Master thesis in Systems Thinking and Business Modeling

Group Modeling in System Dynamics
- a Case Study

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ABSTRACT

A group modeling process, using system dynamics, is used to model a stroke ward. The purpose is to model quantitative and qualitative factors useful in room planning and dimensioning and to contribute to research studying the usefulness of simulation modeling as a planning tool in the design of new health care environments. The process is carried out within tight constraints on time and resources, while striking a balance between developing the group process and achieving a model. The group is intended to be representative consisting of different interested parties and is too large to benefit a good group process. Participants have different agendas and there is ambiguity of problems and goals. The challenge is to develop a model within the resource constraints and yet meaningful to the stakeholders, by using process consultation methodology. The modeling moves from basic causal loops to a model of patient flows. The difference between discrete and continuous modeling raises the issue of possible causes of goal erosion. Getting access to data turns out to be a major problem and in the end limits the scope and usefulness of the models. A "flight simulator" is constructed for testing policies to attain optimal dimensioning of the ward

The report is written in English.

Keywords: system dynamics, group modeling, stroke, process consultation

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Typographical conventions

Sections of quoted text and diagrams are shown with a light grey background.

Introduction

The project at hand is a group modeling process, intended to describe the stroke process at the hospital in Falun. This was done as a part of a larger research project carried out between Chalmers and the County Council of Dalarna. My role was to facilitate group modeling and to do the actual modeling. This thesis mainly describes the group modeling process.

The project leaders description of the project

The project leader participates in the larger research project and described the project at hand as follows:

> The aim of the present research project is to study the usefulness of simulation modeling as a planning tool in the design of new health care environments. The present project is a development of the one "Simulation as a planning tool for health care premises" within Formas research program "The building proprietor with the customer in the centre". The project is collaborative between the County Council of Dalarna and Chalmers University of Technology. At Chalmers, this project is one of several projects that deal with health care environments in order mainly to strengthen the work carried out in early stages of the design of new health care facilities. One of the most important objectives of the present project is to integrate knowledge from the caring and the architectural sciences and to incorporate this into the process of designing new health care environments."
>
> The modeling process will be carried out during a period of approximately 6 months (spring 2004). Five workshops will be planned during the spring of 2004. These workshops will last for two-three hours. The numbers of actors in the project design group will be approximately ten individuals. During the research project, a model of a selected care process/care problem will be developed in collaboration with actors in the group. The model should be based on the concept of patient -centered care and the discussion in the project design team will guide the modeling process. Issues to consider are for instance the care planning process, the communication process with the patient, cooperation between professions and units for maintaining continuity or the decision sharing between the patient and professionals.
>
> Information on present patient flows, and national and international guidelines for stroke patients will be used in the modeling process.
>
> A diagram of important variables will be developed together with the actors. Simulations of the model will be performed continuously throughout the process. The experimental condition of the model will be formulated together with the group participants.
>
> The study will identify variables determining the structural behavior of the patient care planning process. A second purpose is to explore policy interventions for improving the process.
>
> Research questions:
>
> Which is the main structure (variables) of the system underlying the care planning process?
> Which are the factors that influence the quality of the care planning process?
> What are some of the most important policies for the purpose of improving the care planning process?

Table 1 The project leaders project description

Background, needs and aims of the client system

Participants in the group modeling were representatives from the stroke unit, associated personnel and also representatives from the property owning and facilities management company of the county council. A new building is planned, into which the stroke unit is to be moved. This case was to be used as an opportunity for the research project, described earlier, to test their assumptions. According to the project leader the stroke unit had already submitted their needs for the new facilities. A doctor had stated that as long as they get 16 beds they would be satisfied. However, the property unit wished that the stroke unit should review their procedures and study ways to become more efficient in the use of resources. The project leader wished to develop a qualitative model showing how care planning could improve the efficiency of the system, measured in health outcomes for the patients. This meant that at the outset there were at least three sets of aims and problem definitions for different stakeholders.

Purpose

The purpose was to carry out a group modeling process, within very tight constraints on time and resources, while striking a balance between developing the group process and achieving a model, with which the group identified itself, and which also was useful for the purpose of the stroke unit and for the research of the project leader. The intention was also to spend additional time exploring the model for the mutual benefit of the project leader and myself.

As suggested in the title, the problem description appeared to be vague and the participating stakeholders had different agendas. Therefore it was a challenge to attempt to develop a model, which was to be meaningful for all the participants.

Research question(s)

The main research question was how to develop a model in a group process, with stakeholders with differing objectives and agendas? With my personal background as a trained and experienced process consultant a subsidiary question was how to combine the “soft” side of modeling, i.e. the group process, with the “hard”, structural side of system dynamics? At issue was also how to combine the quantitative and qualitative sides, of the project leaders research questions, in a relevant model?

Literature review

In this literature review I first look into what has been published in the field of group modeling in system dynamics. I then raise the issue of seeing this as a subset of a larger range of possible consultative interventions, pointing to what might be a suitable meta-theory for choosing interventions. During group modeling, processes occur between the participants. I therefore look into process consultation to find advice for the process leader. I make the point that effective group modeling attempts to influence the construct of meaning for the participants. Then I further explore research in group size, seating and the composition of the group. Finally I describe other attempts to model health services.

Group modeling

There are several articles in the system dynamics literature describing modeling in groups.

Vennix and Gubbels (Vennix and Gubbels 1990) describe a systematic, Delphi-like approach to knowledge elicitation in a health care setting. A combination of questionnaires and meetings were used to identify variables and their dependencies. The procedure was highly structured and the participants had a distinct role as experts. Implicitly the underlying problem appeared to be accepted and understood by all the participants.

However in a later article Vennix (Vennix 1999), describes what is probably the more common situation, i.e. the participants have different perceptions of the problem or may not even be in agreement that there actually is a problem, what Vennix describes as ”messy” problems. This is more in accordance with the constructivist viewpoint, described later in this paper. In this article Vennix says that the group modeling contains both procedure (structure and process (interaction among participants). Here he emphasizes the role of the facilitator.

This dichotomy between structure and process has also been addressed by Andersen, et al, in two articles (Andersen, Richardson, and Vennix 1997), (Andersen and Richardson 1997), where the authors propose a scientific approach and the use of ”scripts”. In (Richardson and Andersen 1995) they also propose five different roles in the group modeling support team. They suggest that the roles can be combined or distributed among the consultants and the client, but that all five roles need to be present:

> **Facilitator**
> Functioning as group facilitator and knowledge elicitator, this person pays constant attention to group process, the roles of individuals in the group, and the business of drawing out knowledge and insights from the group. This role is the most visible of the five roles as the facilitator constantly works with the group to further the model-building effort.
>
> **Modeler/reflector**
> This person focuses not at all on the group process but rather on the model that is being explicitly (and sometimes implicitly) formulated by the facilitator and the group. The modeler/reflector serves both the facilitator and the group. He thinks and sketches independently, reflects information back to the group, restructures formulations, exposes unstated assumptions that need to be explicit, and in general serves to crystallize important aspects of structure and behavior. Both the facilitator and the reflector/reflector in our experiments have been experienced system dynamics modelers.

Process coach
This person focuses not at all on content but rather on the dynamics of individuals and subgroups within the group. It has been both useful and annoying that our process coach is not a system dynamics modeler; such a person can observe unwanted effects of jargon in word and icon missed by people closer to the field. The process coach in our experiments has tended to serve the facilitator; his efforts have been largely invisible to the client group.

Recorder
Writing down or sketching the important parts of the group proceedings is the task of this person. Together with the notes of the reflector/reflector and the transparencies or notes of the facilitator, the notes and drawings made by the recorder should allow a reconstruction of the thinking of the group. This person must be experienced enough as a modeler to know what to record and what to ignore.

Gatekeeper
This role is filled by a person within, or related to, the client group who carries out internal responsibility for the project, usually initiates it, helps frame the problem, identifies the appropriate participants, works with the modeling support team to structure the sessions, and participates as a member of the group. Aware of system dynamics literature and practice but not necessarily a modeler, the gatekeeper is an advocate in two directions: within the client organization she speaks for the modeling process, and within the modeling team she speaks for the client group and the problem, The locus of the gatekeeper in the client organization will significantly influence the process and the results.

Table 2 Roles in group modeling

The idea of having “scripts” for group modeling might be considered to imply that it is possible to have heuristic procedures. However the notion of “messy” problems might be considered to imply the importance of “outcomes”, rather than method. Process consultants usually focus on “outcomes”, and may switch methodology during the process.

Vennix (Vennix 1996) proposes the following schema, for designing the overall process:

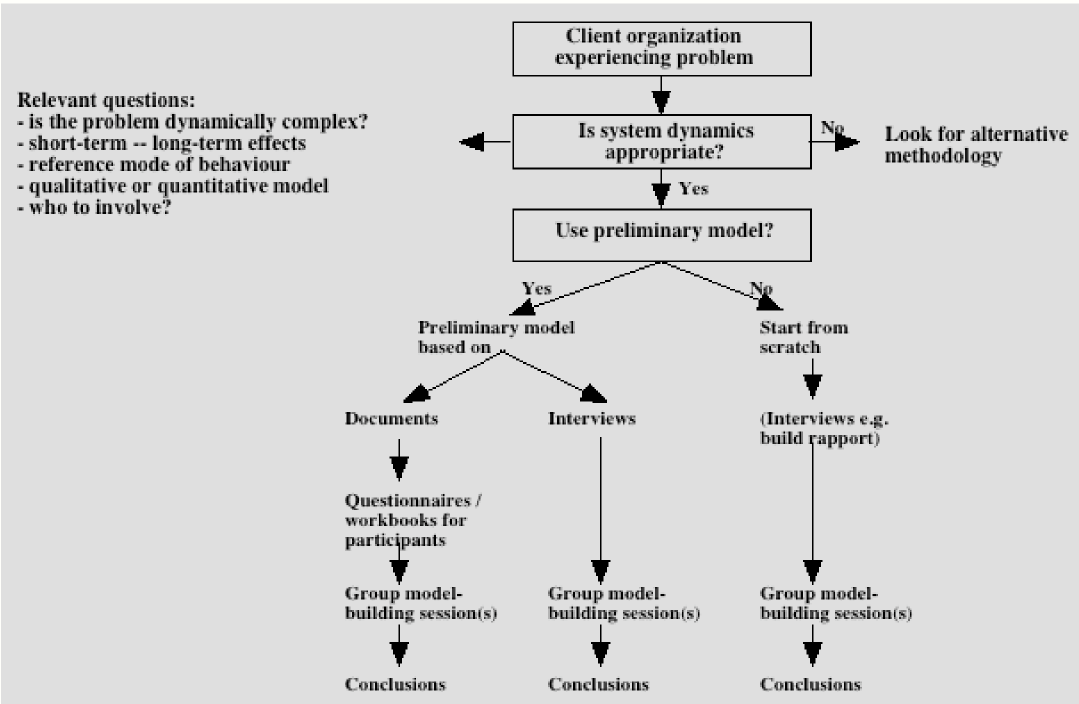


Figure 1 Vennix process schema

Vennix favors processes, where the consultant can study documents, or carry out interviews in order to build a preliminary model, which the group can work on. When this is not possible he suggests starting from scratch by brainstorming in the group to identify relevant variables, to put these together in a causal diagram and then to begin modeling. In this way the group step by step is introduced to the methodology.

Consultation

Having worked as a management consultant since 1988, my experience is that there is a multitude of opinions as to what consultancy is and how it can be approached. I find it useful to use frameworks to understand the multitude of possible approaches and the reasons for choosing one particular approach, Apart from Vennix schema; few of the articles on group modeling provide any diagnostics for choosing any particular form of intervention.

There are very few larger frameworks or meta-theories for the selection of consultative interventions and methodology. One such framework is Consulcube (Blake and Mouton 1986). It is a three-dimensional framework, where an analysis of the client, the focal issue and kind of interventions serve as selector of the intervention to use.

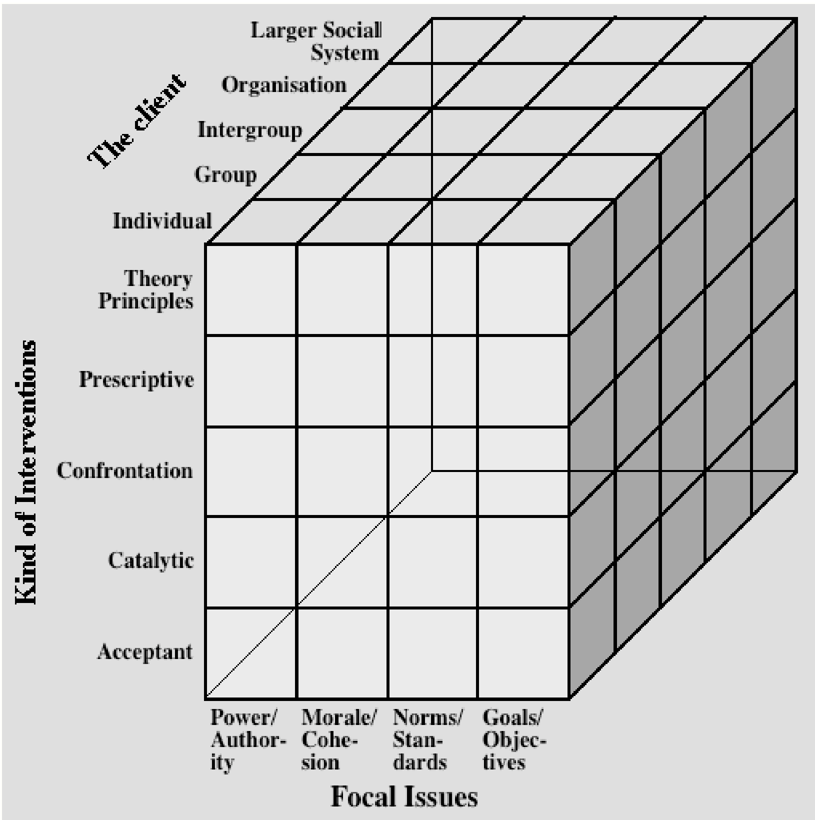


Figure 2 The Consulcube

The first step is to analyze the client. The system dynamics literature speaks of group modeling, without delving into how the group is constituted and what the consequences of that may be.

The first step in the Consulcube is to consider the client, is it:

- an individual,
- a group, which is an established group already working together,
- inter-group, where the intervention is to involve two or more groups, which may have differing agendas,
- an organization as a whole or
- a larger social system, such as a community?

Most group modeling will probably involve either an established group or an ad-hoc group (i.e. intergroup) consisting of members from different groups or organizations.

The second step in the Consulcube is to consider the focal issue at hand, is it a matter of:

- power/authority, i.e. about decision-making
- morale/cohesion, i.e. about organizational culture
- norms/standards, i.e. about operations, how things are done, or
- goals/objectives, i.e. about policy, why things are done.

Most system dynamics interventions are either about operations or policy, or both.

The final step is determining the form of the intervention(s), is it based on:

- theory/principles, i.e. the consultants refers to accepted theory or practice, which then is used as a common base for discussion and problem solving,
- prescriptive, i.e. a patient/doctor situation where the consultant is the expert carrying out the appropriate analysis and then prescribing the correct solution,
- confrontational, i.e. the consultant creates confrontation by holding opposing views or exposing behavior contradictive to espoused behavior,
- catalytic, i.e. the consultant designs and carries out a process, where the consultant is “neutral” as to the content of the process, but ensures that the process is effective, or
- acceptant, i.e. the consultant has a very passive role, mainly listening and nodding.

Before beginning the group-modeling process, its purpose needs to be declared. Most probably it will be concerned with improving operations (norms/standards) or providing the background for policy-making (goals/objectives).

As implied by the name group modeling involves a group. However, that group may be a natural group, such as a management team, or an ad-hoc group (inter-group) consisting of “representatives”, constituted for the need at hand. The distinction between the two will probably be important to make, when designing a group-modeling process. When entering an established group the consultant needs to be aware of the particular culture that the group has developed over time. When working with a mixed group the consultant needs to be aware of often hidden differing agendas and history of cooperation or non-cooperation between the parties of the group.

I would consider most group-modeling exercises as catalytic, where the consultant and the sd-method do not take sides in what is being modeled. The purpose of the consultant is to make sure that the process moves forward. However, it is probable that the consultant at times should be confrontational, i.e. question the hidden assumptions of the client. Although systems thinking and system dynamics are used as a theory, they are not theories of the solution, but to the solution process.

The knowledge elicitation by Vennix and Gubbels (Vennix and Gubbels 1990), appears to involve a mixed group from various parts of an organization, using theory and principles to identify norms and standards. Whereas his later article (Vennix 1999) he describes groups that normally work together, such as management teams.. The focal issue appears to be standards as much as attaining cohesion in the group. The interventions shift between catalytic (the process consultant) and theory (using SD methodology).

Process consultation

Using the Consulcube I proposed that the interventions in this case should be catalytic and at times confrontational. This is very much the basis of process consultation. Schein (Schein 1999) defines process consultation as *A philosophy about and attitude towards the process of helping individuals, groups, organizations and communities. It is based on the central assumption that one can only help a human system to help itself*. Schein goes on to describe ten principles for process consultation:

> **Always try to be helpful.**
> Consultation is providing help. Obviously, therefore, if I have no intention of being helpful and working at it, I am unlikely to be successful in creating a helping relationship. If possible, every contact should be perceived as helpful.

1. **Always stay in touch with the current reality.**
   I cannot be helpful if I do not know the realities of what is going on within me and within the client system; therefore, every contact with anyone in the client system should provide diagnostic in formation to both the client and to me about the here-and-now state of the client system and the relationship between the client and me.
2. **Access your ignorance.**
   The only way I can discover my own inner reality is to learn to distinguish what I know from what I assume I know, from what I truly do not know. I cannot determine what is the current reality if I do not get in touch with what I do not know about the situation and do not have the wisdom to ask about it.
3. **Everything you do is an intervention.**
   Just as every interaction reveals diagnostic information, so does every interaction have consequences both for the client and me. I therefore have to own everything I do and assess the consequences to be sure that they fit my goals of creating a helping relationship.
4. **It is the client who owns the problem and the solution.**
   My job is to create a relationship in which the client can get help. It is not my job to take the clients problems onto my own shoulders, nor is it for my job to offer advise and solutions for situations in which I do not live myself. The reality is that only the client has to live with the consequences of the problem and the solution, so I must not take the monkey of the clients back.
5. **Go with the flow.**
   All client systems develop cultures and attempt to maintain their stability through maintenance of those cultures. All individual clients develop their own personalities and styles. Inasmuch as I do not know initially what those cultural and personal realities are, I must locate the clients own areas of motivation and readiness to change, and initially build on those.

6. **Timing is crucial.**
   Any given intervention might work at one time and fail at another time. Therefore I must remain constantly diagnostic and look for those moments when the client's attention seems to be available.
7. **Be constructively opportunistic with confrontive interventions.**
   All client systems have areas of instability and openness where motivation to change exists. I must fins and build on those existing motivations and cultural strengths (go with the flow), and, at the same time seize targets of opportunity to provide new insights and alternatives. Going with the flow must be balanced with taking some risks in intervening.
8. **Everything is data; errors will always occur and are the prime source of learning.**
   No matter how carefully I observe the above principles I will say and do things that produce the unexpected and undesirable reactions in the client. I must learn from them and at all cost avoid defensiveness, shame, or guilt. I can never know enough of the client's reality to avoid errors, but each error produces reactions from which I can learn a great deal about the client's reality.
9. **When in doubt, share the problem.**
   I am often in the situation where I do not know what to do next, what interventions would be appropriate. It is often appropriate in those situations to share the problem with the client and involve him or her in deciding what to do next.

