Using complex System Dynamic models; an example concerning the Dutch dental health care system

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Abstract

Recently a System Dynamic simulation model of supply and demand of the dental health care system in The Netherlands has been developed. This model includes major demographical, pathological, psychological, sociological and economical processes comprising the demand side. The supply side covers the availability of dentists, dental hygienists and factors which determine their productivity.

The main purpose of the model is to create an instrument for analysing the Dutch dental health care system. A relatively simple model with e.g. 20 state variables just describing the main concepts of this system was not considered to be sufficient. Therefore, starting from a simple model, during the past decade a far more complex model has been developed. It contains for instance 440 state variables. This model has already proven to be very satisfactory with regard to its descriptive qualities. However, the necessity for working with complex models has also negative side-effects. Apart from the great efforts needed constructing, validating and analysing the model, it is well known that the more complex the model, the more difficult to communicate about its results and properties, with people for whom the model might be useful. This is even more so if it concerns people from outside the academic world (in this case for instance the dental profession or policy makers).

In this paper attention will be focussed firstly on a short introduction concerning the model and its structure. Secondly, our experiences with the model will be used as an example of our ideas about how to construct sophisticated models with a high descriptive quality, while at the same time making them at least acceptable for those who might use its results, but were not directly involved in the construction of it.

1 INTRODUCTION

A major problem for people working in the field of System Dynamic modelling is the discrepancy between the potential of System Dynamic techniques as perceived both by System Dynamic experts and their clients, and the actual impact of System Dynamic modelling. Especially evaluations of projects concerned with System Dynamic modelling in the public sector have often brought to light that the actual impact on the people who have the power to use the model's results has been minimal. A bottle-neck often encountered is the transfer of experiences and knowledge of the model constructors to the users of the model's results. Two possible solutions for this problem are the demand for small models concerning restricted problems and involvement of the intended users of the model's results in every phase of its construction (Meadows and Robinson, 1985).

In this paper we will discuss a project in which a model of the Dutch dental health care system was developed. For reasons discussed later in this paper both of the two options suggested to facilitate the transfer of knowledge were not feasible. We certainly do not pretend that we can give a methodology of eliminating the problems occurring in communicating about the results of this type of projects. This paper can be considered, however, to be a case study concerning some practical aspects of making complex models easier to understand.

2 THE MODEL AND ITS HISTORY

During the past decades the imbalance between demand and supply of dental health care in The Netherlands has been a matter of serious concern. In attempting to tune supply and demand, policy-makers have to deal with a complex socio-political system and as a consequence of this, with a dynamic, non-equilibrium system (Forrester 1969; Mesarovic, 1970; Klabbers et al., 1980). It has become increasingly clear that both systems-approach and computer simulation offer favourable perspectives for a more adequate integration of policy-options in complex social systems.

For the sake of surveying and investigating the structure and behaviour of the dental health care system more systematically in 1979 a research project has been initiated at the dental school of the University of Nijmegen on System Dynamic computer-simulation models of the dental health care in The Netherlands. In the past ten years three System Dynamic models have been developed. The model which is subject of this case study is the third model. Since its structure and characteristics are rooted in the two predecessors we will not only give a description of this third model but also briefly introduce the first two models.

Firstly, a relatively global model was developed. The relative simplicity had some disadvantages. For instance, no difference was made between age-groups and only one "treatment" was considered. This model has been embedded in an interactive computer-simulation game (Klabbers et al., 1980). In this game three groups of actors were considered: government, parliament and the dental profession. Each group only had access to partial information and different policy measures. The experiences during the game-sessions were twofold. Firstly, players were enthusiastic and expressed to have gained valuable insight in the complexity of the issue. Secondly, especially dentists felt the need to look into the problem area in much more detail, focussing on age-groups, pathology etc.

As a result of this experience a model more detailed in its description of the dental health care system was developed and implemented on a mainframe computer (Truin, 1982). This model had a level of detail specialists in the field of planning the Dutch dental health care system considered minimal to give an adequate description of the dental health care system. The population for instance was differentiated by age, insurance status and dental attendance behaviour. The model consisted of two submodels concerning pathology, a submodel concerning the dental attendance behaviour, a submodel covering the supply-side and a submodel covering the 12 most important treatments. The model was able to reproduce fairly well the behaviour of the Dutch dental health care system as observed for the period 1970-1984, and it has been used to perform scenario-analyses concerning dental health care during several years. However, due to the implementation on a mainframe which made the model quite difficult to handle and due to its complexity, it was very difficult to communicate about the results of the model. Mainly for this reasons it was decided to develop a third model. Roughly speaking this model was intended to be at least as good as the second model with respect to its descriptive qualities, while at the same time eliminating its drawbacks.

