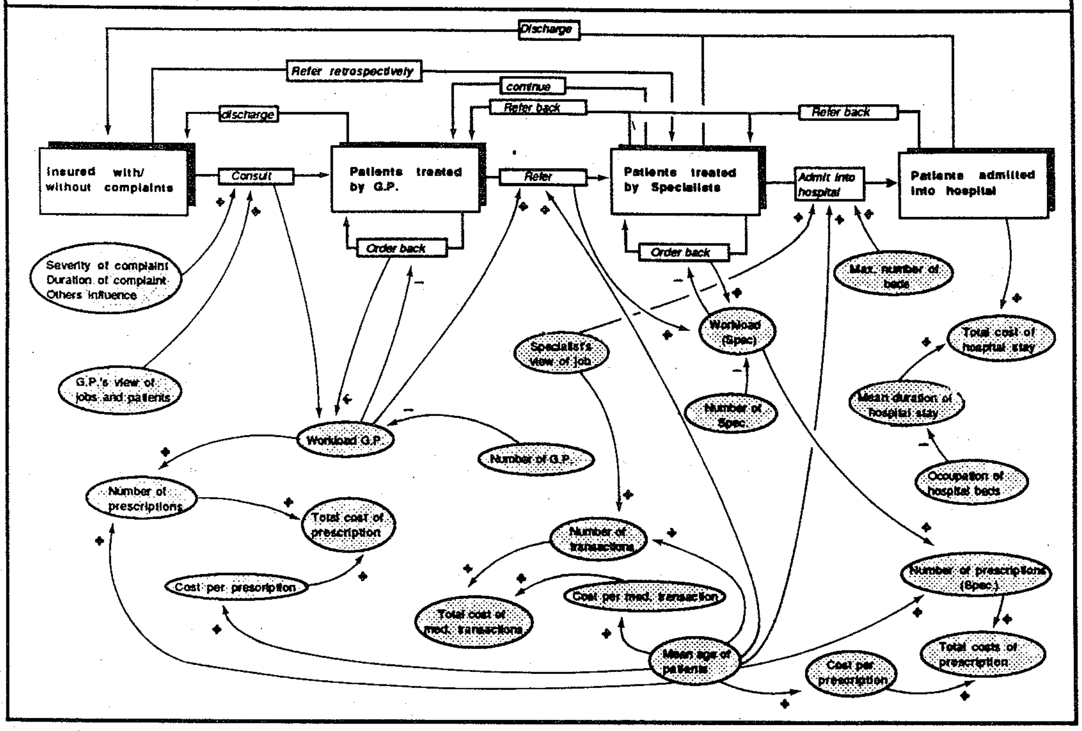


Because our inspection of health care cost figures indicated that this part of the system (i.e. general practitioners, medical specialists, hospitals) accounts for approximately 75% of the total regional health care costs, we decided to restrict the model to this subsystem. Another reason for this is that this subsystem includes referrals of patients by general practioners to medical specialists, which is a much debated subject with regard to reducing health care costs.

In this "patients' flow model" we subsequently included the decisions and actions displayed by each of the three groups in this model, i.e. patients, general practitioners, and medical specialists (see figure 3). Patients decide whether to see a doctor or nor (consult). General practitioners generally display one or more of four kinds of decisions after examination of a patient: send the patient home (discharge), prescribe some drug(s), refer a patient to a specialist, request a patient to return (order back). Medical specialists decide to: reexamine a patient, apply medical surgery (medical transactions), prescribe a drug, or have someone admitted into the hospital. Most of these decisions and their subsequent actions can be subdivided into two components: a volume and a cost component. For instance: the <u>number</u> of prescriptions by a general practitioner or a specialist (volume) and the <u>price</u> of the drug prescribed (cost). It is precisely the kinds of decisions and actions mentioned above that produce medical health care costs.

Up to this point, construction of the preliminary model was rather easy. The more difficult part was to determine factors that influenced the kind of decisions and actions discussed above. We thus turned to the literature and based on this literature, plus insights from the project group, we decided to incorporate a number of factors into the model. Each of these influenced one or more actions, as can be seen in figure 3. For instance, the workload of the general practioner (workload G.P.) affects the number of prescriptions.

Figure 3: Preliminary conceptual model



After having developed this initial model we decided to publish it in a Dutch medical journal in order to make health care professionals acquainted with it (Vennix, Gubbels and Post 1986(a) and (b)).