Table 3 Principles for process consultation

Working with groups

Process consultation usually takes place in groups. It can therefore be useful to note some points from research in working with groups. The literature in this area is overwhelming, many having roots in action research at the Tavistock Institute. Much of the literature is therapeutic in its nature or touches on process consultation. Here I build on Sjölund and Adizes. Sjölund (Sjölund 1979) takes up the points of group size and the placement in the room. He discusses studies made by Bales and Bourgatta in 1955 considering group size and if the number of participants is odd or even. First Sjölund introduces a table from Bales:

Odd number of participants			Even number of participants		
Size	Participation in %		Size	Participation in %	
	Highest	Lowest		Highest	Lowest
3	47	35-25	4	35	30-20
5	55	25-10	6	43	25-10
7	55	20-10	8	40	20-5

Table 4 Sjölund group sizes

Sjölund draws the general conclusion that group size is a determinant of the quality of the discussion in the group. The larger the group the more "air space" is taken by one or a few highly vocal people, while those taking little part grow more silent.

According to Sjölund, Bales says that groups with an odd number of participants more easily splits into subgroups with different opinions, and that Bales suggests that a group of five would be the ideal group size. In a smaller group fewer points of view would be represented, and in a larger group there would be opinions that were not expressed.

Sjölund questions this and proposes six as the ideal group size as it holds a better balance in both the balance of the discussion and the possible number of held views. This means that when selecting participants for a group modeling process one needs to strike a balance between group sizes and adding all possible competences and stakeholders to the group.

According to Sjölund, the spatial structure of the group is more important than usually considered. People on the edges may have difficulties joining the conversation, and passive people seek such placement. People who are interested in participating place themselves centrally. People also tend to seat in clusters. Group modeling builds on active participation. Spatial factors thus need to be considered. Avoid seating with sharp corners and match the number of chairs with the number of participants.

In group modeling, the intention is to arrive at a useful model. This means that the group needs to be efficient and that it has the capability to take decisions. According to Adizes (Adizes 1992),when a group holds the needed contributions of authority, power, and influence over a decision or problem and are in agreement on what to do, they are coalesced. When that is the case it holds the control of the design of a good solution and its implementation. In other words, its ability to decide and to implement efficiently and effectively is very high.

Authority is defined as the legal or formal right to take a decision, usually that of a manager. A person with power has the possibility to grant or withdraw expected contribution, e.g. a specialist or a union representative. People with influence have personal connections, which they can use in a political sense; they can also be experts in the sense that they have special knowledge. Adizes framework can be useful when selecting the participants of the group.

Epistemology and the construction of meaning

How do we know what we believe to know? (Watzlawick 1984)

In the introduction to *The invented reality* Watzlawick (Watzlawick 1984), tells of an unpublished experiment of his colleague Alex Bavelas: The experimenter reads along list of number pairs to the subject, who after each pair has to state if the pair “fits” or not. Unknown to the subject the experimenter randomly states if the subject is correct or not, distributed along half a bell curve. In the beginning all suggestions are wrong, and at the end most are right. After the experiment the subject is told how the experimenter answered. Usually the subject refused to accept that there was no pattern, but insisted, sometimes aggressively, that his or her interpretation was correct, that they really had discovered a pattern, no matter what the experimenter said. This anecdote is usually seen as an archetype of how human beings construct meaning. It is also interesting, as the constructed meaning in this case has no bearing on reality.

When entering a group-modeling process, all participants will have their own sets of perceptions of their personal realities, what Watzlawick and others call constructions. Watzlawick makes the point of how entrenched such constructions are and that they are not readily changed. This emphasizes the suggestion made earlier that group modeling can be confrontational, in the sense that it can reveal “truths”, which challenge the “weltanschauung” of the participants. It is also important to realize that if such a challenge is counter to the prevailing view of participants they also can become very confrontational and challenge the assumptions of the model. It is therefore very important to do as Schein suggests and follow the flow of the group, so that the participants have brought the assumptions of the model forward.

How can I know what I think until I see what I say? (Weick 1995) Here Weick opens up an interesting point, that the person is not aware of their construction not only until it is spoken, but also written down. It could also mean that there exists a possibility to use group modeling to clarify the participants own thinking, using the rigorous language of systems thinking and system dynamics.

In *Sensemaking in organizations* Weick (Weick 1995) proposes seven properties of sensemaking:

1. **Identity**: The recipe is a question about who I am as indicated by discovery of how and what I think.
2. **Retrospect**: To learn what I think, I look back at what I said earlier.
3. **Enactment**: I create the object to be seen and inspected when I say or do something.
4. **Social**: What I say and single out and conclude are determined by who socialized me and how I was socialized, as well as by the audience I anticipate will audit the conclusions I reach.
5. **Ongoing**: My talking is spread across time, competes for attention with other ongoing projects, and is reflected on after it is finished, which means that my interests already may have changed.
6. **Extracted cues**: The "what" that I single out and embellish as the content of the thought is only a small portion of the utterance that becomes salient because of context and personal dispositions.
7. **Plausibility**: I need to know enough about what I think to get on with my projects, but no more, which means sufficiency and plausibility take precedence over accuracy.

Table 5 Properties of sensemaking

However, the last point indicates a possible personal threat to the participants. Their personal constructs, which they consider as plausible, may be shaken by the accuracy of a rigorous model. Weick writes about "retrospective sensemaking, where people, after the fact, construct their path to where they now are.

Gergen (Gergen 1999, 2001), writes on the theme of social constructivism, how groups of people through conversation make constructs and create meaning together. This is also a consideration when group modeling, such at the one at hand, where there are at least two groups of stakeholders. It is probable that each group have their particular ongoing conversations, leading to different constructs, so that a modeling process needs to make participants understand not only what makes sense to them selves, but also what makes sense to others.

In this perspective group modeling can be seen as a process during which individual and social constructions are developed and challenged, The group uses systems thinking and systems dynamics to makes sense together, discovering and creating a common view and construction. This also means that one has to thread carefully during group modeling so that challenges to the present constructions are not perceived as threats. It is important that the group is active in the sense that they themselves are in charge of discovery and the unveiling of new truths. The job of the process consultant is to be in pace with the group and use systems thinking and system dynamics to capture their assumptions and to create new learning by mapping the assumptions on causal loop diagrams and stock and flow diagrams.

Modeling health services

The project leader and I have independently reviewed health services models presented in System Dynamics Review, at the latest conferences and used a bibliography prepared by the Health Policy SIG of the System Dynamics Society. We also have searched PubMed for relevant sources.

Wolstenholme (Wolstenholme and Stevenson 1996) has described and modeled how lack of beds in community care delays leads to patients being held in hospitals longer than necessary. In (Wolstenholme 1999) system dynamics is used to propose the creation of intermediate care to handle the interface between hospital care and community care.

Cavana et al (Cavana et al. 1999) describes the different world views of clinicians and policy managers. This can be seen as an indication that a mixed group with different stakeholders may have differing and even divergent views on the same issue.

Wolstenholme, (Wolstenholme et al. 2004) has published an interesting paper following patient flows across unit boundaries. However, these, such as most published health care models are quantitative and continuous. Petersen (Petersen, Breddam, and Jest 2004) is one of the few exceptions, modeling discrete patient flows, with the aim of identifying bottlenecks and sector overcapacity.

One conclusion after an extensive literature review is that the intent of the project leader to explore qualitative modeling in health care planning appears to be novel and unresearched.

At the conference of the System Dynamics Society in 2004 this author presented a paper (Holmström and Elf 2004), also in a Health Care environment, using discrete modeling and incorporating both qualitative and quantitative parameters. Because of the discrete modeling the model showed a lot of “noise”, which was questioned by one of the reviewers. However, my experience is that a model, which does not reflect the strong variations in workload etc, is not seen as adequate representations of reality, by hospital staff. In this case the problem at hand was also very clearly a matter of qualitative issues, tied to the physical flow of patients and staff.

System dynamics

In any systems modeling it is useful to keep in mind Stermans (Sterman 2000), proposed steps of the modeling process:

1. Problem articulation (boundary selection)
    - Theme selection: What is the problem? Why is it a problem?
    - Key variables: What are the key variables and concepts we must consider?
    - Time horizon: How far in the future should we consider? How far in the back lie the roots of the problem?
    - Dynamic problem definition (reference modes): What is the historical behavior of the key concepts and variables? What might be their behavior in the future?

2. Formulation of dynamic hypothesis
   - Initial hypothesis generation: What are the current theories of the problematic behaviors?
   - Endogenous focus: Formulate a dynamic hypothesis that explains the dynamics as endogenous consequences of the feedback structure.
   - Mapping: Develop maps of causal structure based on initial hypotheses, key variables, reference modes and other available data, using tools as
     - Model boundary diagrams
     - Subsystem diagrams
     - Causal loop diagrams
     - Stock and flow maps
     - Policy structure diagrams
     - Other facilitation tools
3. Formulation of a simulation model
   - Specification of structure, decision rules
   - Estimation of parameters, behavioral relationships and initial conditions
   - Tests for consistency with the purpose and boundary
4. Testing
   - Comparison with reference modes: Does the model reproduce the problem behavior adequately for your purpose?
   - Robustness under extreme conditions: Does the model behave realistically when stressed by extreme conditions?
   - Sensitivity: How does the model behave given uncertainty in parameters, initial conditions, model boundary and aggregation
   - …Many other tests
5. Policy design and evaluation
   - Scenario specification: What environmental conditions might arise?
   - Policy design: What new decision rules, strategies and structures might be tried in the real world? How can they be represented in the model?
   - "What if…" analysis: What are the effects of the policies?
   - Sensitivity analysis: How robust are the policy recommendations under different scenarios and given uncertainties?
   - Interaction of policies: Do the policies interact? Are there synergies or compensatory response?

Table 6 Steps of system dynamics modeling

Methodology

Plan for the group meetings and modeling

Using the Consulcube (Blake and Mouton 1986) as a metatheory to analyze the group modeling at hand , my judgment was that the client system at hand was Intergroup. There were to be two major categories of attendees, care providers and architects/facility managers, each in turn consisting of further subgroups. Already at the outset of the process there were indications that the different groups had different agendas and perceptions of the problem, and maybe even be in disagreement as to if there actually was a problem.

The purpose of the group modeling was to arrive at a useful sd-model, i.e. the focal issue probably mainly was concerned with operational procedures, i.e. Norms and Standards. It could also have involved policy issues, i.e. Goals and Objectives.

The interventions mainly needed to be Catalytic, eliciting knowledge and building structure based on the statements of the group. At times it would probably be necessary to use the results of the model to challenge the group, i.e. using Confrontational interventions.

Since this was an ad hoc-group it would not be necessary to build more cohesion than needed for managing the process itself.

The group modeling was to consist of five modeling meetings, preceded by an introductory meeting describing the background of the project and it's objectives. Each meeting would take two hours. The allocated time was short for an in-depth group modeling, so some work was be done between meetings to organize the outcome from the previous meeting and prepare for the next.

The scope of the project leaders research questions was too wide to be covered in so few and short modeling sessions. We decided to aim for a simplified model, which could be elaborated on. This meant that the focus of the group modeling session was be to be helpful to the participants and aiding them in discovering what was important for them (Schein 1999).

In principle we intended to follow Vennix (Vennix 1996) suggestion of beginning from scratch, when one has not been able to build a preliminary model based on interviews or documents.

During the first meeting we planned to use brainstorming techniques to elicit both health and room related parameters, affecting the outcomes of the stroke treatment process. Time allowing we intended to start causally linking some parameters together.

Between meetings one and two I was prepare a causal diagram together with the project leader. The second meeting was to begin by explaining systems thinking notation and then letting the prepared causal diagram unfold step-by-step inviting discussion and change. The intent was to finalize the causal diagram.

The third meeting was to be an introduction to sd-modeling. Terms and notation was to be introduced, beginning with a very simple patient logistics flow. Modeling would then follow the flow of the discussion in the group.

Between the third and fourth meeting statistics and data was to be collected so as to have a fairly substantial logistics model at the fourth meeting and then adding qualitative variables. Between meetings four and five the model was be finalized and presented at the fifth meeting for discussion and conclusions.

The intention was to first build a model that replicated the present behavior of the system, and then to revise it to reflect any planned organizational or other changes. The modeling process was in principle to follow Stermans schema (Sterman 2000), with the exception of not fully developing the causal loop diagrams before moving on to sd-modeling, as proposed by Vennix (Vennix 1996).

During the group modeling I was to have the roles of facilitator, modeler and process coach. The project leader was to have the roles of gatekeeper, reflector and expert.

Expert modeling

The plan was that when the group modeling was concluded, then modeling was to continue in a smaller group consisting of the project leader and me. The intention was to add to and refine the model, so as to be useful in the research program of the project leader.

Project meetings

Meeting	Planned	Revised	Actual
Contracting project			4/2
Meeting with project leader			5/2
Meeting with project leader			26/2
Group modeling 1	19/2		9/3
Meeting with project leader			18/3
Meeting with project leader			26/3
Group modeling 2	9/3	31/3	5/4
Meeting with project leader			22/4
Meeting with project leader			23/4
Group modeling 3	31/3	22/4	4/5
Meeting with project leader			19/5
Group modeling 4	22/4	10/5	24/5
Meeting with project leader			25/5
Meeting with project leader			26/5
Group modeling 5	10/5		3/6
Meeting with project leader			23/6
Meeting with project leader			19/8
Meeting with project leader			25/8

Table 7 Project meetings

There was also an initial meeting with the group on 31/1, when the background to the project was given and some preliminary discussions took place. I did not attend this meeting as my part in the project then had not been finalized.

Compared to plan, there was some initial turbulence regarding the dates. The first group meeting 19/2, was moved at close notice, and a new set of dates was decided. However, at the first meeting it was clear that the schedule had to be revised a second time. All changes were due to the difficulties of getting such a large group of people on finding suitable dates.

Each meeting was scheduled to take 2 hours. In reality this was shorter as people arrived late and took a coffee break.

Initially it was intended that I meet with the project leader 6 times before and after meetings. We actually had 12 meetings. Much of this was related to difficulties in fact-finding mainly patient statistics and medical evidence.

My original estimate was that 160-200 hours would be needed for the group modeling, project meetings and work in-between meetings. For cost reasons this was cut down to 80 hours, which put very tight limitations on the scope. The project leader and I were in agreement to do joint additional work to expand the model. When the project was terminated I had worked approximately 250 hours. The additional time was mainly due to delays in receiving data.

The group

The group was to consist of 13 people, in the following roles, apart from the project leader and myself:

- Stroke nurse, contact with rehab, primary care and national stroke registry
- Ward manager, stroke, neurology and diabetes
- Manager neurology open clinic
- Care development, medical clinic
- Auxiliary nurse stroke
- Head physiotherapist, medical clinic
- Manager medical clinic (doctor)
- Doctor, neurologist
- Facility manager
- Health planner, county council (liaison between care and facility mgmt)
- Planner at the facility management company (former nurse)
- Architect, also active in the research project at Chalmers
- Architect

My impression is that the group was composed so as to be representative of all the involved stakeholders. However, the neurologist did not attend any meetings. The manager of the clinic only attended the first meeting. The attendance was high among the others, there usually were 11+2 people present.

According to Sjölund this would lead to a high skew between the most active and the least active. The sessions were taped, but the quality is such that it is difficult to identify the speakers. However, my strong impression is that about one third of the participants were significantly more active than the others. Those most active were:

- Stroke nurse, contact with rehab, primary care and national stroke registry
- Ward manager, stroke, neurology and diabetes
- Head physiotherapist, medical clinic
- Planner at the facility management company (former nurse)

Using Adizes (Adizes 1992), definition of a group capable of taking decisions, this group did not have CAPI (coalesced authority, power and influence). The manager of the clinic only took part in the first meeting, meaning that the group did not have a participant with the authority to take decisions. Since the neurologist did not attend, no doctor was present, with his or her expert perspective.

However it is notable that of the four people most active, the three from the care-giving side all held power held in their roles and the fourth from the facility management company had strong influence from her knowledge of care and her position in facilities.

The four most inactive could probably have been excluded from the group, without any problems.

Sjölund notes that people sitting on the edges can become marginalized and that people wishing to be active tend to take center seats. The most active people either took any place at the bottom of the U or in or close to the middle of the long-sides.

All group sessions were in the same room, with seating in u-form. Tables and chairs took up so much space in the room that it was difficult to move about. This meant that it was very difficult for the participants to spontaneously get up and be active at the whiteboard. The room and seating were more appropriate for lectures than group processes.

Boundary issues

Most stroke patients arrive by ambulance. All pass the emergency rooms of the hospital. The shorter the time is between the stroke and coming under care, the better chances for survival and for the future health status of the patient. From ER the patients are moved to the stroke ward and some of them afterwards pass the rehabilitation ward. When patients are ready for discharge from the hospital they move into community care, independent living or independent living with support. After discharge, responsibility for the patient is moved to the primary care, where follow-up and treatment has a significant effect on the re-occurrence of stroke.

The main purpose of the project was to study the stroke ward, so that was the main boundary of the modeling. However international and national guidelines recommend that the rehabilitation is included in the stroke ward. The hospital in Falun has decided to keep the two wards separate. But all international and national statistics and evidence include the rehabilitation. This means that for the purpose of making national and international comparisons rehabilitation needs to be included in the model.

The progress of the project

The introductory meeting 31/1

I did not take part in the introductory meeting 31/1 as my role was then not yet finalized. However I have access to the minutes. The research leader presented the project. The architect involved in the research project took up the importance of operational development as the foundation for the design of the building. In the minutes I particularly noted the problem definition of the ward:

To few beds (8-10 at the stroke unit), leading to that patients are placed on other wards. To be prepared for the stroke patients, the wards needs to have a capacity utilization of 85%, which now is 102%.

The number of stroke patients will increase by 30% over a 10-year period??

The facilities are not entirely adapted to the needs of the stroke unit

The staff (doctor, stroke nurse, occupational therapist and physiotherapist) has to move between wards, which takes time.

Group meeting 1; 9/3

The plan for this meeting was to use brainstorming techniques to elicit both health and room related parameters, which affect the outcomes of the stroke treatment process. Time allowing we intend to start causally linking some parameters together.

However, the project leader recapitulated the purpose of the project. This and the ensuing discussion took up the first of the two allotted hours. Two interesting statements of purpose were made during the discussion.

The manager of the clinic stated that under no circumstances should the need for new and adequate premises for the stroke unit be questioned.

The facilities manager stated that staff costs, is the largest cost segment of the county council. Therefore it was in the interest of the facilities company to engage in discussion how facilities could be designed so as to promote efficiency and lower staff costs.

The project leader reiterated the fact that there are both national and international guidelines for the stroke process. We then proposed that we begin the identification of care related parameters by listing quality indicators of the guidelines:

- Comparisons with national stroke registry
- Percentage registered
- Autopsy – cause of death
- Trained staff
- 80% occupied beds
- Max 15 beds

- Competence certificates
- Individual care discussions with patients
- Follow-up by doctors

Once these parameters were listed we explained that these probably were only a few of the qualitative care related parameters that influence the health outcomes of the patients. We then elicited additional parameters and noted them on the whiteboard. This was done with brainstorming-like techniques. We supported the addition of more parameters and played down any attempts to discuss or criticize.