3 OVERVIEW OF THE MODEL

3.1 Global properties of the model

The model is a deterministic discrete time model with time steps of one year. It contains about 440 state variables and the number of parameters is over 4000. The model and its supporting software is implemented in Pascal on a Macintosh IIcx computer. Amongst the supporting software are facilities for quickly reviewing the results of a run, and software for changing parameters by filling out spreadsheets. Total runtime for a 40-year run using all submodels is about 5 minutes.

3.2 Model structure

The entire model can be seen as three linked models. The first part being a population model, the second part consisting of submodels modeling the demand side of the dental health care system and the third part describing the supply side.

The population model is off-line and acts as a driving function of the demand model. It generates data of a population consisting of seven age groups. Each of these age groups is subdivided into two or more groups with a different socio-economical background. These groups for instance may represent people with different socio-economical status (SES) or may reflect differences between people taking part in different insurance-programs. In the implementation discussed here the subdivision into socio-economical groups is based on the criterion "insurance": the first socio-economical group consists of people participating in a public insurance system called the Sickfund comprising about 70% of the population, the second of people having a private insurance for their health care expenditure.

The Demand model includes four submodels: Visit, Caries, Periodontal Diseases (i.e. the PD-model is concerned with diseases of the tissues supporting the teeth: bone tissues and gums) and Treatment. Each socio-economical group in the demand model in its turn is subdivided into three groups: people visiting a dentist regularly, people visiting a dentist irregularly and people without a natural dentition (edentulous). The population structure thus obtained is the backbone of the model. Notwithstanding the links between the different cells of the population (induced for instance by demographic processes or changes in dental attendance behaviour) the Demand model contains a complete and self-contained submodel of each cell. As a result of this for each cell a set of state-variables (e.g. average number of decayed teeth per person, or percentage of people suffering from calculus) and a set of parameters (ranging from sugar-consumption to price-sensitivity for dental treatments considered) is provided. An impression of the model structure is given in figure 1. All cells have the same internal structure. For obvious reasons the cells containing edentulous people have a much simpler structure.