THE DELPHI-QUESTIONNAIRE

As stated in one of the previous sections, we decided to consult a large number of persons in the health care system on this model, in order to circumvent the biased viewpoint effect of one or a few participants. Two problems arose at this point: the selection problem and the questionnaire design problem. The selection problem refers to the question how to ensure that respondents with different viewpoints will be approached. The design problem can be stated as: how to formulate the questions for respondents about the preliminary model.

With respect to the first problem we proceeded by first making a distinction within the health care system between three kinds of fields, i.e. the actual care system itself with its interest groups (either general practitioners, medical specialists or patients), the policy making field with regard to health care (e.g. planning institutions) and the research field with regard to social and behavioral processes in health care (e.g. university health care departments). Within these three fields (care, policy making and research), we made a list of (appr. 20) organizations active in each. Next, we attempted to identify several potential respondents in these organizations. Ultimately, we ended up with a list of some sixty respondents, fairly well spread over the three fields mentioned above. We took several precautions to avoid the problem of low response in mailed questionnaires. To raise the response rate, for instance, we enclosed with the questionnaire an abstract of the article as well as the article on the preliminary model itself. Furthermore, we pointed out to the respondents that we needed their expert opinion in order to be able to improve the preliminary model. Ultimately, these precautions led to a response rate exceeding 95%, which is very high for a mailed questionnaire.

The second problem, how to formulate the questions about the model, was more difficult to solve. In order to simplify matters for the respondents we decided that the questionnaire should only contain questions on binary relationships, i.e. relationships between two variables. We subdivided the questionnaire into a number of sections, each dealing with one of the decisions or actions mentioned in the previous section (e.g. prescriptions, consultations). One section, for instance, might focus on the decision of general practitioners to prescribe drugs. This was then considered to be the "dependent variable". In each section a number of statements were presented describing a relationship between this "dependent" variable and some independent variable. For instance, in the section 'prescriptions by general practitioners' one of the statements was:

"The heavier the workload of a general practitioner, the higher his number of prescriptions".

Participants were asked to state whether they "agreed fully", "agreed partially", "disagreed partially", or "disagreed fully" with the statement. This provided insight into the number of people agreeing with the statement. However, if we would have designed the entire questionnaire in this fashion, it probably would not have been of great help to us. A problem remains if for instance half of the respondents agrees with a statement and the other half does not. We were not only interested in finding out whether someone agrees or not with a relationship, but we were also interested in discovering all kinds of causal arguments that were generally used by respondents and which were not included in our preliminary model. To extract these causal arguments we asked the respondent after each statement to indicate <u>why</u> one did or did not agree with the statement. It is exactly this procedure which generates all kinds of causal argumentations used by respondents. Content analysis with regard to the answers to the "why

questions" revealed a number of interesting things. For instance, new concepts that might be included in a causal relationship, thereby clarifying it. This is typical for those who agree with a statement. An example: our statement "older patients are referred more often to a medical specialist than younger patients" (a typical statistically established relationship) produced the following argumentation structure in response to the why question: "agree, because older people often have a more complex pathology, which impedes a correct diagnosis so that a specialist's opinion is needed". By means of this process, one has obtained a chain of causal linkages between four concepts, instead of the original two.
Other interesting conclusions that could be drawn by studying the arguments from the "why" part of the questions were related to the concepts themselves. For instance, with respect to the statement on the relationship between workload and the number of prescriptions, approximately half of the respondents agreed while the other half did not. This is of course quite confusing. Careful study of the arguments, however, revealed that the two groups did not use the same kind of concept. One group obviously had the temporary rush during the consulting hour in mind (caused by an epidemic of influenza for instance) while the other group presented arguments which were related more to the structural workload.