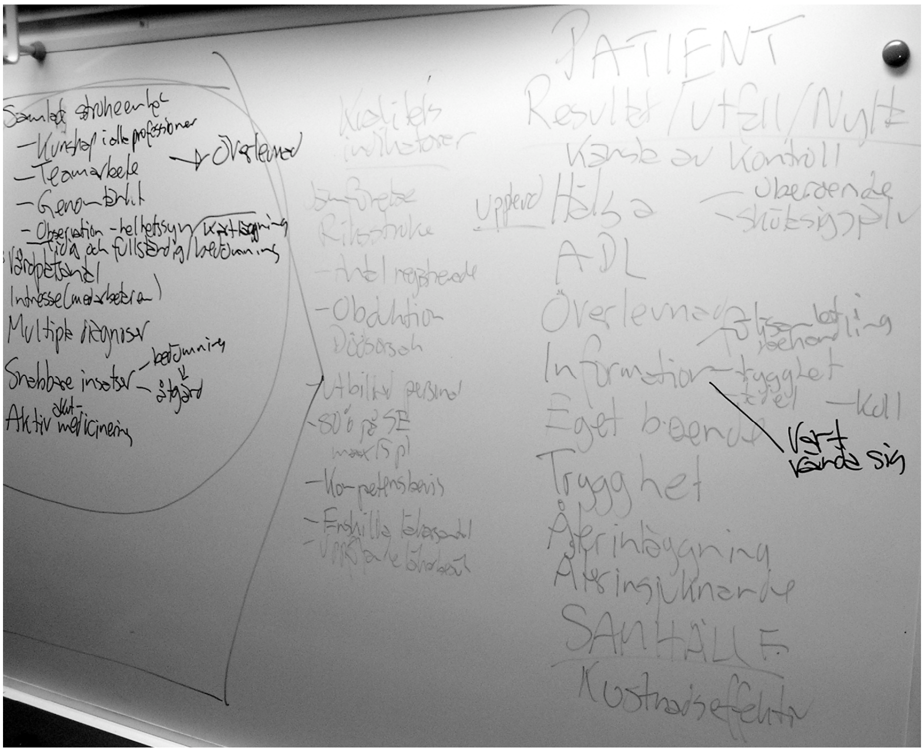


Figure 3 Care parameters

- United stroke unit
    - Knowledge from all professions
    - Teamwork
    - Well thought through
    - Observation – holistic
    - Early and complete investigation
    - Survival
- Number of beds
- Interested staff
- Multiple diagnosis
- Faster action from observation to intervention
- Active emergency medication
- The patient
    - Outcome, result
    - Feeling of being in control

    - Perceived health status
        - Independent
        - Manage on one's own
    - ADL
    - Survival
    - Information
        - Follows the treatment
        - Security
        - Control
        - Take part
        - Who to turn to
    - Independent living
    - Safety
    - Reoccurrence
- Society
    - Cost effective

At the first meeting I handed out a preliminary list of data, which I expected would be needed for the modeling. The head of the clinic stated that he had medical evidence and statistic, which would be useful for the qualitative modeling.

Goal ambiguity

After the first meeting it the goal ambiguity became more obvious.

At the introductory meeting, the manager of the clinic, made statements indicating that the caregivers see the problem mainly as an issue of capacity. As if their position could be abbreviated to “Give us more beds, and allow us to reduce bed utilization”.

The facilities people want the caregivers to work through their processes, so as to become more efficient. Their position might be abbreviated as “Redefine your work processes and tell us what facilities you then need”.

The project leader sums up her position in an email to me: “It is not sufficient for me to ask the group what they think of the instrument as such, since the project entails to create a model good enough to answer some of the vital questions of hospital care”. I see her position to use the work in the group to address larger issues, than the group itself probably will take up spontaneously.

However, at this point I was not overly concerned about the somewhat different aims of the stakeholders in the group. The project leader and I had spent quite some time discussing the general findings of medical evidence in the treatment of stroke.

There is a Swedish national stroke registry (Riks-Stroke 2002). There is an international group The Cochrane Collaboration, which has a stroke group, gathering medical evidence and statistics. There appears to exist a lot of evidence of qualitative factors leading to better health outcomes for stroke patients.

My hypothesis at this stage was that we first identify relevant variables and put them together in a causal loop diagram. Then move on to building a quantitative patient flow model and then "piggy-backing" the qualitative variables, for which there exists medical evidence. In this way the ward would get their quantitative analysis, the facilities people would get the work processes on the table for discussion. And the project leader would get her model incorporating care and room variables.

Between meetings 1 and 2

After the first meeting I began preparing a causal loop diagram based on the discussions. The project leader and I met and revised the diagram to the following:

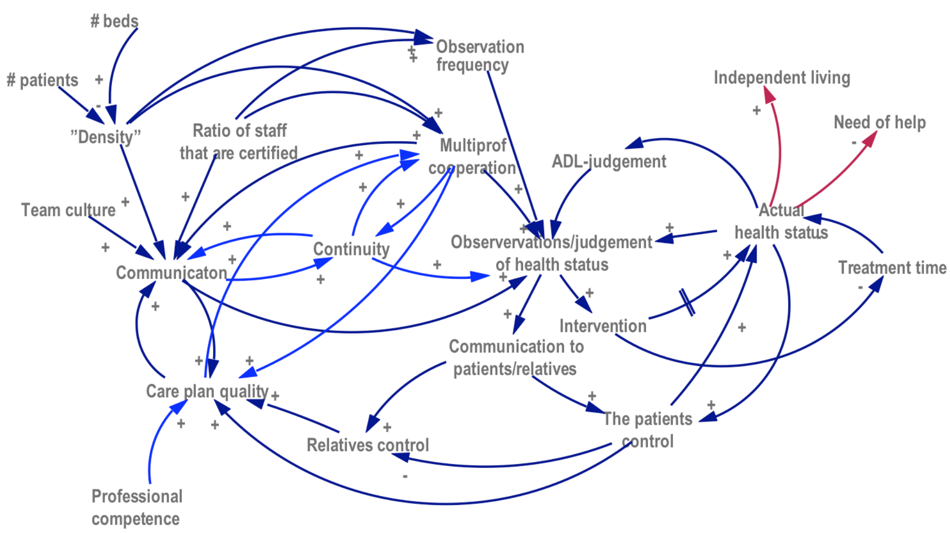


Figure 4 Causal loops - care parameters

We decided not to identify and name individual loops. We did note that all loops were reinforcing, which naturally is the case in a healing system.

For the second meeting I prepared a set of slides letting the causal diagram above unfold.

Meeting 2; 5/4

The revised plan for this meeting was to quickly repeat the work done at the previous meeting, present the causal diagram and start identifying room related variables. The recapitulation of the highlights of the previous meeting is important in group processes; one needs to reconnect to the previous meeting so that one can continue. This was done with the use of a slide reiterating the identified parameters.

I then showed the slides letting the causal diagram unfold step-by-step, inviting discussion and asking for clarifications at each step. The loops that were added in each step were colored red, so that they would be seen easily. The slides are shown below, in reduced size so as to show the principle.

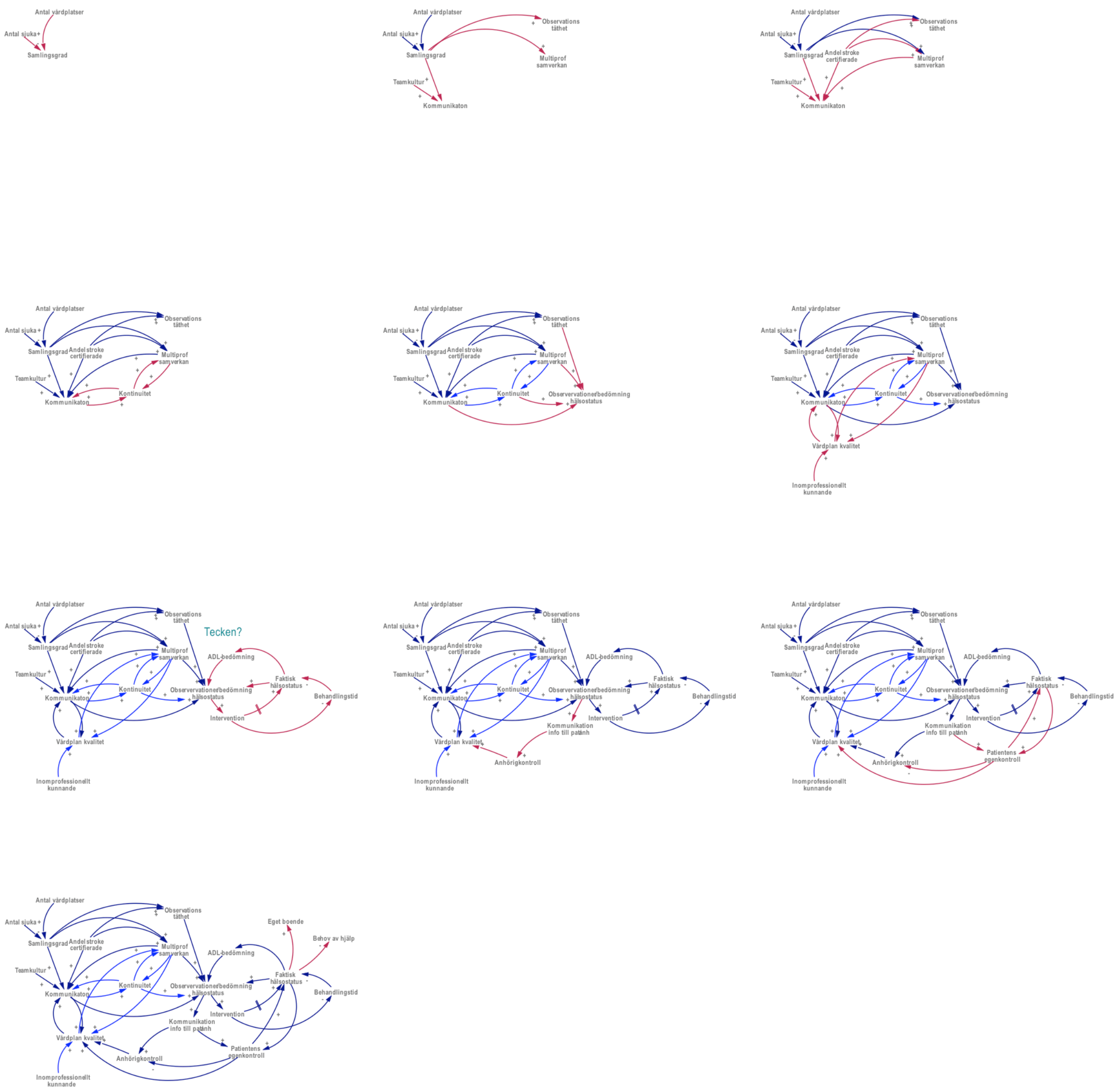


Figure 5 Presentation care parameters

The working through of the loops went very well. Many of the participants were actively involved in discussions, clarifying terms and loops. After the presentation we moved to Vensim and made changes together. The participants were not inclined to simplify the diagram; the tendency was instead to add more detail. This was the final result:

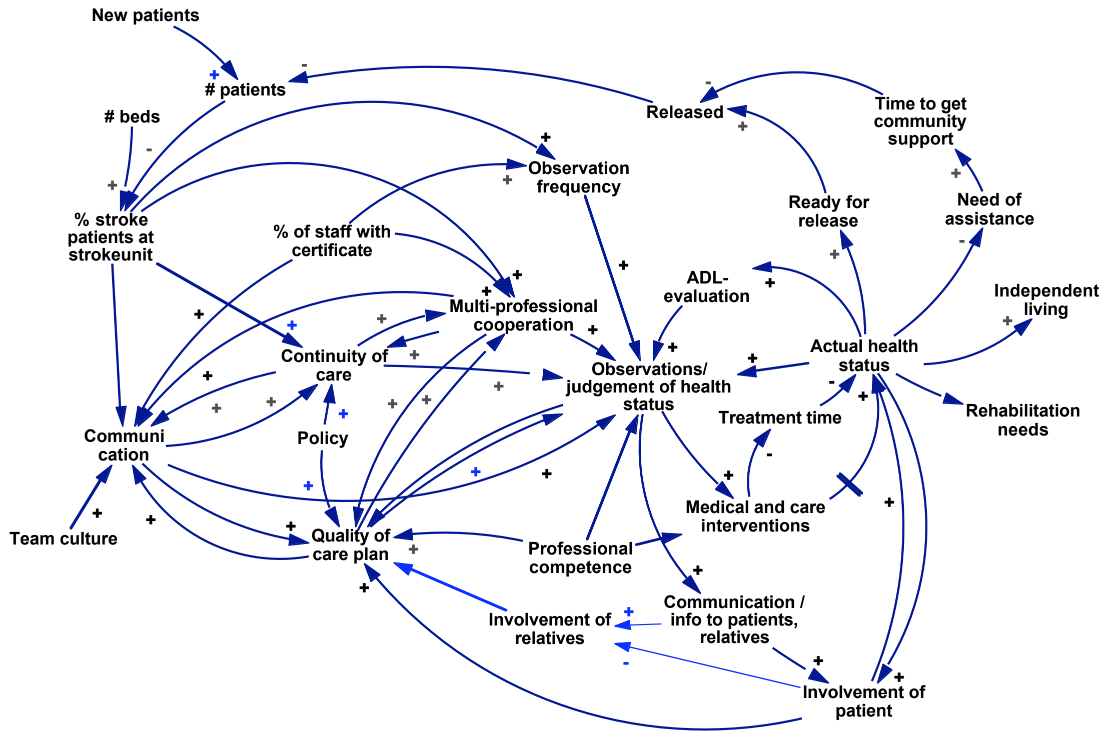


Figure 6 Revised causal loop - care parameters

After the exercise on of the participants commented that although she understood and agreed with the results, she would never be able to tell others about the complicated diagram. We then moved to brainstorming and noting room-related variables in a similar manner to getting the care-related variables at the first meeting. The participants were now fairly familiar by what we meant by both parameters and causality, so some initial causality was noted already during the elicitation.

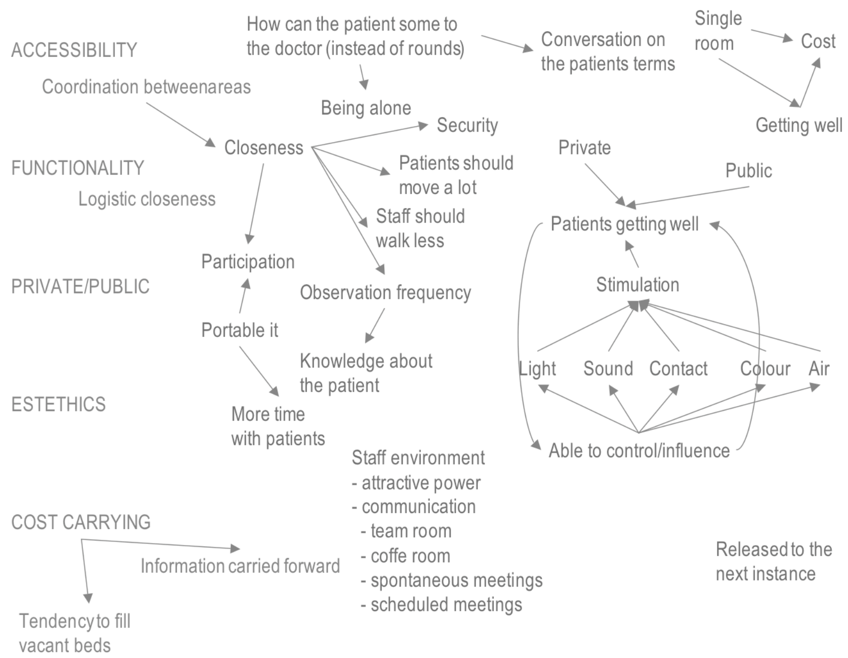


Figure 7 Room parameters

Between meeting 2 and 3

Before meeting the project leader I had prepared a preliminary causal loop diagram with the room variables. After discussion and revision it looked like this:

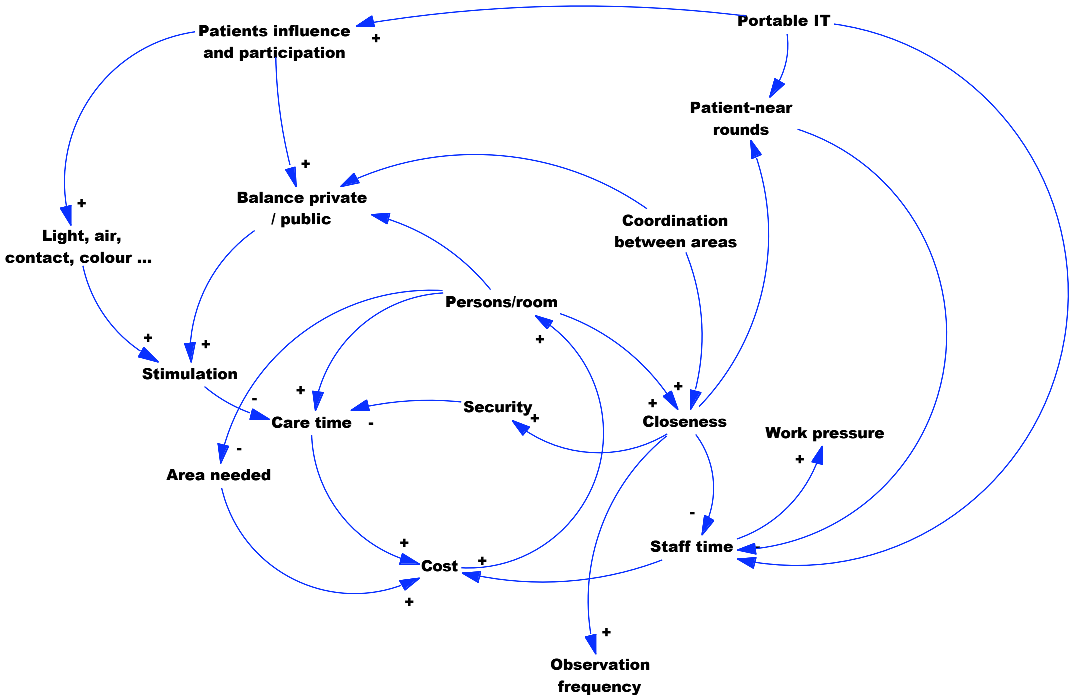


Figure 8 Causal loops - room parameters

We decided not to combine the two causal loop diagrams into one, as the overlapping variables would make the combined diagram very "messy". There would be little value added by making the diagram more complicated. We decided to adhere to the original plan and move on to basic system dynamics modeling at the third meeting.

Between the meetings I began to draw up a preliminary patient flow model. The purpose was to have a mental model of how to proceed in an interactive modeling process at the third group modeling session. The initial concept was to start out basic model sector with patient flows. Once the logistics flows were in place the intent was to "piggyback" co-flows and sectors for staff resources, facility resources and the development of the illnesses.