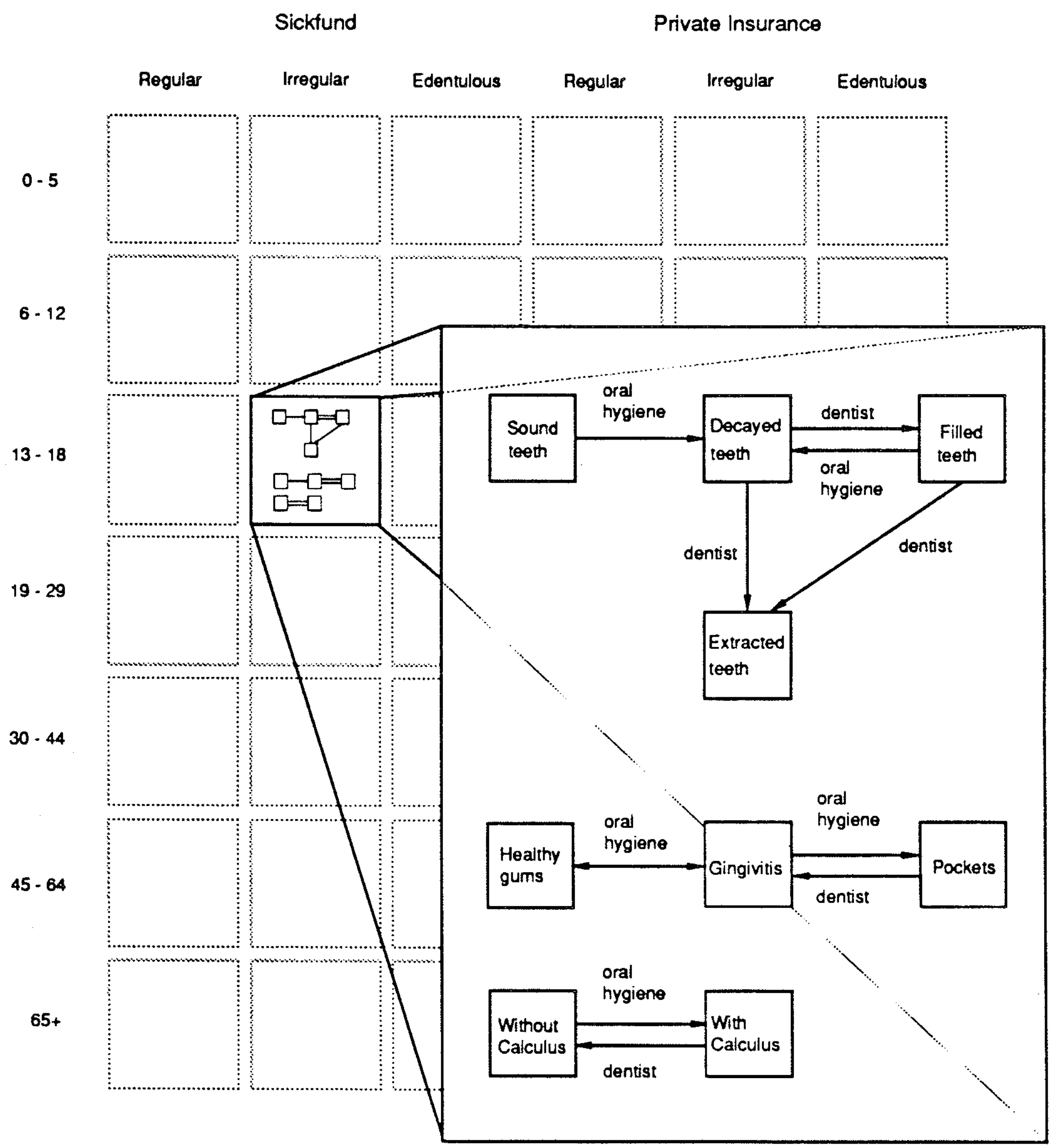

Figure 1: Structure of the model at population level

In the Supply model it is calculated how many full-time equivalents (fte) are available for tasks related to the treatment of patients. This is done separately for dentists and dental hygienists.

The Supply model and the Demand model are dynamically linked. This is done mainly by two variables. The submodel Treatment uses the number of fte available which is calculated in the Supply model and the Supply model uses the workload for dentists and dental hygienists which is calculated in the Treatment model. In the figure below an overview of the submodels building the overall model and the major interactions between these submodels is given.