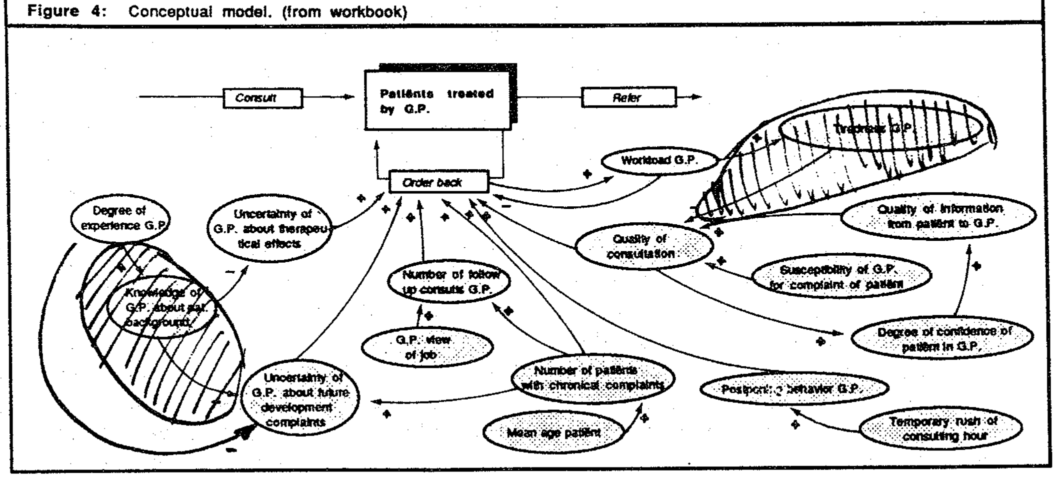
Each section in the questionnaire, focusing on one "dependent" variable, thus contained a number of these statements together with "why questions". In addition, at the end of each section we asked respondents to add variables, not yet mentioned, which they perceived to affect the dependent variable. Here too, some respondents came up with interesting new variables. For instance, influence of the advertising done by the pharmaceutic industries and the demands of the patients on the manner in which general practitioners prescribe drugs. On the other hand, this obviously generated a host of factors which might influence some dependent variable. That is why we decided to end each section with a question in which the respondent was asked to name the three independent variables that he/she considered to have the greatest effect on the dependent variable. Answers to this question helped us decide which factors to incorporate in the final conceptual model.

THE DELPHI-WORKBOOK

In the second cycle of the Delphi we switched to a workbook which was based on the results of the questionnaire. It was used for two purposes. First, it enabled us and the respondent to focus on sets of interrelated variables instead of only binary relationships. Second, the workbook was also used as a means to prepare participants for the workshop. Since no more than ten participants could attend the workshop and because time restraints only allowed two workshops to take place, we had to make a selection from the sixty respondents who participated in the first cycle. We selected those respondents who presented us with the most detailed comments and arguments in the Delphi-questionnaires. The workshop could only be held for the first echelon (general practioners), since a number of medical specialists (the second echelon) refused to cooperate because of a conflict between their interest group and the insurance companies. Consequently, for the second echelon we had to confine ourselves to structured interviews with only a few (cooperative) medical specialists.

The workbook contained four submodels of the first echelon. Each of these incorporated one central dependent variable, i.e. consultation by patients, prescriptions of drugs, referrals and 'back orders' by general practioners. These submodels were gradually introduced into the workbook. This was done by first describing the most important results of the questionnaire with respect to the submodel. More specifically, starting with the dependent variable (e.g. number of 'back orders' by general practitioners) we first presented a number of statements with regard to variables directly affecting the dependent variable. These were derived from the respondents' answers to the question pertaining to the factors they considered most influential. Next, new variables were added, based on the preliminary model, the results of the questionnaires and our own insights. These, in turn, explained the first group of variables which directly influenced the dependent variable. Gradually, a complex network of interrelated variables was constructed, aimed at explaining the dependent variable in question. This was done by presenting the relationships in the form of statements and summarizing these in a causal diagram at the end of a set of interrelated statements. The respondent was asked to comment on our arguments and to indicate in the final diagram of the submodel which parts he/she did not agree with by circling these parts (see figure 4).

Figure 4: Conceptual model. (from workbook)



After having completed one submodel, the respondent continued with the next, following the same procedure. The completed workbooks were sent to us one week before the workshop.

THE MODEL DEVELOPMENT WORKSHOP

Developing a simulation model involves considering multiple relationships simultaneously, thereby refining and purifying the conceptual model. In policy oriented modeling, this is generally done by discussing parts of the model in a (small) group. This phase cannot be covered by questionnaires or interviews since the discussions are essential to the development process. That is why we designed a structured workshop for discussion of submodels. For the design of this workshop we based ourselves on experiences and guidelines described by Hart et.al. (1985), Mason and Mitroff (1981) and Duke (1980). We designed a structured workshop approach for nine participants that took about four hours to run (the absolute time limit for most participants) and was held twice with two different groups.