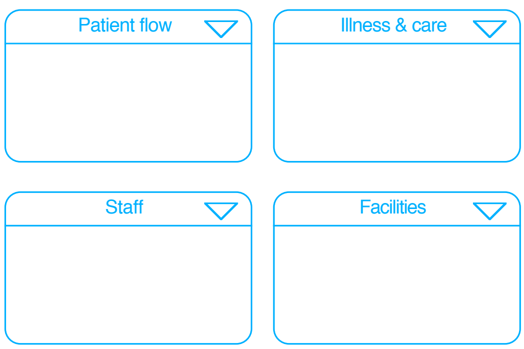


Figure 9 Initial hypothesis - model sectors

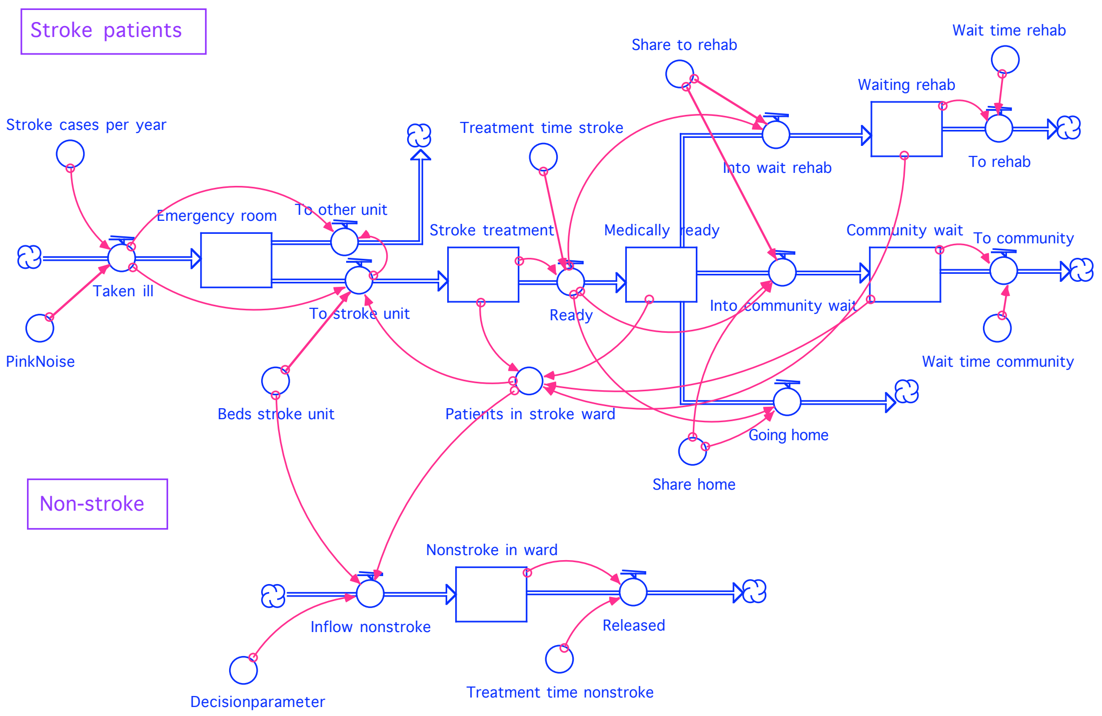


Figure 10 Initial hypothesis - stock and flow diagram

I also sketched an initial model, and discussed it with the project leader. At this stage we knew that there was an inflow of 462 stroke patients per year and an average total time in the ward of 4,2 days. The purpose of the model was to recognize that when patients are medically ready for release, many remain, waiting for beds in rehab or community care. We knew the share of patients going to rehab, community care and home. Although at this stage I accidentally omitted deceased patients. We were also aware that there were non-stroke patients in the ward, but did not know how decisions were made to admit these.

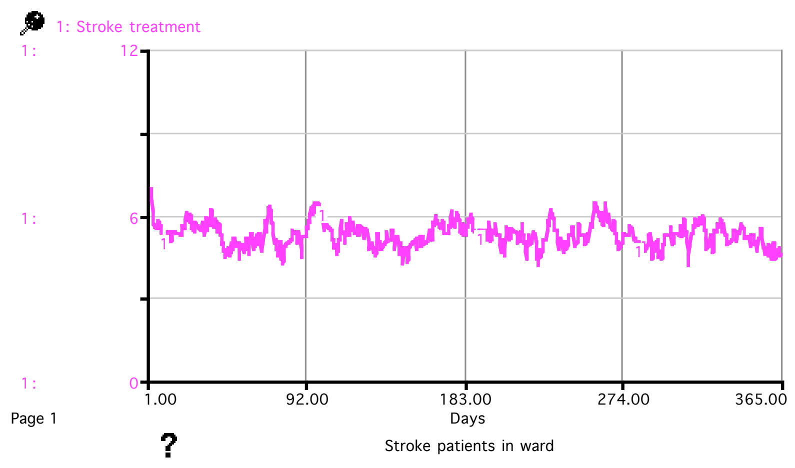


Figure 11 Initial hypothesis - patient stock diagram

A quick analysis showed that stroke patients occupied less than six beds. Since ward management wanted to have 16 beds the discrepancy puzzled us. Intuitively it seemed as if not all patients were accounted for.

In the preliminary model I used a pink noise function to create a variable inflow of patients. In a more developed model it would probably be better to use functions so as to create a discrete flow of patients. But my intent was to initially model a continuous flow and not confuse the group by adding to many functions in the beginning.

Group meeting 3; 4/5

The meeting began by revisiting the last meeting by showing the slide with the room related variables and then moving to the causal loop diagram. There was little discussion at this time. We then showed the two sets of causal loop diagrams together and noted that they would connect at several points, but that we would not do that as it would become to messy to overview.

We then moved into system dynamics, and I used bathtub dynamics as a metaphor to explain the notation. First I drew the stock of patients in the ward. Added an inflow. Explained the "valve" and added a variable for the total number of patients per year. Opened up the valve and put in the equation to get the flow of patients per day. Then drew a diagram of the number of patients in the ward. Noted that it naturally was skyrocketing, as there was no outflow. Added an outflow, a variable for average treatment time and an equation in the outflow. At each point verifying the data with the group. This is what we then had:

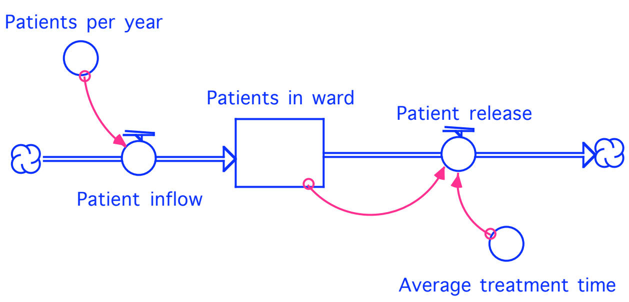


Figure 12 Meeting 3 - initial simple model

Model equations in appendix, page 62.

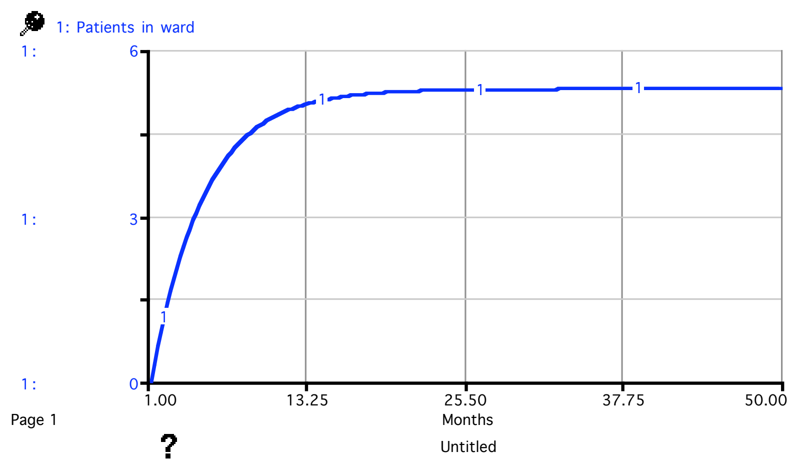


Figure 13 Initial simple model, stock diagram

The ward (stock) was initialized at zero, and the stock stabilized at 5,3, as noted when building the preliminary model. So far things had been easy and everybody seemed to understand the notation and what the model was doing.

I then noted that we only had about 5 people in the ward, that they had 12 beds and that as far as I understood the beds were not empty, so where did all the others come from? Was there something wrong in the data?

The head nurse responded that it was not strange at all. The numbers of stroke patients (462 per year) were patients, that when released from the hospital had a stroke diagnosis. In addition there were patients that were admitted on a suspected stroke diagnosis and later were released with a different diagnosis. "How many are these", I asked. "Don't know", was the answer, "but we can find out until the next meeting".

During the discussion I had added a parallel flow of patients. Since we did not have any data on the number of patients, we estimated the number of beds occupied by these (approximately 4 beds), assigned them the same treatment time and iteratively worked out an annual number of patients. This meant that we now had accounted for 10-11 occupied beds, so we moved on.

We then added three additional outflows, so that we could account for patients who continue to rehabilitation, go to independent living, go to community care or are deceased. We added a stock to each flow (except deceased), indicating that there is a waiting time between the moment a patient is medically ready for release and when the actual release is made.

This meant that the total time in the ward (average 4,2 days) needed to be split up into two time slices, actual treatment time and waiting time. No data was available for the split. But the average total time was known as well as the total time for patients waiting for community service. We decided to use the available times do roughly estimate the split times, until further data was available.

The discussion in the group was quite lively, so I managed to add to the model and explained afterwards, which flows I had added and why. This is what the model now looked like (see next page):

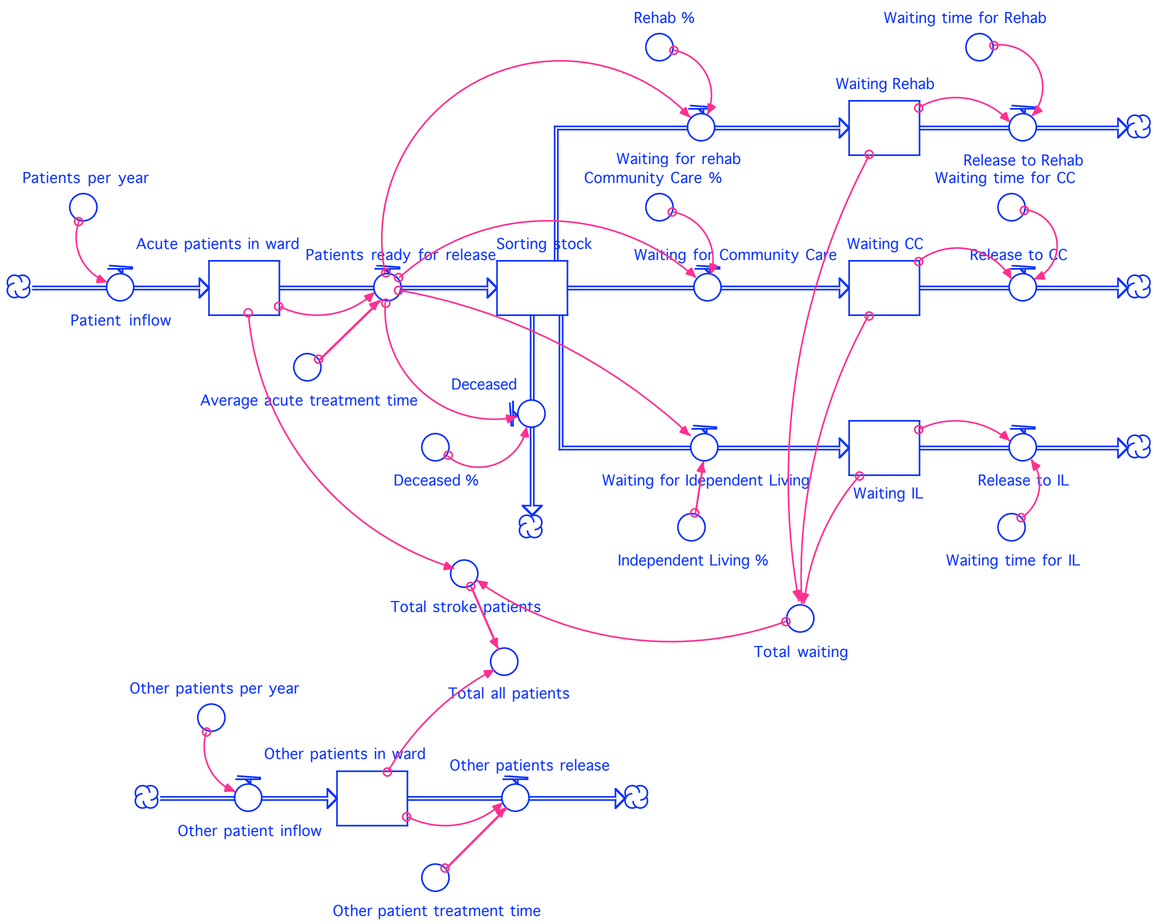


Figure 14 Meeting 3 - final model

Model equations in appendix, page 62.

At this point I created the following graph of the most interesting stocks:

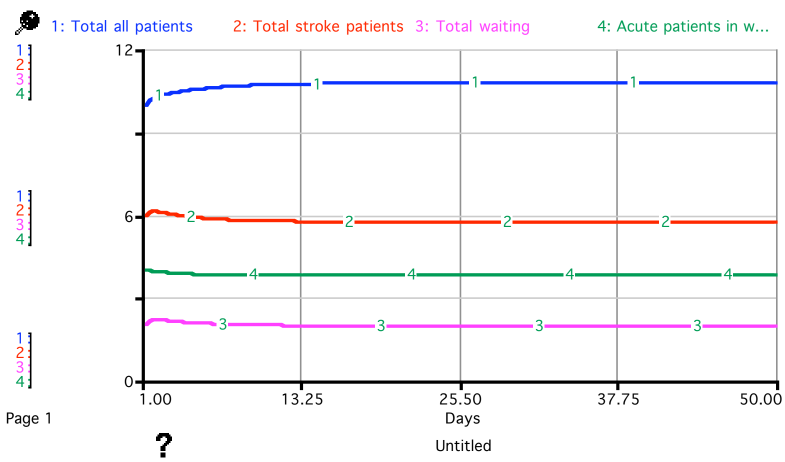


Figure 15 Main stocks of final model, meeting 3

Although using rough estimates for waiting times and the patients admitted with a stroke, but released on another diagnosis, we appeared to account for the use of most beds.

The number of actual stroke patients remained around six. An additional five non-stroke patients were in the ward, which raised the issue of where these patients best should be treated. That remained an open issue throughout the whole modeling process as no doctor came to the meetings.

Of the six stroke patients about four were in the acute stage and two were waiting to be released to other care forms. This made the architects rally interested, as the need for acute capacity appeared to be four rather than the presently assumed twelve. This raised the issue of designing the ward so as to concentrate the acute patients to a special area to be able to supervise them closer.

I also asked if it would be possible to consider the waiting patients to a dedicated unit caring for patients waiting to be released to other care forms. Several nurses and physiotherapists made the point that moving around patients could be detrimental to their health.

At the end of the meeting I began to sense an ambiguity as to the number of available beds, which hitherto had been stated as being 12. The ward nurse then explained that the ward had 22 beds in total, and that 12 of these in principle were reserved for stroke patients. The remaining beds were intended for kidney and dialysis patients. These can come directly to the ward, without passing the emergency rooms. Many of these do not need to be admitted immediately. Depending on the number of available beds staff can delay admitting kidney and dialysis patients for a few days. The number of beds taken up these patients usually is ten, but can peak up to 12. This meant that the next iteration of the model had to have functions so as to vary the number of beds available for stroke patients between 10 and 12.

From the notes from the preliminary meeting I understood that the model needed to be extended so as to account for an overflow of stroke patients spilling into other wards, because of a shortage of beds. At the end of the meeting we discussed the reason for this; patients with other diagnosis are admitted when other wards are full and beds are available in the stroke ward. Almost 40% of all stroke patients are diverted to other wards.

At this point I made a mental note of the importance of moving to discrete modeling. This would give the necessary variation in stroke patients, providing occasional empty beds, to be filled by other patients.

One of the architects remained after the meeting, he, the project leader and I had a discussion about the consequences of the insight that a significant number of patients were just waiting to be moved to another caregiver. He told us about hospitals he had seen were the patients in the acute phase were kept together and observed closely, almost as in intensive care. Patients who were stable were rotated to peripheral rooms.

Between meeting 3 and 4

Requests for statistics, medical evidence and other data

Shortly after the meeting I sent a request to the project leader with a revised list of data. I wrote "We need the evidence before our meeting as it completely will determine how we build the qualitative variables".

Number of patients

- Number of patients, per year, arriving at the emergency rooms, given the diagnosis of possible stroke.

- Number of patients, per year, given a stroke diagnosis. (As well as statistical spread or a list of intake dates during a quarter or a whole year.)
- Number of kidney/dialysis patients per year (it was stated that there were two categories, those in for a shorter or longer time, respectively. Is it possible to get the number per category?
- Number of other patients, per year.

Treatment times, time in ward(s)

- Average time in emergency ward (approximately)
- Average treatment time, from incoming until medically ready for release (as seen by the stroke unit)
- Average waiting time after being medically released until actually released
    - To community care
    - To independent living with support
    - To independent living without support
    - To rehabilitation ward
- Average treatment time/time in ward for
    - Patients with suspected stroke, released on another diagnosis
    - Kidney patients (split into long and short time)
    - Other patients

Other data

- Staffing levels (number, time spent on stroke unit, and staff category, scheduling)
- Average treatment/care time per patient and staff category, per time unit (day, week??)

Intake policy. I gathered that patients are prioritized as follows

1 Kidney patients

2 Suspected stroke patients

3 Other patients

As there is an almost infinite flow of other patients, an unrestricted intake of these would lead to there never being any beds for kidney or stroke patients, how are these patients admitted? Is there an implicit or explicit policy for reserving beds for kidney and stroke patients?

Medical evidence

- What affects the treatment time and how?
- What affects the outcomes (community care, independent living, lethality) and how?
- Is there any connection between treatment time and actual time in ward?
- What in a unified stroke unit has an affect, and how? What differences are there in outcomes when compared to when patients are dispersed?
- How much and how does the share of staff with stroke certification affect outcomes?
- How does the quality of the care plan affect outcomes and how much?
- Information and communication with patients' affects what and how much?
- Information and communication with relatives' affects what and how much?

- Continuity affects what and how much?
- Teamwork affects what and how much?

Other data

- Wished follow-up and treatment in primary care (time per time unit, hours per week, month?)
- Share of patients receiving this follow-up
- Relation between the quality of follow-up and getting stroke again/returning to hospital.

Discussions with project leader regarding statistics, data and medical evidence

The project leader and I met twice between meetings 3 and 4. I began to understand the difficulties in obtaining the factual data I had requested. The project leader had been promised personal access to the patient administrative systems, but it was probable that very little of the desired data would be available in time for group modeling.

Considering the probable lack of data I began to realize that the large model envisioned in Figure 9 Initial hypothesis - model sectors, page 24, and was probably unattainable. It would therefore be necessary to focus the group modeling to areas where data was available.

At this point it also became clear to me that the national and international definition of a contained stroke unit included patients in rehabilitation. In the case of Falun, the latter are in a separate ward in a separate clinic. This meant that we for the sake of studying the actual stroke ward needed its data. It also meant, that we, for comparison, needed to include rehab patients. I drew the diagram below and pointed out that the minimum data for a logistical model needed the actual numbers or percentages of the flows in the diagram below. As time was getting short we were beginning to realize that it would probably be impossible to get all the data we wished for.

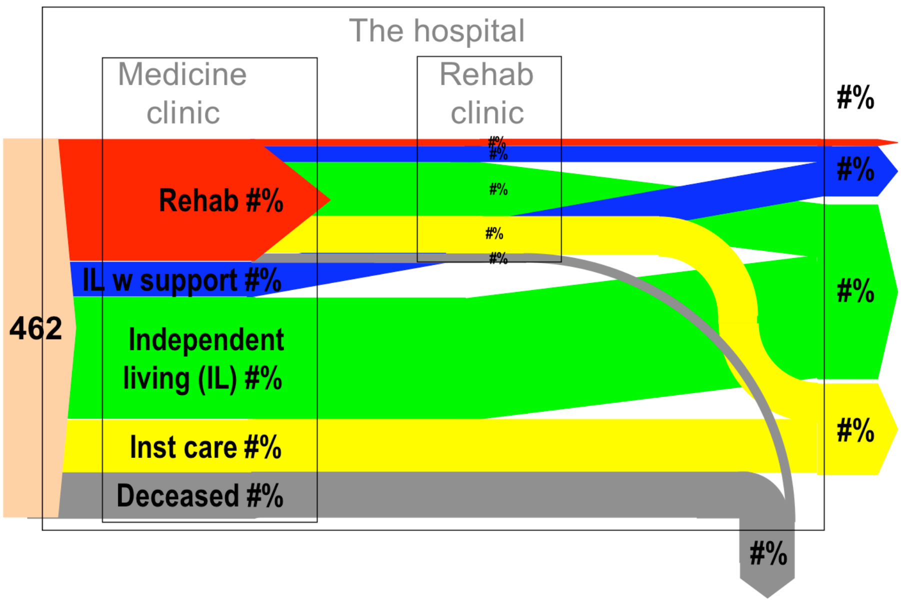


Figure 16 Minimal logistical data required

The project leader also described the general conclusions and causality of the medical evidence. And also undertook to find relevant numerical data and send to me. We were in agreement that it was vital to find data as soon as possible as this would influence the design of the qualitative parts of the model, and time was getting short. At this point it was 5 days until the fourth meeting and 15 until the fifth and final meeting. We decided that the project leader should present the medical evidence during the fourth meeting.