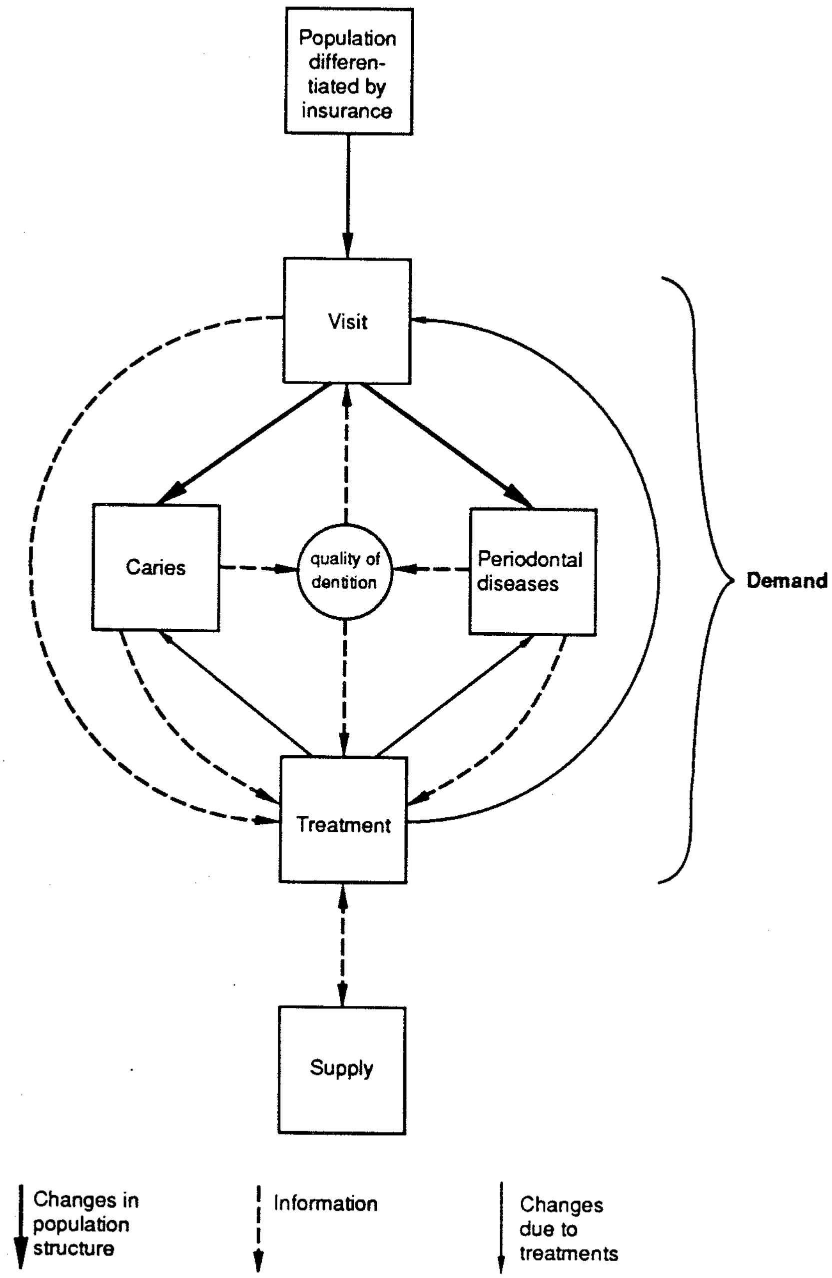

Figure 2. Submodels building the overall model

4 HOW WE MADE THE MODEL MORE ACCESSIBLE

Before we discuss some decisions we have made to make the results of the model more accessible, we firstly want to clearly distinguish between two very different types of the use of results of System Dynamic models: these can be referred to as the "figure"-level and the "insight"-level. By the "figure"-level we want to express the direct use of results of a model, often given in figures or graphs. In this type of use the reference run is interpreted as a prediction of the future behaviour of a system, results of scenarios are considered to give an accurate assessment of the impact of certain changes in policy decisions or values of parameters. When using System Dynamic models in this way the model often is viewed as a black box. Looking at our experiences in the past the question whether results of System Dynamic models are used on the "figure"-level is determined mainly by two factors. The first factor is the authority of the constructors of a model and/or the institute they are working for. The second factor consists of the results themselves. If they suit a certain group of possible users they will certainly use them, if not the results will not be used. The case study in this paper is not about possibilities for making the use of model results on the "figure"-level more efficient. This has two reasons. Firstly, the two factors determining to what extend model results will be used on a "figure"-level can not easily be influenced. Secondly, this is not the level of use the project concerning the Dutch dental health care system was aiming for.

This project aimed for the construction of a System Dynamic model which could be used on the "insight"-level. On this level the model is used to identify processes responsible for the dynamic behaviour of the main variables in a system, integration of knowledge from different scientific fields concerning the system into one coherent framework, ruling out contradictory policy options, separating attainable and unattainable policy goals etc. The discussion of the decisions made to make the model more accessible is entirely focussed on the use of the model on the "insight"-level.

In our discussion we want to make a distinction between two groups of ideas concerning the accessibility of our model. The first group consists of ideas more or less directly related to the contacts with users of the model's results, the second group are the ideas related to the structure of the model.

4.1 Considerations with regard to the contacts with users of the model

In the period that we were about to finish the construction of the model with respect to the model structure and were able to start the validation, we were asked by the Department of Public Health to establish a scenario project in the field of dental health care. Object of this scenario project was to bring together a group of representatives of the most important groups active in the field of dental health care (the scenario committee). General aim of the project proposed to us was to gain insight in the developments of the state of oral health of (some parts of) the Dutch population in the next 25 years, and to analyse the effects and side-effects of policy options being considered and changes in the dental health care system, such as proposed changes in the structure of the insurance system. The scenario committee consisted of dentists, dental hygienists and economists representing the universities, the Dutch Dental Association, the Dutch association of dental hygienists, public and private insurers and the Sickfund board.

From this project and our experiences with these users, we compiled five basic notions discussed in sections 4.1 and 4.2, which we think might be useful for others working in projects with complex System Dynamic models.

4.1.1 Reconstruct models in cooperation with its users

Although the model's structure was more or less completed, we decided to use the opportunity offered by this project to establish a "quasi" participatory model construction. So we discussed thoroughly the content of each submodel, giving the scenario committee the opportunity to suggest changes they felt necessary to answers the questions they had in mind. This approach demanded a large time investment of the research group which resulted only in minor changes in the original model. But the whole process has been very fruitful with regard to its intended side-effect: making an important group of users of the model acquainted with the model and giving them the feeling that this isn't just a model but, at least partially, *their* model.

For System Dynamic modeling involving very complicated models due to the mere time span of the model construction it can be very difficult to create a participation of the intended users of the model and its constructors. In these situations we think it might turn out to be an efficient investment of time to *reconstruct* the entire model with groups of users, thus strongly enlarging the chance that the model will be used on the "insight"-level.