On the basis of the comments given by participants in the workbooks, we formed three groups of three persons. Each discussed one submodel in more depth during the workshop. From the four submodels in the workbook we selected those three for the workshop that received most criticism in the workbooks. The procedure for the workshop was roughly as follows:

- introduction and explanation of the purpose of the modeling project (appr. half hour).
- subgroup activities (appr. one hour).
- plenary session (appr. 1½ to two hours).
- evaluation (appr. half hour).

After the introduction, participants first worked for approximately one hour in subgroups on one of the submodels. We used a few aids to structure the discussions in the subgroups. First of all, each of the members of the group was assigned a role. For instance, one person took notes and presented the results in the plenary session, while another person was responsible for time management. Second, we copied diagrams from the workbook and by using three different colors indicated which of the three persons had commented on what parts of the submodel in his/her workbook. The colored parts of the submodels had to be discussed first during the subgroup meeting. Participants were asked to make changes in the diagrams according to the results of their discussions, i.e. adding or deleting variables or relationships. After having completed their discussions, one person was responsible for integrating all the final changes into a large diagram that was then put on the wall in the plenary session room. On the basis of this diagram the spokesperson of the subgroup explained the results of the discussions and the changes made in the submodel by the group. The other two subgroups were permitted to ask questions and comment on the results. The same procedure was used in discussing the results of the activities in the other two subgroups. After having completed the discussions on the submodels, we presented the plenary group with the consequences of linking the submodels, i.e. the emergence of a number of feedback loops. The concept of feedback and some important feedback loops in the model were discussed. These feedback loops were assessed with respect to their plausibility and the model was modified if necessary. Finally, we conducted a short evaluation of the workshop and the modeling project. All discussions during the workshops were recorded on tape and minutes were made.

SUMMARY AND FUTURE PROSPECTS

In this paper we concentrated on a structured approach to knowledge acquisition for model development. We suggested that when the group to be consulted is large, a three step approach is an appropriate way to tackle problems, using different kinds of data collection methods. The first stage, developing a preliminary model, is necessary to facilitate the process of knowledge acquisition with experts unfamiliar with modeling. There are two advantages associated with using a Delphi approach in the second stage. First, a great number of respondents can be questioned, thereby mitigating the biased viewpoint effect. Second, the questionnaires can be used to generate and prioritize a number of important factors that should be included in the model. A disadvantage of this procedure is that there is no opportunity for immediate discussions between experts. That is why a third stage is necessary which permits discussions about the model. This was done in a structured workshop setting that was prepared by having participants fill out a workbook. The results obtained from the questionnaires, the workbooks as well as the discussions in the workshops were used by the project group to develop the final conceptual model. This model was then formalized and tested. Several experts, who have detailed knowledge with respect to certain parts of the model were consulted in the course of this process.

The procedure we developed has thus far only been used once. It is our opinion, however, that it is sufficiently general to be used in developing other models for public policy problems. If the method is used more frequently in the future it will no doubt certainly be refined and improved.

As stated in the introduction, consulting a number of experts is not only useful from the point of view of knowledge acquisition, but also from the perspective of knowledge diffusion. Dissemination of the results of a simulation model study is often quite difficult. The model is usually the result of a lengthy research process spanning several years, involving considerable learning and various kinds of implicit as well as explicit choices made by the modeling group. If potential users think that the model is too opaque or if they don't agree with certain assumptions in the model, the chances that the model results will be used in the policy process might be decreased drastically. That is why we decided to publish the 'preliminary model' in an early stage and to consult a large panel of experts (including potential users). This increases the chances that their assumptions will be made explicit and possibly included in the model. Furthermore, in addition to writing a comprehensive research report, our goal is to develop a simulation tool with which policy makers, aided by the modeling group, can carry out all kinds of simulation experiments themselves (Vennix and Geurts 1987). This also includes challenging and changing the model's assumptions. The simulation tool will be used as a teaching and training device in a course on regional health care policy development. Several organizations will be invited to participate in this course. Part of the course will be devoted to training participants in model oriented thinking in health care. This will be done by discussing the conceptual simulation model, by adapting it to their own specific region and by changing some of the model's assumptions. These changes will be implemented in the simulation model and its effects on model behavior studied. Next, participants will be put in a position to develop different scenario's and policy plans and to implement these in the model. The result of these simulation experiments will be discussed and a number of conclusions with respect to the model's usefulness as well as regional health care policy making will be formulated.

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