Revised model

At this stage I was in a quandary. I needed to migrate to a discrete model, but was reluctant to do so until I had access to substantial logistical data. So in lieu of additional data I remained with a continuous model; renamed the flow for suspected stroke patients, to clarify the difference to other patients; added flows for stroke patients diverted to other wards, kidney patients and patients with other initial diagnosis than stroke.

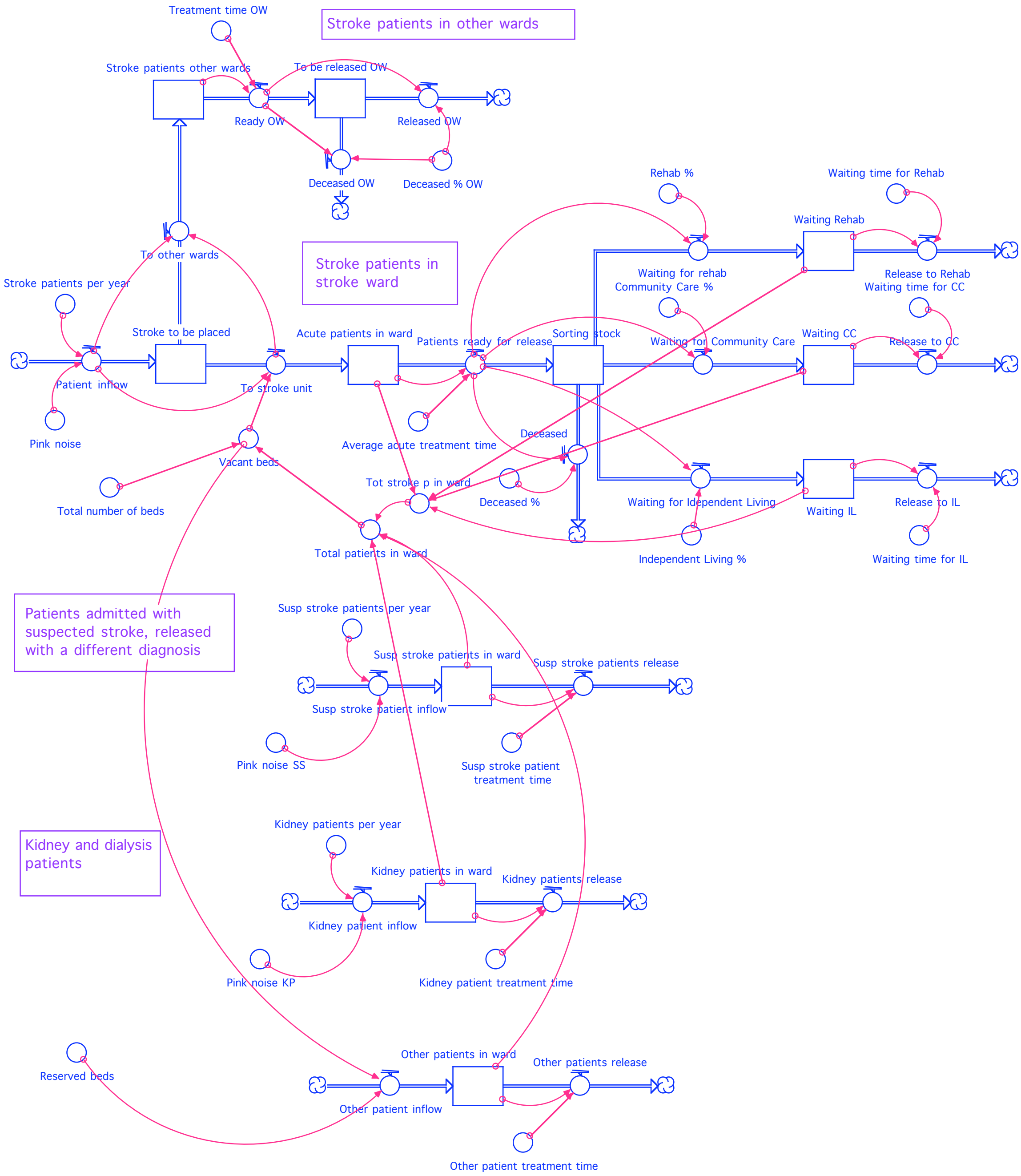


Figure 17 Model prepared for meeting 4

Model equations in appendix, page 63.

Group meeting 4; 24/5

During the first hour the project leader made an extensive presentation of medical evidence from the Cochrane study. Cochrane is an international collaboration collating data from many medical studies into consistent descriptions, thus containing larger populations than the smaller included studies. The project leader also presented results of research describing how room factors affect health outcomes.

The evidence was again mainly descriptive in its character and contained no usable quantitative data. The intent had been for me to start building on now available data and extending the model. As there was no available data, this was not possible. The introductory presentation had also taken such a long time that there was little time left for any hands-on modeling. I therefore walked through the model as prepared for the meeting. Repeated the main structure and introduced the latest additions. And we together reviewed diagrams of the main stocks.

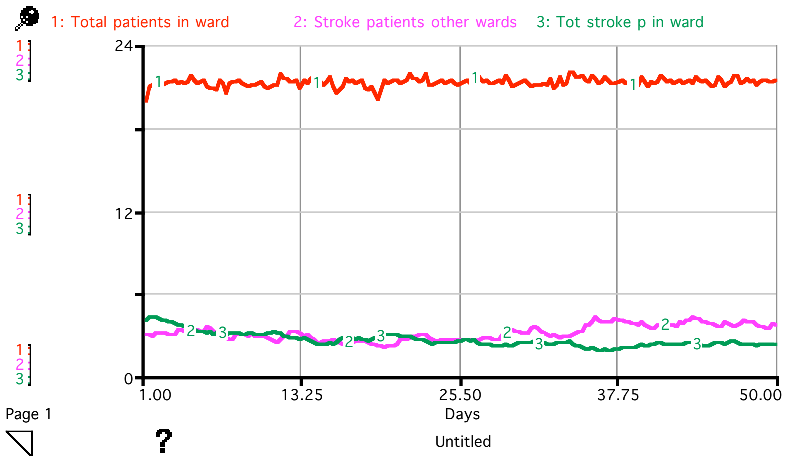


Figure 18 Main patient stocks, meeting 4

In this model I had as yet not introduced discrete modeling. However, the model contains randomized pink noise in the patient flows to create some variation. But this almost continuous flow does not reflect the strong fluctuations, which there actually are.

In building this particular model I included a variable for reserved beds. This was as I intuitively felt that without any form of reserve, the inflow of other patients could squeeze out the stroke patients, as other patients arrive more often than stroke patients.

At the meeting we did several runs, varying the number of reserved beds. I summarize them in the graph below, showing the ratio of stroke patients treated in the ward as to the total number of stroke patients, varying the number of reserved beds.

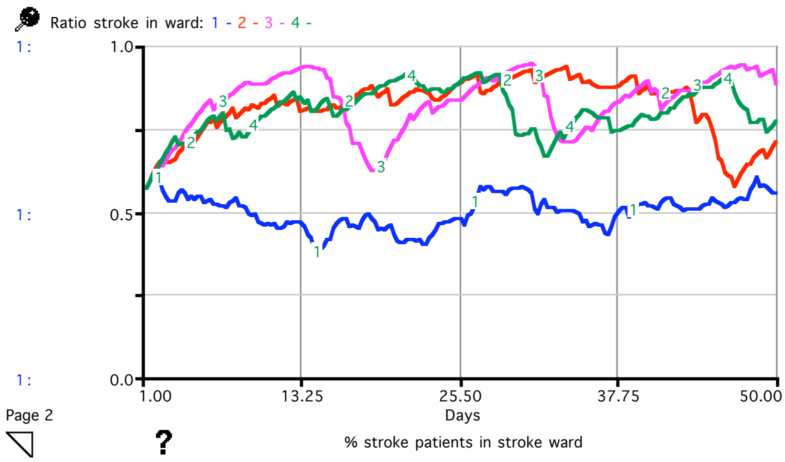


Figure 19 Ratio of stroke patients treated in stroke ward

Simulation	1	2	3	4
Beds	0	1	2	3

Without any reserved beds about 50% of all stroke patients are treated at other wards. Reserving beds raises the ratio to about 75-85%. We discussed the policy in use, and the ward nurse described that they attempt to reserve 1 bed. The actual ratio is about 60%.

Summing up I said that before the next meeting we probably would have better statistics and the medical evidence to extend the model to be both discrete and take into consideration qualitative factors.

Between meeting 4 and 5

Time was now running short, seven working days lay between meetings 4 and 5. Vital data to build a consistent model was still missing as well as the medical evidence.

Assuming that the data might arrive late I began converting the model to be discrete. My intention was to entirely randomize the arrival of new patients. One way of doing this would be to use a Monte-Carlo function. The number of stroke patients was 462 per year. The used time unit was day. This meant that on average would be more than one patient per day. Monte Carlo randomly delivers one pulse, with the stated probability. As the probability is greater than one I needed to circumvent the Monte Carlos limit of only handling probabilities less than one. I did this by creating a sub model, with three parallel Monte Carlo flows. I built it as a sub model to hide the complexity from the participants in the group.

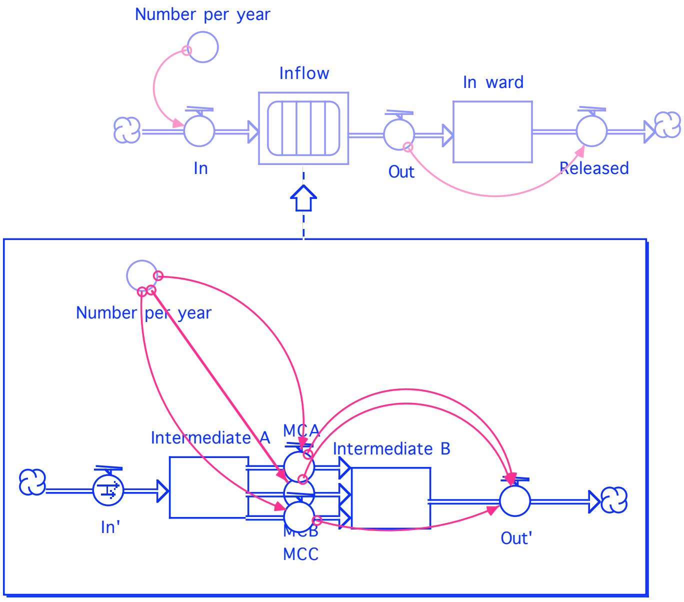


Figure 20 Generic sub model

Model equations in appendix, page 65. However the central generic equation is as follows:

```
MCA = MONTECARLO((Number_per_year*100)/(365*3))/DT
```

By laying three parallel Monte Carlo inflows, I circumvented the limits of the Monte Carlo function so that the model can handle a daily probability higher than 1. It also creates a randomization so that patient at times can arrive with very short intervals.

I met the project leader the day after meeting four and introduced the concept of the sub models. We talked through the urgency and necessity of data and medical evidence. At a second meeting on day two after meeting three I had revised the entire model to be discrete and had begun to flesh out the principles of the qualitative parameters.

The project leader stated the following qualitative influences according to Cochrane:

- Better diagnostic procedure, comprehensive assessment
- Better nursing care
- Early mobilization, to avoid lying in bed
- Prevention of complications
- More efficient rehabilitation procedure, active physiological training, early rehabilitation plan
- Early assessment of release needs

Together we reviewed the parameters identified during the first two meetings, compared them to the influences according to Cochrane, and decided to include the following qualitative variables in the model:

- Interdisciplinary teamwork
- Room and team
- Room and assessment
- Systematic assessment and planning
- Inclusion of patients and relatives

- Room quality

I tested a card sorting exercise with the project leader, in order to prioritize between the factors to use as weights in the model. We decided to do a similar exercise with the group during meeting five.

The project leader promised to immediately review the Cochrane database for data to put into the model.

The model as it was prior to meeting five contained discrete modeling, sketched qualitative factors and their influence on treatment time and the release outcomes.

At this stage the model began to more complicated and difficult to overview. I realized that it would be desirable to use arrays, but could not do this because of lack of time and a bug in iThink 8 for Mac, which made it difficult to work with sub models. I had to create sub models in iThink 7 and paste them into a version 8 model.

I also sectioned the model and used labels to identify parts of the model sector. This was the present state of the sectors:

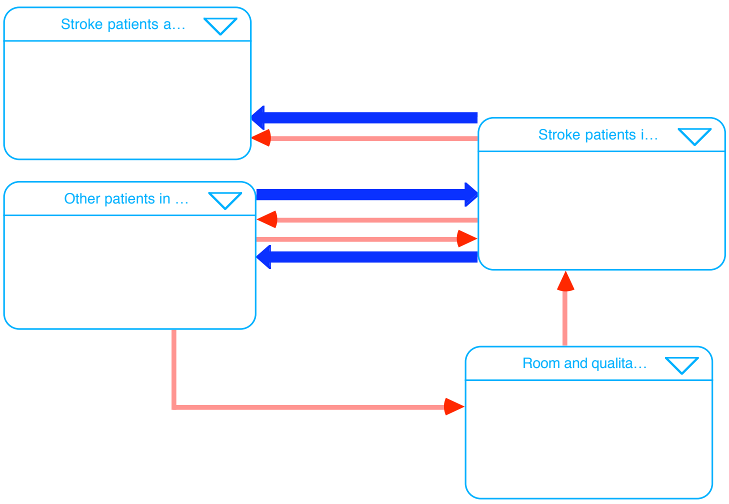


Figure 21 Model sectors prior to meeting 5

Based on the anecdotal representation of the medical evidence I built the qualitative sector as follows:

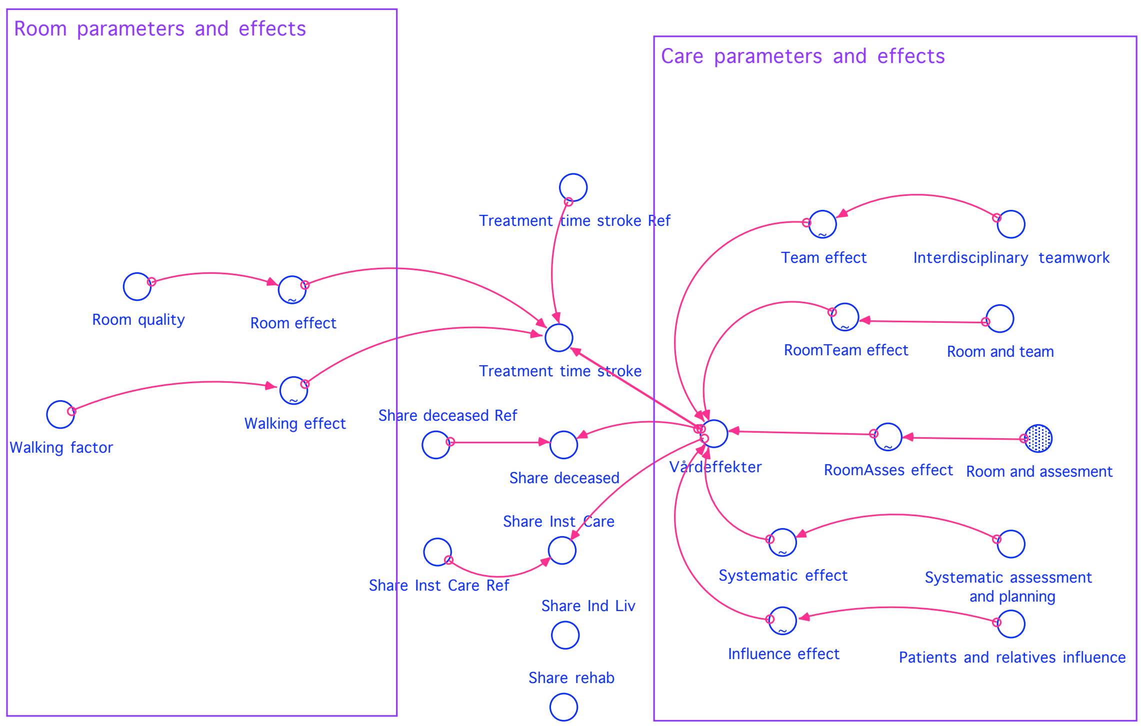


Figure 22 Qualitative sector

The intention being to enter the reference data for known variables, such as treatment time, deceased ratio etc. Then allowing the identified parameters to affect the reference values and having non-linear relations defining the effects.

Statistical data from the ward was still not available. On the day before the fifth and last meeting, with less than 24 hours to the meeting I received the following data regarding medical evidence from the project leader:

Cohrane:

	Organized stroke care	Conventional care
Home, independent living	44%	38%
Home dependent	16%	16%
Institutional care	18%	20%
Dead	22%	26%

In the same article it says:
Assessment and monitoring of care, medical and physiotherapeutic factors are important
Early management:
Physiological management
Early mobilization
Nursing care such as careful positioning and handling, prevent sores, feed/swallow, avoid catheters, antiembolic treatment
Neuroprotection:
Plasticity
Repair
Regeneration
Work organization:
SU
Medical protocols and nursing protocols and quality protocols

Table 8 Medical evidence from Cochrane data base

Looking at the data I considered the difficulties of building a dynamic model, where the qualitative variable was whether the ward was well organized or not. I could see no way in which the model could be truly dynamic as there was nothing in the model, which influenced the quality of the organization. There was apparently no data in Cochrane stating that workload or patient flows etc influenced the quality of work. Talking this over with the project leader, I suggested that treatment time might be influenced. However, treatment time was found to depend on national and local tradition and culture.

My hypothesis at this stage was that organization was to exogenous to the model. It could be possible to assume several forms of organization and spatial layouts of the ward and use Delphi-like methodology to assess the effectiveness of each. However, I did feel that this would be inadequate.

I spoke to the project leader about the shortcomings of the medical evidence and got a suggestion that I might find useful data in the national statistics. I began to analyze the national data and found that it also was inconsistent. It did not account for 100% of the patient flow. As we ourselves at this stage did not have the full patient data made it impossible to do comparisons.

At this stage with only hours to go until the meeting I worked at high pace trying to develop the qualitative sides of the model. I had then already rebuilt the model to be discrete. In retrospect my opinion is that I should have cancelled meeting 5 and postponed it until august/September, since there still was no consistent patient data and the medical evidence was far from my wish list. However, I felt the pressure of finalizing the group modeling before the long vacation period and felt that the project leader and I could sort things out together ourselves and present the final results to the group after the vacation period.