4.1.2 Keep discussion about structure and validation wide apart

During the meetings with the scenario committee it turned out that whenever structural aspects and validation were discussed at the same time, it was impossible to make any progress. One might say that understanding a model only has to do with being familiar with its structure and is completely independent of its validation. Validation is most important for giving people confidence in the results of a model. So when trying to let people understand a model don't talk about validation. As soon as people understand and accept the structure of a model, discussing questions related to validation will be less complicated.

4.1.3 Do not bother someone with all details

A very important factor determining the behaviour of our model is the population model. For instance, the oral situation of the 55-years old in 10 years depends on a large set of variables, the most important one being the oral situation of the 45-years old now. So in explaining the model we were tempted to spend a lot of time talking about the population model and its interactions with the pathology models. This turned out to be a waist of time. The intuitive ideas people had about the population model and its interaction with the rest of the model come very close to the actual implementation and in that case not much is gained by a discussion of the ins and outs of the population model.

4.2 Considerations with regard to the model structure

4.2.1 Let the model consist of submodels which are as independent as possible

The reason for this is relatively simple. A strength of System Dynamic models is the possibility to incorporate explicitly dynamic relations between various variables. In the mental models people use this type of relations is often absent. As a consequence discussions about the content of a submodel will become more difficult if it can not be separated from dynamic feedback relations between variables in more or less "remote" parts of the model.

In our model an example can be found when looking at the Supply model. We have chosen the working potential, for tasks related to treatments, of dentists and dental hygienists as the only output of the Supply model and its only input from the Treatment model is the utilization level of dental services. By this choice discussion of the Supply model can focus entirely on its intended themes such as the age structure of the dentist population, fractions of people leaving their profession, number of students in education etc. If only a small part of the processes governing the management of practices by dental practitioners were part of this submodel, communications about this submodel are very likely to be "contaminated" by the need to address questions concerning treatment strategies, relations between changing pathology and the need for dental care etc.

4.2.2 Make relations as flexible as possible

On the previous page we discussed the fact that talking about the structure of a model and about its validation should be kept wide apart. This will only be possible if relations in the model are implemented flexibly. Looking at our model for instance, the chance that sound teeth will become decayed will depend on the use of sugar and the fluoride intake. So in the model functional relationships between both the use of sugar and the fluoride intake and the chance of becoming decayed had to be incorporated. To allow for a very wide set of possible relations, the model contains not only two sets of six parameters defining these relations separately for each cell of the population, but also the possibility to choose from a variety of interactions by simply changing parameter values. The flexibility we aim for can also be achieved using other constructions, but anyhow, maximising the opportunities to tune a model by picking the right parameter values is important.

This flexibility has also other advantages. The construction of complex models is very expensive and takes lots of time. By making the model flexible the time span in which the model can be used without the necessity for major changes can be enlarged. Besides this, a flexible model can more easily be transferred to other similar situations. In our research project we intend to start a project where our model will be adapted to the British situation. First impressions are that large parts of the model can be used after only minor adjustments. If we would try to transfer the predecessor of our last model, this would take a far larger amount of time, although its content is very comparable; it just lacks the necessary level of flexibility.

5 DISCUSSION

Communications about System Dynamic models are most effective if the models are relatively simple and have a restricted problem as its subject. Participation of the intended users of a model in every phase of its construction can also be recommended to maximise the impact of System Dynamic models. Unfortunately, in certain cases the construction of a complex model can turn out to be a necessary condition for its results to be accepted and for practical reasons full participation can be impossible. In this paper a model of the Dutch dental health care system is introduced which is presented as a case study about communicating about complex models. A number of our ideas about how we tried to reduce problems in transferring the model's results are discussed. A project in which these ideas are brought into practice is now halfway its two-year period. Though maybe a little premature, our experiences with this project indicate that the approach of participatory model reconstruction turns out to be fruitful and essential for the success of the project.

We have established a situation which takes position between two modus operandi. The first modus is to build a simple model together with the people who should use it. As we discovered with our first model, this is useful for those who take part in the project, but the resulting model was too superficial to have an intrinsic value. The second modus is to construct a complex, highly detailed model without direct cooperation of possible users outside the academic world. This can result in a model which has a high intrinsic value, but which for possible users will remain a black box which makes its use on an "insight"-level hardly possible.

Our approach now, which is a compromise between these more extreme approaches, already resulted in a model which has a relatively high level of detail and has been constructed in cooperation with a scenario committee consisting of representatives of the organisations which might use it. The second year of our project will be used for scenario analysis and then the effectiveness of the cooperation will come to an important test. How will the directly involved representatives react on results which conflict with their interests? As we see it now, our approach has involved enough participation of the scenario committee to grow above the "figure"-level of use and make them think about the how and why of the results of this System Dynamic model.

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