This was the state of the model prior to meeting 5:

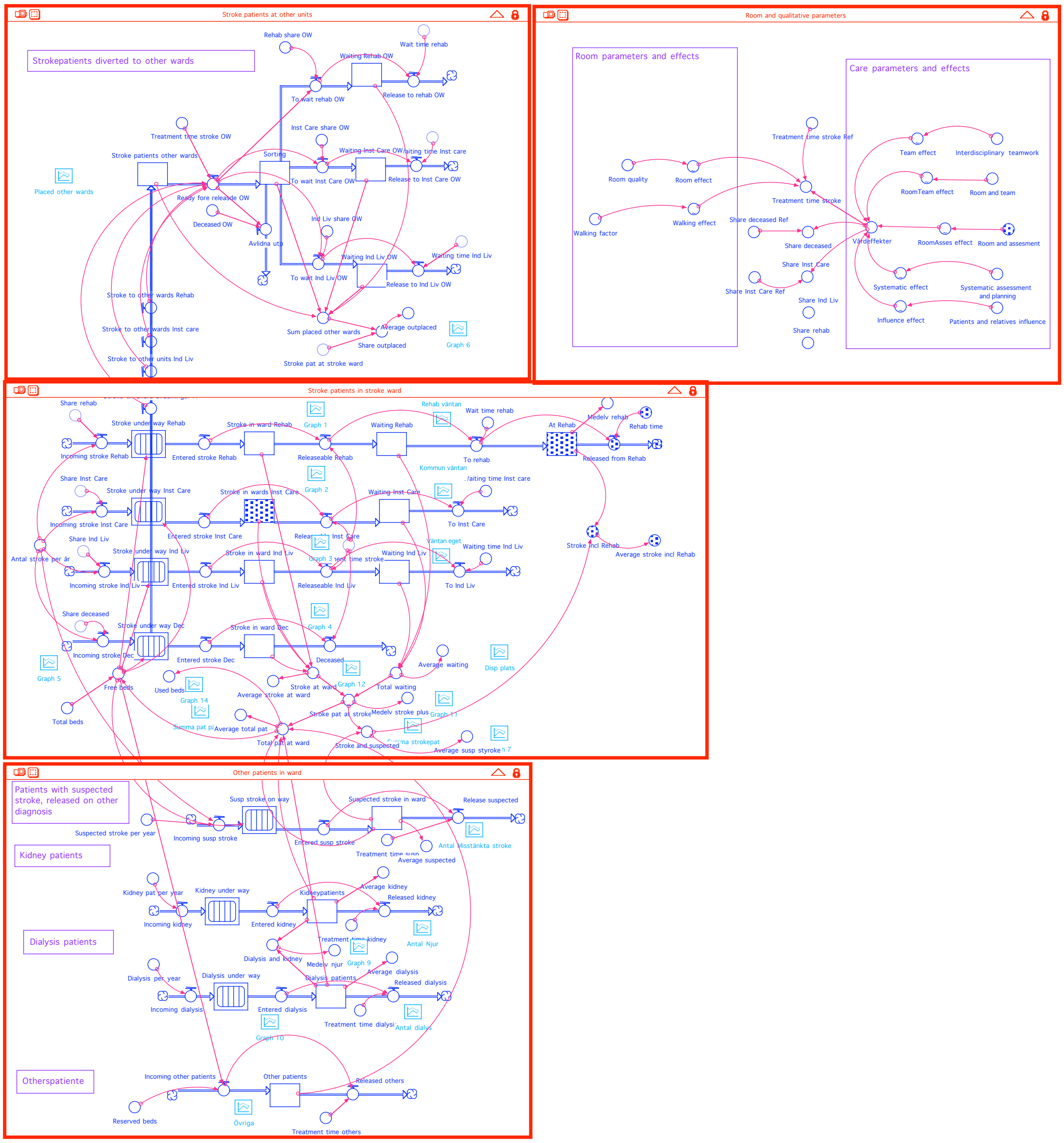


Figure 23 Model meeting 5

Model equations in appendix, page 65.

The model was now discrete, with considerable variations in patient flows. I applied qualitative factors assuming that the ward was an average ward, in between organized stroke unit and conventional unit. The differences were hard to discern in the graphs, as the variations in the discrete model was significantly higher than the effect of the relatively small differences between organized and conventional wards.

I felt that the model at this stage was quite "messy". Considering the short time between meeting 4 and 5 and the lack of consistent data, I had not yet migrated the model to use arrays. The model contained several virtually identical patient flows. Moving over to discrete modeling I had to move the "sorting" of patients by release destination, already when the patient entered the system. Otherwise, using discrete modeling and the actual sorting point, each whole patient would have died to 12%, entered rehab to 32% etc.

Considering the "messiness" of the model and the short time of each meeting I decided not to show the group the mode. Instead I prepared a series of slides to be able to walk through the essential points made in the model.

Meeting 5

Prior to the meeting the project leader expressed disappointment, not being informed about the latest development of the model. I explained that due to late and missing data, the latest version had been finalized in the last hours before the meeting. And that we both needed to continue working on it as the project leader got consistent patient data.

At the beginning of the meeting I explained the constraints of the model, as we still did not have the complete consistent patient data, needed to do national and international qualitative comparisons. After this I walked through the slide presentation.

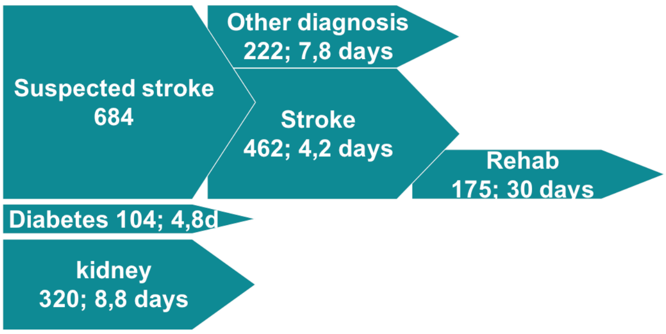


Figure 24 Slide - main patient flows

This slide shows the main patient flows and total treatment times. Apart from this we knew the outflow of stroke patients to Institutional Care, Independent living etc. The most important missing data was a similar breakdown of the patients from Rehab. Without this data it would not be possible to do national or international comparisons.

I also explained that the following slides show patient data and flows based on the assumption that all stroke patients pass through the stroke ward.

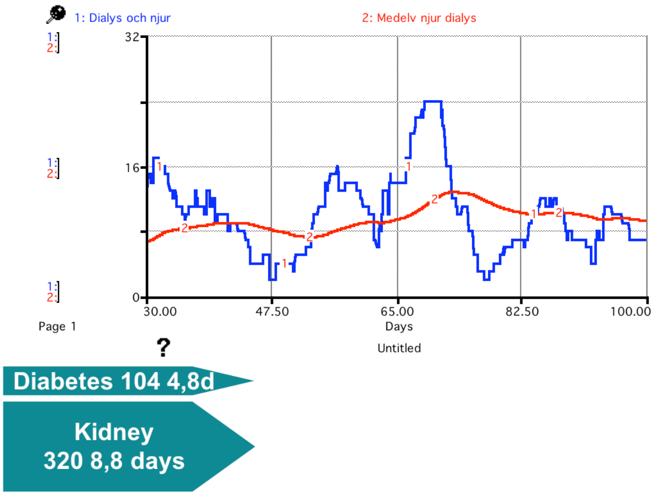


Figure 25 Slide - flow of kidney/diabetes patients

This graph shows the day-by-day discrete flow of kidney and diabetes patients, and a 20-week moving average. My understanding from meeting 4 was that this category averaged 10 patients and peaked to 12. These patients also had top priority to beds. The response from the ward staff was that I had misunderstood this. The swing in patient flow is not as dramatic as modeled. These patients are seldom in acute need of treatment, meaning that staff can use their discretion to decide when to take the patient in. The result of this is that the actual number of patients never is below 10 and can peak at 12, but never above 12. I promised to revise the model accordingly.

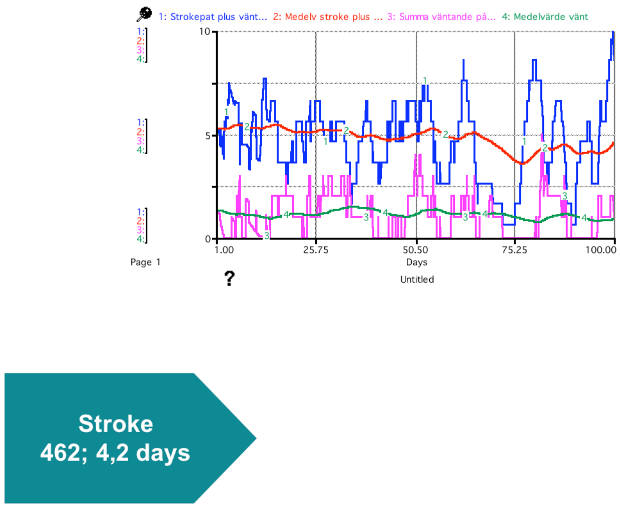


Figure 26 Slide - stroke patients

This slide shows the patients that are released with a stroke diagnosis, i.e. the real stroke patients. We noted that the number of patients average about five and that less than two of them are waiting to be released. In other words the number of patients in the acute stage are about three. Since this is a discrete simulation, the numbers peak, but never to the number stated as necessary beds.

The easy conclusion would be that the ward is over dimensioned. But that does not take into consideration the patients, which are admitted, suspected of having stroke, but turn out having another illness.

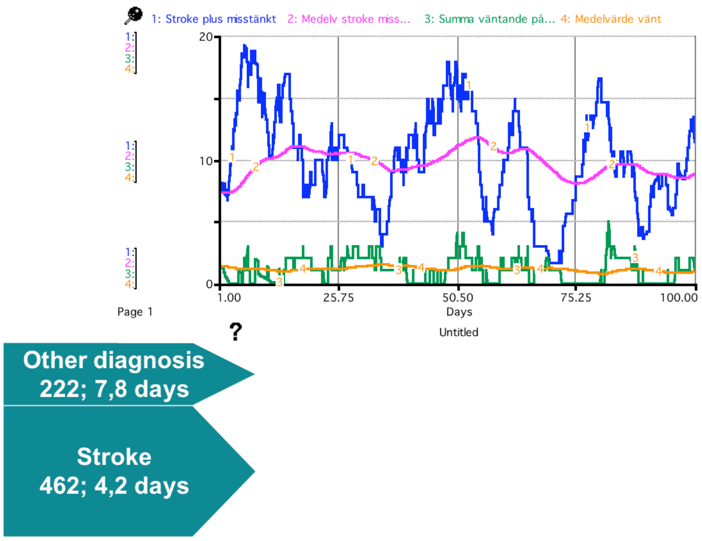


Figure 27 Slide - flow of actual and suspected stroke patients

The purpose of this slide is to raise the issue of where patients with suspected stroke, but released on another diagnosis, best are treated. If they are best treated as stroke patients then the ward averages about 10 patients, with peaks at 18, meaning that normally any patients over 12, would overflow to other wards.

This was discussed at the meeting. On one hand it is preferable that all stroke patients are admitted as soon as possible, preferably not even passing the emergency rooms. Time is vital for achieving effective treatment and good health outcomes. However, these patients then fill up part of the ward, leading to an overflow, and stroke patients getting treatment, which could have been better.

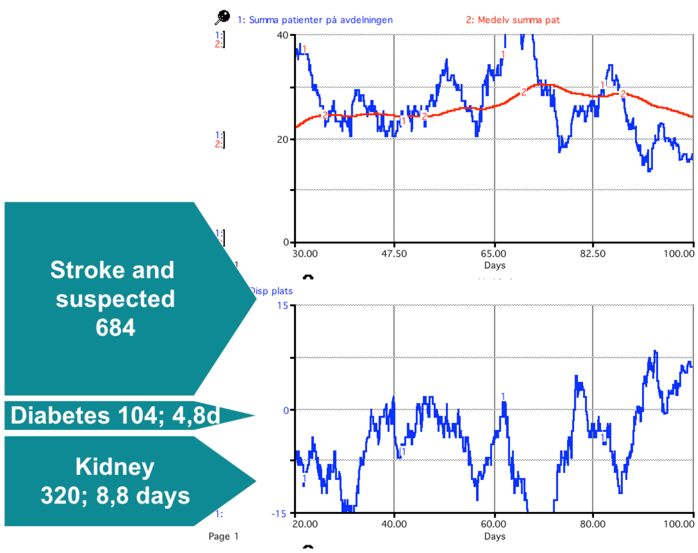


Figure 28 Slide - all patients and available beds

This slide show all the patients accounted for so far. The total number of patients averages between 25-30, above the total capacity of 22. The lower graph shows the discrete number of available beds, strongly negative most of the time. This is of course exacerbated by the fact that the model has allowed a to high variation in the number of kidney and dialysis patients.

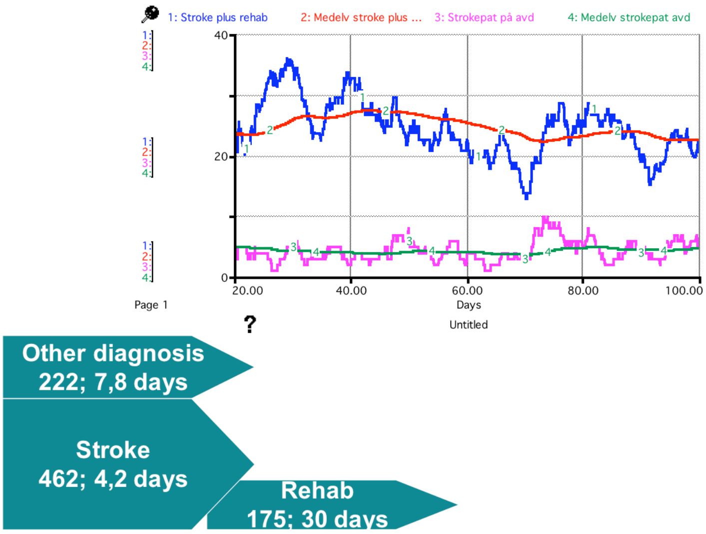


Figure 29 Slide - patient flows including rehab

According to the national guidelines (Socialstyrelsen 2000) and to international medical evidence the best results are achieved within a complete stroke unit including rehabilitation. At this hospital, rehabilitation belongs to the rehabilitation clinic. The project leader and I included this slide with the grand total of stroke patients to raise the boundary issue. This was not a discussable issue as all care staff made it very clear that it had been decided after extensive discussions.

I then moved to a series of slides with data from the national statistics. These include patients having passed a rehabilitation ward, since we still did not have the complete patient data it was at the moment impossible to do comparisons. We went through these slides was to discuss what could be modeled later.

I plotted the national data into scatter graphs and drew red triangles to indicate trends.

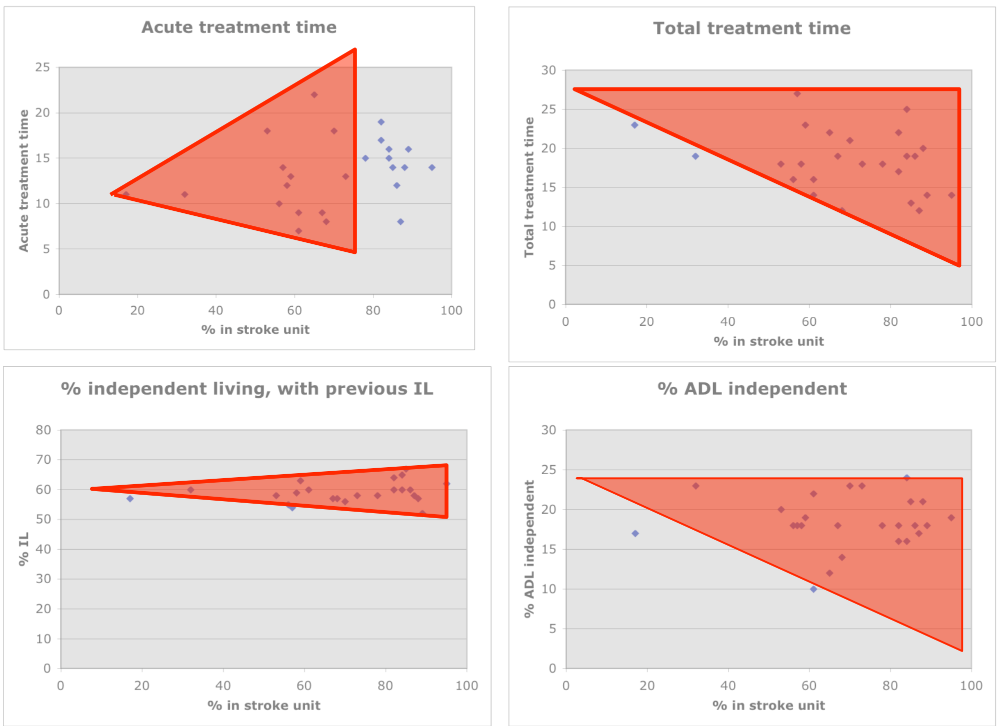


Figure 30 Slides from national statistics

The first slide showed the acute treatment time compared to the proportion of patients treated in dedicated stroke wards. As can be seen the data is very inconclusive. The total treatment time, in the second slide, shows a correlation with the percentage treated in stroke wards. The same with the fourth slide showing the percentage of ADL-independent patients. (ADL = Activities of Daily Living). The third slide, showing how many of the patients who previously lived independently, still do it afterwards, is also inconclusive,

The project leader then recapitulated the main parameters defined during the first meeting, and discussed their connections with the qualitative results of Cochrane:

- Interdisciplinary teamwork
- Room and team
- Room and assessment
- Systematic assessment and planning
- Inclusion of patients and relatives
- Room quality

Based on the card-sorting prioritization exercise that I had done with the project leader before meeting 5, I had developed another Delphi-like exercise to elicit both priorities and indicated non-linear relationships for the qualitative parameters. For each parameter, a card was to filled in as below.

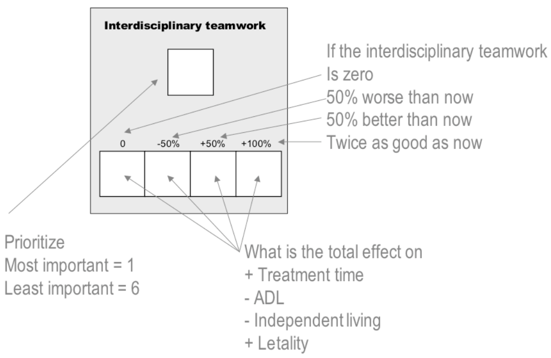


Figure 31 Elicitation of non-linear relationships

It quickly became apparent that I had overestimated the decisiveness of the group. One of the opinion leading participants expressed doubts as to their capability to make such estimations. The more unsure members of the group also expressed doubts. Realizing that this was a dead end I retreated and suggested that they just prioritize between the factors. This was accepted and the results were as follows:

	1	2	3	4	5	6	7	8	9	10	11	Avg
Interdisciplinary teamwork	1	1	1	3	1	1	1	1	2	2	3	1,5
Systematic assessment and planning	2	2	2	1	2	3	2	2	1	1	1	1,7
Influence of patients and relatives	3	3	3	4	3	2	3	4	4	6	2	3,4
Room and team	5	6	4	2	5	6	4	3	6	3	5	4,5
Room and assessment	4	4	6	5	4	4	5	5	5	4	4	4,5
Room quality	6	5	5	6	6	5	6	6	3	5	6	5,4

Table 9 Weighting of qualitative parameters

There was a brief discussion after the meeting, between the project leader, one of the architects and my-self. I made the point that the more parameters were included, the less the effect of each one would have. After some discussion, we decided to eliminate the *Room and team* factor as it partially is embedded in *Interdisciplinary teamwork* and *Room and assessment*.

After meeting 5

My formal obligations were fulfilled after a follow-up meeting in June, with the project. As the project leader and I had agreed to continue working together, developing the model for our mutual benefit, I continued development of the model. Based on this after meeting 5 I suggested having a sixth group meeting where the project leader and I could present the refined models.

In the preparations for meeting five I had noted that any changes in the qualitative parameters were not distinguishable in the discrete model. I therefore worked in parallel with two different models: a discrete quantitative model and a continuous qualitative model.

The qualitative model

The medical evidence from the Cochrane study was disappointing, as I noted on page 37. The main problem was that the study distinguished between well-organized or conventional stroke wards, factors, which were exogenous to the present model. I could see no way in which these factors dynamically could interact with the present model, as there was no evidence as to how workload, patient flows etc influenced the evidence data. The second problem was that we still did not have the missing data needed to build a consistent model comparable to national or international data.

However, I revised the causal loop diagrams to reflect the selected parameters. This was done so simplify the causal loop diagram and connect it with a representation of the stock and flow diagram. The intention was to show it to the group so that they could see main functionality of the model, without getting confused by the “mess” of the details in the full model.

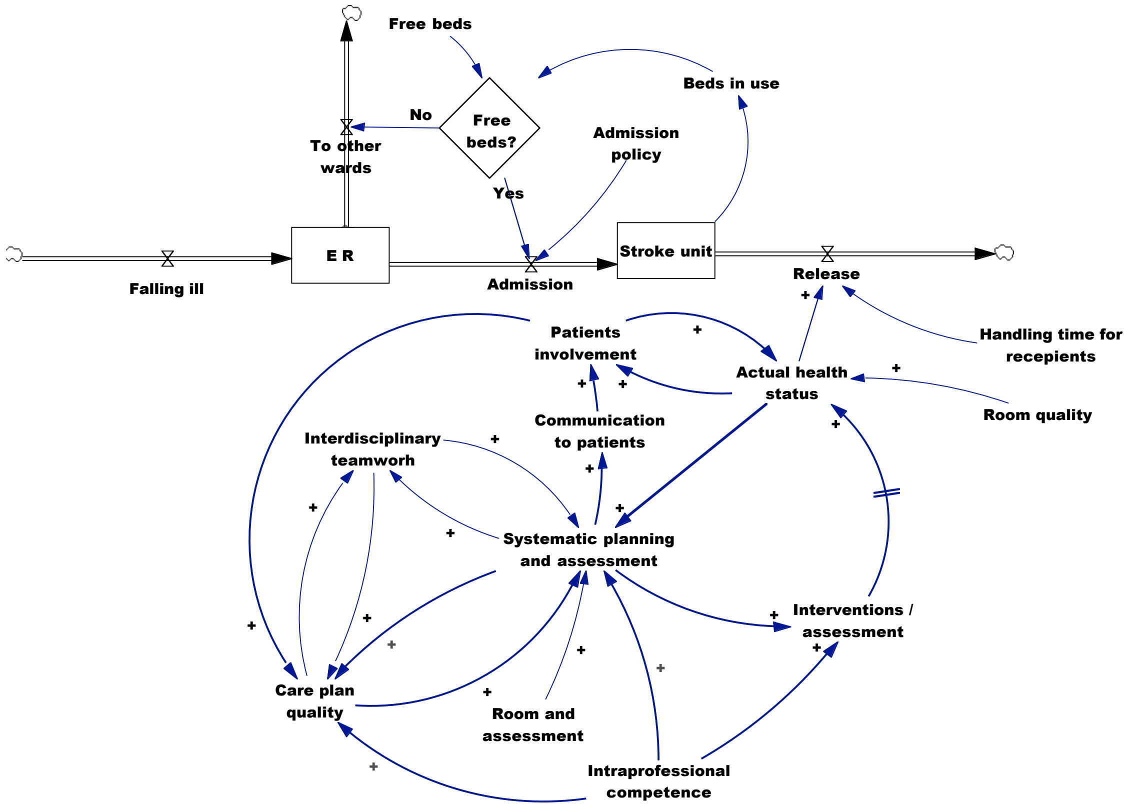


Figure 32 Simplified causal loops

However, based on the ranking pf the qualitative parameters I revised the qualitative and continuous model as follows:

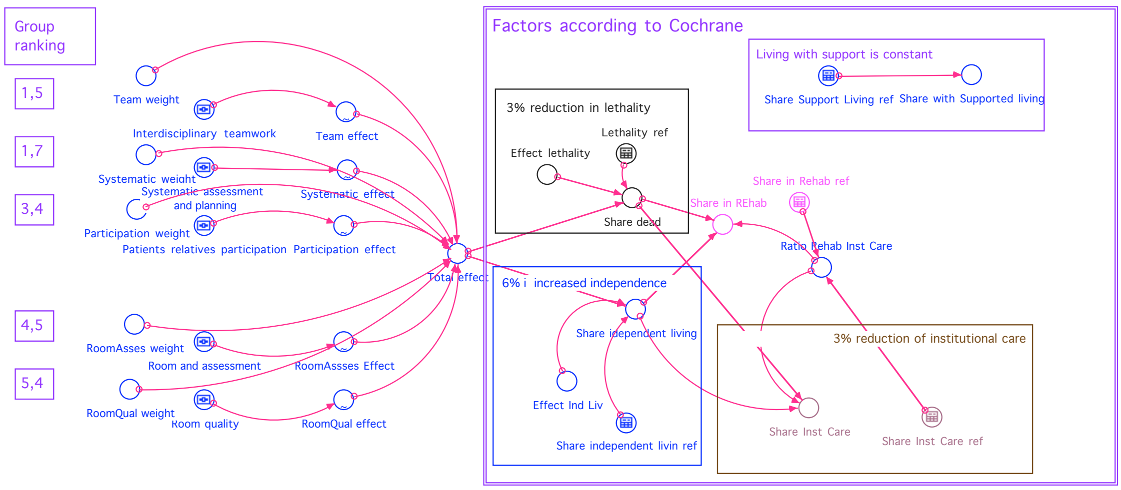


Figure 33 Qualitative model

The equations are on page 67.

As the participants at meeting 5 were reluctant to make any non-linear assumptions, I have made estimated and identical non-linear functions for all parameters:

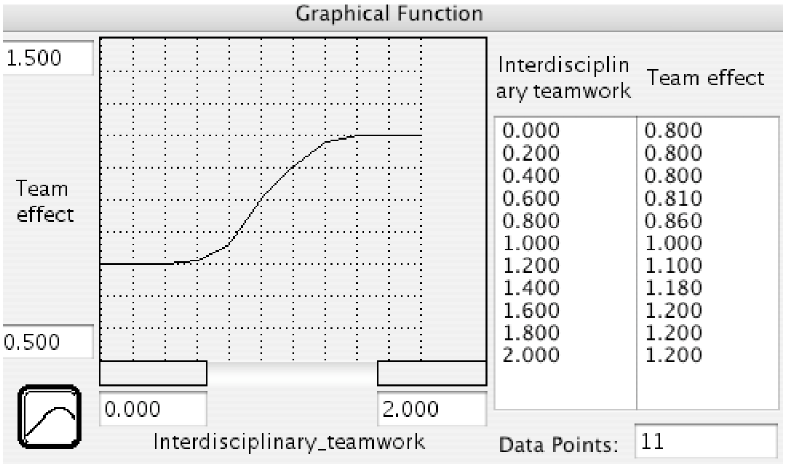


Figure 34 Non-linear qualitative function

As the medical evidence was based on the exogenous factor of whether the ward was well organized or conventional, I decided to build a simulator like graphical interface. My idea was that staff could suggest different ward organizations and evaluate them according to the component factors of the medical evidence. For each factor I made a slide, where the number 1 corresponded to everybody's opinion of an average ward. Any proposed organizational changes could be evaluated as being 50% worse or better than average. In such a way the effects of the proposed changes could be evaluated. But these were of course not dynamic effects. Each change would lead to a new static situation, with no change over time except for the moment of change.

The interface also contained all the basic statistics, so that they easily could be revised if questioned.

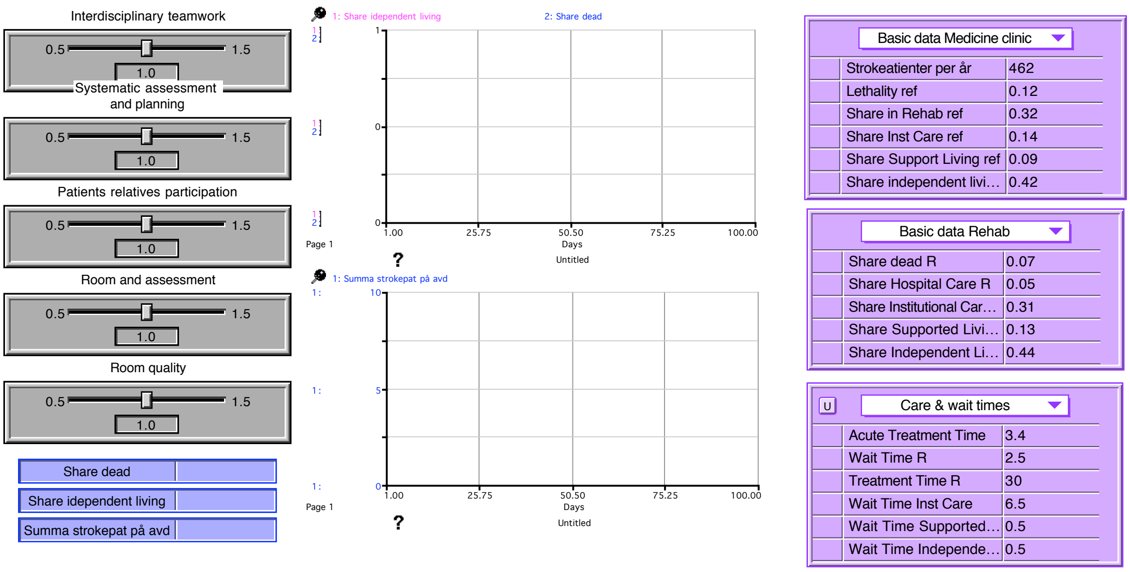


Figure 35 Qualitative simulation dashboard

The patient data

The people supplying the project leader came up with additional, but incomplete data in June. The minimum of data, which were required to build a consistent model were not received until August. The main patient flows were as follows:

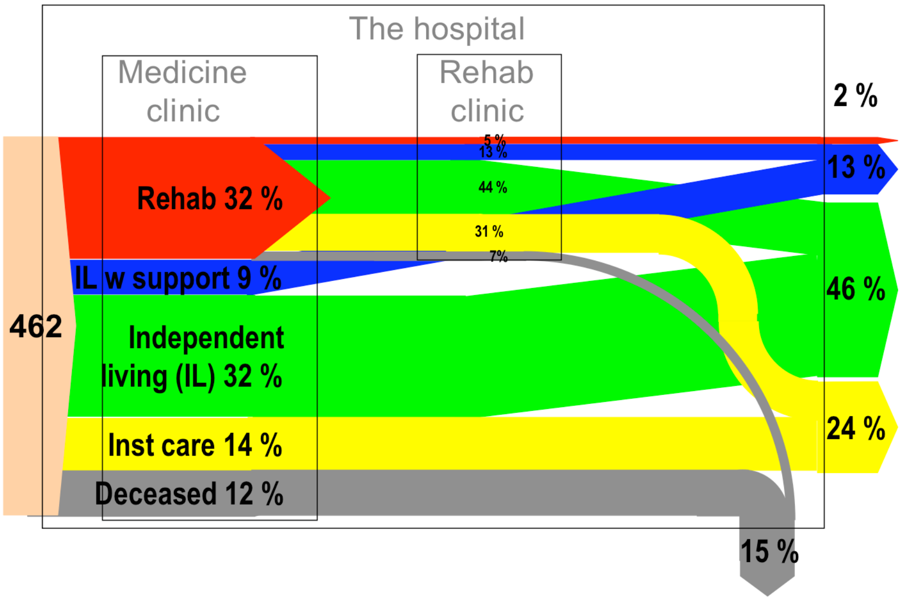


Figure 36 Main patient flows

Now that all patients were accounted for it was possible to add the patients passing through both the stroke ward and the rehabilitation ward. I drew up the following slide to show comparisons with national and international evidence:

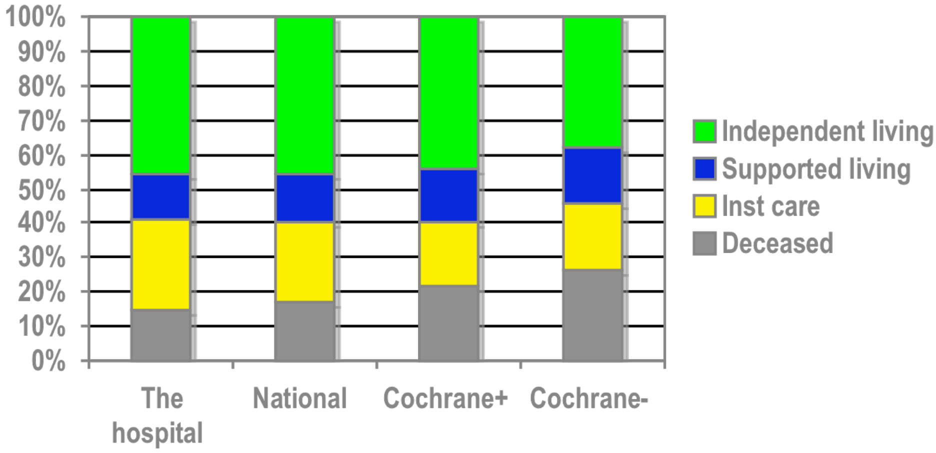


Figure 37 National and international comparisons

Looking at the data, the hospital under study has lower lethality rates than the national average and the Cochrane data. Cochrane+ refers to well organize stroke units. Cochrane- refers to conventional units.

Adding those who co to institutional care, he hospital is in the same level as the national average and a well-organized ward according to Cochrane. And better than an average conventional ward.

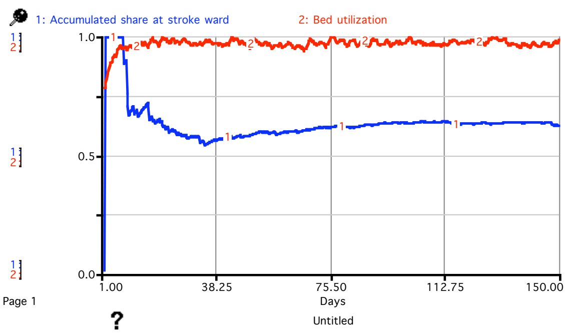
Finally looking at those who go back to living independent, the hospital is on the same level as the national data and slightly better than a well organized stroke ward.

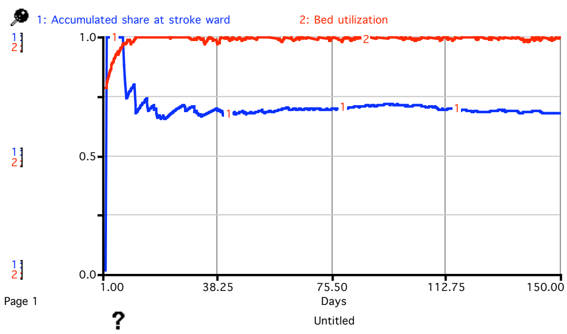
This compilation was a blow to the qualitative model. If the ward and the hospital were on the national average and on the same level as Cochranes well organized unit, what was the problem? Unfortunately neither the national or Cochranes data give any information of the upper quartile of the well performing wards, which could have given some scope for modeling improvement.

At this stage I was very surprised that nobody knew how well the hospital compared to the national and international data. Had I known this when undertaking the task of modeling I would have been very hesitant indeed. The lack of supporting data would have necessitated interviews and data gathering so as to support the intentions of the project leader in modeling the qualitative sides of care giving. And at the same using resources on a scale not available for the project. At this stage my intentions were to bring this up with the project leader to see what assumptions we could make to "rescue" the qualitative model, while still maintaining rigor.

The quantitative model

The initial step was to verify the model by testing that the model represented the present organization, i.e. 12 stroke beds, 0-1 reserved beds, 100% of all suspected stroke patients, kidney/dialysis in the ward, and empty beds utilized by letting other patients in. The simulation is run for 150 days, long enough for the averages to stabilize, as it is not possible to initialize the model so that is stabilized at the outset for all possible combinations.





0 reserved beds

1 reserved bed

Figure 38 Verification of qualitative model

The average of stroke patients treated at the ward is 57%, when no beds are reserved, and 75%, when 1 bed is reserved. The actual value is less than 60%. When asked about the reservation policy, the ward nurse had said earlier that they try to reserve 1 bed. It appears that the model reflects the actual situation fairly accurate. Bed utilization is 100% and 98% respectively. The actual bed utilization is close to 100%, which also would indicate that the bed reservation policy is not very successful.

At the introductory meeting one of the doctors suggested that the ward be expanded to 16 beds and that it was to have a bed utilization of 85%. In the simulation below ward sizes are 12-20, and 2 beds are reserved, corresponding to approximately 85% utilization. The simulation seems to imply that no matter how large the ward is, it does not receive all the stroke patients, even though there theoretically should be ample space. This is due to a never-ending supply of other patients, which arrive faster than the stroke patients.

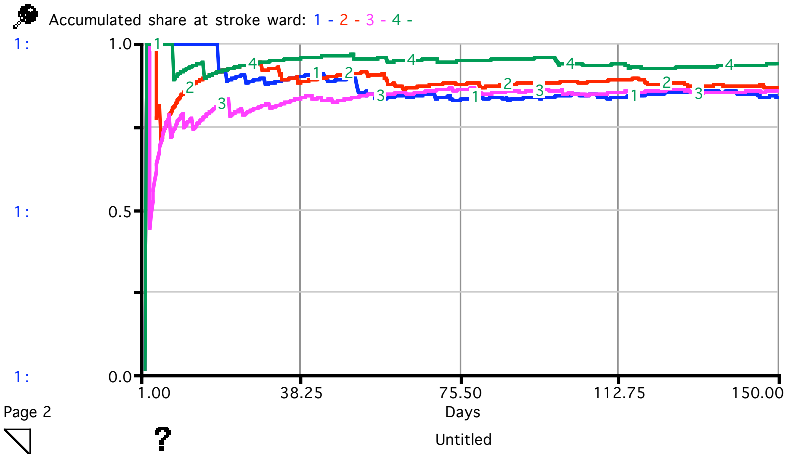
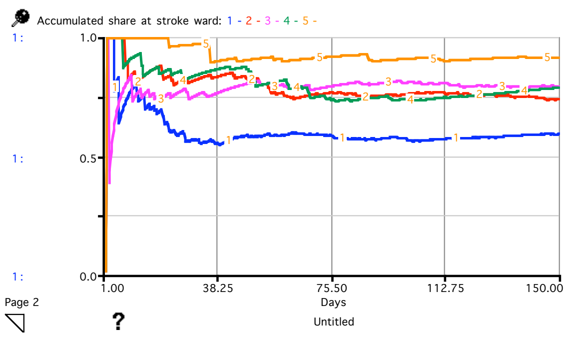


Figure 39 Share of stroke patients at different ward sizes

Run	1	2	3	4	5
Beds in ward	12	14	16	18	20

Increasing the number of beds did not seem to be the most effective policy, so the two other policy levers were tested: reserved beds and share of suspected stroke patients. Increasing the number of reserved beds has an effect on the share of stroke patients treated at the ward, but it does not seem to improve above about 80%, in spite of incurring the heavy cost of underutilizing beds.



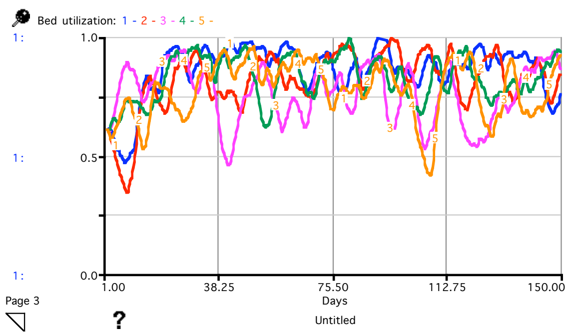


Figure 40 Simulation different reservation of beds

Run	1	2	3	4	5
Reserved beds	0	1	2	3	4

In the simulation below the effect of different screening policies at the emergency rooms are tested. The screening has an effect on the share of patients initially suspected with stroke, but do not have it. By improved screening non-stroke patients are diverted to other wards. Screening does have a slight effect, but as before empty beds are quickly filled by other patients.

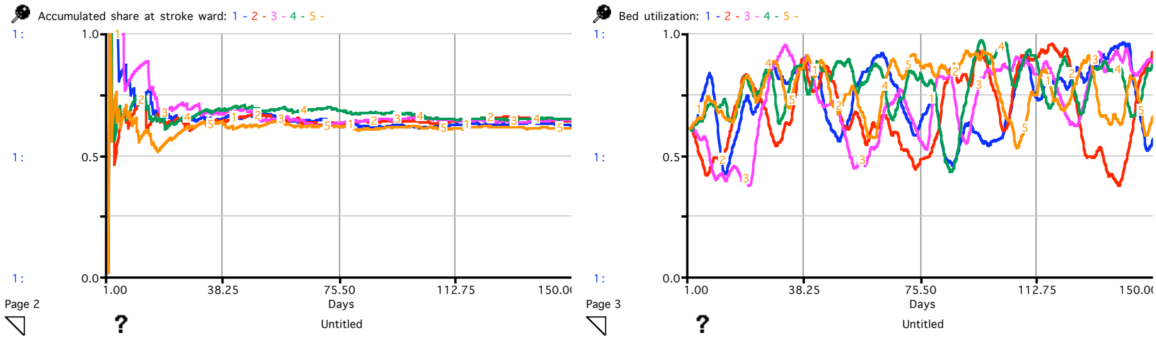


Figure 41 Simulation different screening of suspected stroke patients

Run	1	2	3	4	5
% of suspected stroke patients	0	25	50	75	100

Finally an entirely different policy was tested, by not allowing any patients with other diagnoses enter the ward. However, suspected stroke patients were accepted without improved screening. In the simulation below the ward size is varied. With a ward of 12 beds, over 80% of all stroke patients were treated at the ward, but bed occupancy fell to about 75%. Increasing the number of beds led to almost all stroke patients being admitted to the ward, but at a gross inefficiency in bed utilization.

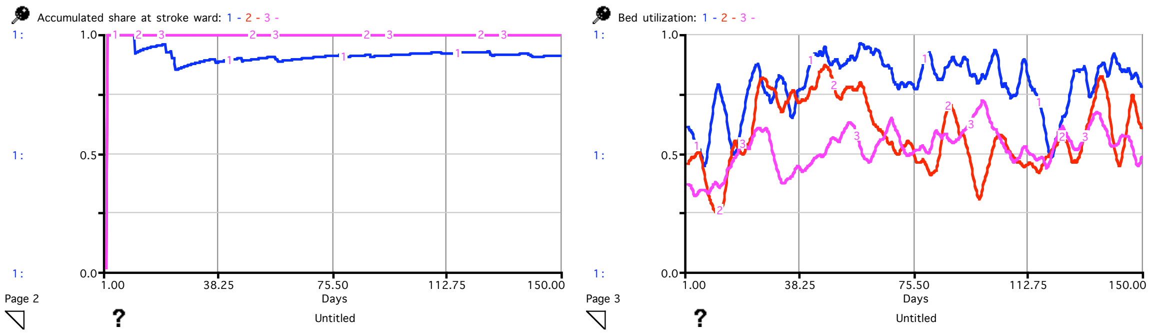


Figure 42 Simulation, no other patients

Run	1	2	3
Beds in wards	12	16	20

After these sensitivity simulations it was clear that no single policy be optimal. I then prepared a dash-board focusing on key variables and key results. The purpose was to create an opportunity for ward and clinic management to explore the effects of different policies. The intention was also to start by running the model with the present organization, i.e. together with kidney and dialysis patients, and to show that the model reflected the present situation. After which the flow of kidney and dialysis patients would be diverted, so as to reflect the proposed new ward. These are the key variables:

- Stroke beds: Initial value = 12, but can be increased to 20, so as to be able to test how different values change the results.
- Reserved places, i.e. the number of empty beds reserved for future incoming stroke patients. Said to be 1 at present, but can be changed between 0 and 5, to test the effect of different policies on key results.

- Received share of non-stroke patients, i.e. the patients suspected to have stroke, but are released on another diagnosis. At present all such patients are admitted. The purpose is to test the effect of different screening policies on key results.
- Kidney dialysis on off, i.e. the present or future ward organization.
- Others on off. This enables to switch of the flow of other patients to the ward, i.e. to explore the results of dedicating the ward entirely to patients with actual and suspected stroke.

The key results shown in the diagram are:

- The accumulated share of stroke patients, which are treated at the ward as compared to all stroke patients irrespective of ward. This is to be able to test different policies so as to treat as many patients as possible at the ward.
- Bed utilization. The present utilization is almost 100% and in the introductory meeting one of the doctors stated that 85% was desirable to be able to treat all stroke patients at the ward.
- The average number of patients at the ward:
    - Stroke patients in the acute phase
    - Stroke patients waiting to be released
    - Suspected stroke patients
    - Other patients

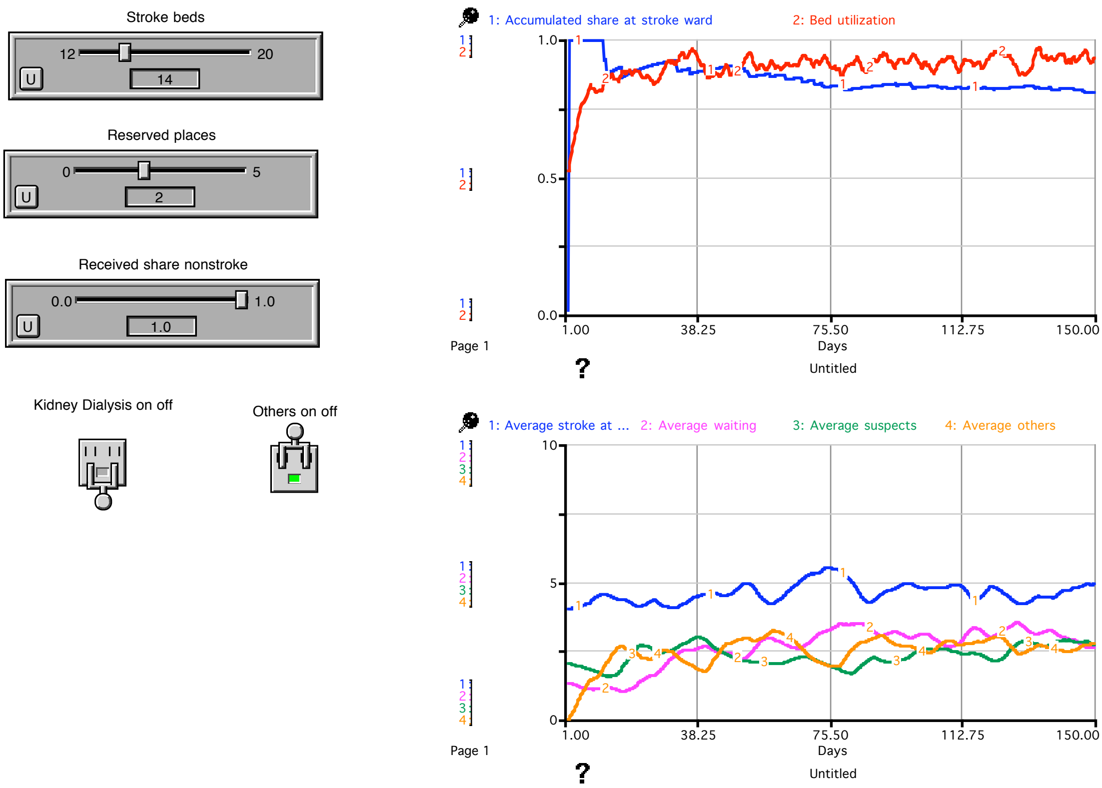


Figure 43 The quantitative dashboard

Termination of the project

After meeting 5 the project leader and I met three times. In June to discuss the outcomes of meeting 5, and twice in August after the patient statistics became available. We were in agreement that the qualitative model was a disappointment, since the medical evidence did not support a dynamic model and now that patient data was available, the data showed that the ward was better than the average well-organized ward.

In view of this the project leader wished to refocus on the causal diagrams of the qualitative factors and develop a model based on these. Since my formal obligations had ended in June, we agreed to terminate my participation in the project.

Conclusions and recommendations

The research question(s)

The main research question was how to develop a model in a group process, with stakeholders with differing objectives and agendas? With my personal background as a trained and experienced process consultant a subsidiary question was how to combine the "soft" side of modeling, i.e. the group process, with the "hard", structural side of system dynamics? At issue was also how to combine the quantitative and qualitative sides, of the project leaders research questions, in a relevant model?

Group modeling and consultation

Vennix schema (page 5) was very useful in designing the overall flow, i.e. starting by identifying parameters, sketching causal loops and then moving to stock and flow diagrams.

Richardson (Richardson and Andersen 1995) proposes five roles in the group modeling process. One of them, the gatekeeper, is the project leader of the client system. All four other roles are distributed among the consultants. In a consultancy setting I would find it hard to have more than two consultants in place, while that is probably the minimum required to keep a momentum in the process. Minimally there should be two roles: the modeler and the facilitator. The facilitator focuses on the group process and eliciting contributions from the participants, this is a combination of Richardson's facilitator and process coach. The second role is that of the modeler In addition Richardson proposes a recorder, this role would probably be dropped for reasons of cost and the task taken over by somebody in the client system.

In the literature review I suggested using the Consulcube (Blake and Mouton 1986) as a meta-theory to understand the client system, it's needs and the required intervention(s). Any consultative intervention needs to assess this initially, and the Consulcube can be a useful framework for doing so.

Process consultation

Most group modeling is probably an intervention where the purpose is to develop a model, which the group feels that it owns. It is therefore important to have the basic attitudes of process consultation:

- Helpfulness, the position is to assist the group in developing their model
- Building on the current reality – One can only build on what is known and has been made explicit in the group
- Going with the flow. Build on what currently is important for the group.
- Addressing ones ignorance. The process consultant need not pretend to be an expert in the field of the customer. Ones ignorance is a resource when eliciting facts from the group, and for opening up areas, which might otherwise be ignored by the group.

In therapy and in process consulting many practitioners emphasize the importance of having a "contract" with the client. What they mean is that the client has defined a problem to be worked with; has defined a desired outcome and undertakes to work with the practitioner to solve the problem and attain the outcomes. In this case the commitment of the group was maybe limited due to the lack of a clearly defined problem. The first step in Stermans schema (Sterman 2000) is problem articulation and asking the questions *What is the problem? Why is it a problem?* I suggest that sd-practitioners ensure that they not only have a problem definition, but that they also have a “contract” with the group and their full commitment.

Group factors

If the group is to develop a model, which is to have a wider acceptance in the client system it needs to have CAPI (Adizes 1992), coalesced authority, power and influence. In this case the group lacked the authority and knowledge of the manager of the clinic. Had the other doctor participated, the knowledge would have been represented, but not authority. If it is not possible to have authority representatives in the group then it should be considered having a steering group, composed of relevant decision-makers. The progress of the modeling group would regularly be reported to the steering group.

According to Sjölund (Sjölund 1979), the group was to large compared to the ideal size of 6-8. As noted earlier the group was composed of representatives of different stakeholders and several had a low level of participation. I would suggest concentrating the group to select individuals with knowledge and capacity to contribute. However, in many cases it is important to connect to several stakeholder groups. A common way to do this is to have a reference group where stakeholders can protect their interests.

Sjölund also raises the issue of seating. The room was cramped so that the participants passively remained in their chairs. For a good process in a group, people need to be able to move around and actively take part in discussions at the screen or the whiteboard. A large room with flexible seating would contribute to less locked seating and more interaction.

Combining hard and soft sides

Stermans schema (Sterman 2000) is a most useful for any approach to modeling. However, in a group modeling setting it is probably important not to confuse participants with to much modeling terminology and a scientifically rigorous approach. Vennix (Vennix 1996) suggests quickly moving from initial causal loop diagrams to early stock and flow diagrams.

I would suggest taking into consideration the background of the participants. In groups of engineers, business administrators, economists etc, it is probably possible to be fairly “technical” and openly show detailed logic of models. However in groups, where the participants are not trained number crunchers it is important to spend modeling time outside the group to simplify the model and reduce complexity. I would suggest considering using software with a less demanding interface, such as MyStrategy, particularly in the beginning.

Procurement and elicitation of data

The modeling was severely hampered by both late and limited data. I suggest that one should hesitate going into group modeling without first having a preliminary study. This should clarify the problem and also provide some of the basic data. Before starting work in the group, data sources and key persons should be identified and be in a state of preparedness. I would also suggest that the appointment of a liaison person in the client system, who is responsible for prompt handling of requests for data.

Combining quantitative and qualitative parameters

Health care is well suited for system dynamics interventions. Even a simple model showing patient logistics contains dynamic loops showing the difficulties in taking policy decisions. Most decision making within health care requires using judgment under uncertainty and necessity of speed. As already has been shown in the literature, system dynamics can make a considerable contribution in quantitative modeling.

The intention of this project was to combine quantitative and qualitative parameters. This intention failed due to the late realization of the content of the medical evidence. However, I am still of the opinion that the considerable variation in patient conditions and progress, combined with the judgmental nature of decision-making indicates that modeling would be enhanced by including qualitative variables.

Suggestions for extensions of the model or further research

Goal conflicts

There are international as well as national guidelines (Socialstyrelsen 2000) as to the organization of stroke care. Guidelines and medical evidence suggest that stroke patients are best treated in a specialized unit with both emergency care and rehabilitation. Socialstyrelsen has recently audited the stroke care in Sweden and clearly criticized much of the present care, particularly for not creating unified stroke units.

Dalarna has created a specific stroke unit for emergency care, but considers the nature of the care there so different from rehabilitation that rehab is done in the rehab unit. It is surprising to note that although a specialized unit has been created, less than two-thirds of all stroke patients are treated there in spite of sufficient capacity.

This is probably due to a goal conflict between the guidelines and financing. Units are paid for actual work done, i.e. they are penalized if beds are reserved and not used for other patients.

Brunsson (Brunsson and Adler 2002) describes what he calls organization of hypocrisy when there is no congruence between talk, decisions and action. In his book he describes many examples of how politically led organizations are unable to live up to their visions. He says that in a normally functional organization, the usual causality is that talk leads to decisions, and decisions lead to action.

Figure 44 Talk, decisions, action – normal causality

However, in the book he gives several examples of dysfunctionality in politically led organizations, and he posits that the causality can be such that more talk makes it less necessary to take decisions, and that decisions when not taken are not implemented. He actually proposes a negative causality.

Figure 45 Talk, decisions, action – "political" causality

Such causality is hardly intuitive. Reading more extensively I rather understand him saying that when politicians talk a lot, they have and create a feeling that they are gripping the situation, which in the short term reduces the necessity of taking decisions. Also taking plenty of decisions also creates the sense of having a grip, so economical realities can postpone the actual action. However, his analysis is that in the long run decisions and actions are undertaken, which is why I draw them with delays in the causal diagram below.

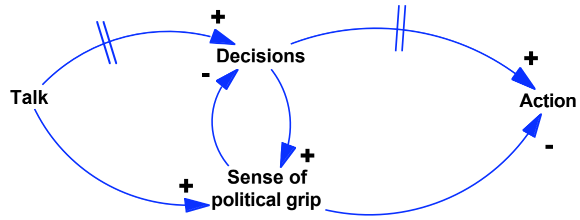


Figure 46 Talk, decisions, action – revised "political" causality

A quote from Brunsson:

> Formal organizations, rituals and double talk all represent ways of coping with inconsistencies between institutional norms and requirements of efficiency. But institutional norms about products, structure, process and ideology can be inconsistent in themselves. Different interests in the environment demand different things of the organization, both regarding products and the ways of producing them. Various professional groups inside and outside the organization have different ideas about how the organization should be run. All three demands not only differ from another they may well be difficult or impossible to combine: they are contradictory or inconsistent.

Table 10 Brunsson on coping with inconsistencies

The ward in question is subject to conflicting demands. Socialstyrelsen have imposed national guidelines (Socialstyrelsen 2000) based on international medical evidence and guidelines. The professionals, i.e. doctors and nurses, have accepted these. Local political entities have agreed to the policy by instituting a stroke ward and given it specialized resources. On the other hand the local political entities subject the hospital, it's clinics and wards to economical constraints. Clinics are paid according to "performance", and not for preparedness in the form of empty beds. So empty beds are filled so as to attain economic targets.

Applying Brunssons reasoning I would be inclined classify the talk and decisions by the politicians to institute a stroke ward as double-talk, as the economic pressure is given higher priority than following qualitative guidelines.

This places the professionals in a double bind (Bateson 1987), i.e. subject to two irreconcilable demands. Bateson used the double bind theory to define one of the first accepted theories of schizophrenia. Being subject to conflicting goals cannot be a good situation. Contradictory demands are common within healthcare and it would be interesting to study if they have effects on work pressure, work morale, or other coping measures.

Erosion of goals

When I was doing the simulations before meeting 5, I was considering the fact that any changes in the qualitative parameters had hardly any discernible impact on the results of the discrete simulations. I compared the continuous and discrete simulations below.

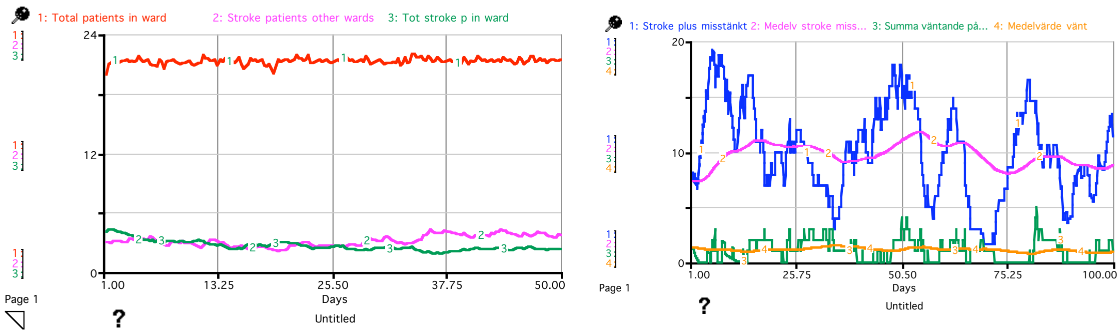


Figure 47 Comparison continuous and discrete simulations

Over the past 10 tears I have had in-depth interviews and conversations with well over 300 doctors and nurses. One lasting impression is the constant flux. There is considerable variation in patient flows. And there is also considerable variation how illness progresses in individual patients. I know of wards and clinics where the workload is tracked on an hourly basis, so as to enable steering staff to the most needy sectors. I have also heard stories of how analysis of best practice has resulted in decisions about treatment methods, and how these decisions erode over a period less than one year, due to the variation in individual outcomes.

I consider it probable that an erosion of goals also exists among staff. When running discrete simulations there is dramatic flux of the number of stroke patients actually in the ward. The variation round the average is considerable. There are probably also significant differences in the progression of the illness and the recovery of the individual patients. I consider it probable that it is difficult to maintain goals and standards under such circumstances, particularly if suitable key figures are not followed up and reported.

I discussed the issue of eroding goals with the project leader and she carried out literature search, but did not find anything of relevance.

It would be most interesting to study erosion of goals, due to workload flux, as a possible explanation to why policy decisions sometimes have little effect over time.

Medical evidence

As pointed out several times earlier, the medical evidence was a great disappointment as it referrer to the exogenous condition of the ward being well organized or conventional. According to the national guidelines a stroke ward should hold between 10-15 patients. I see this as a suggestion that there is some threshold over which it is difficult to maintain the criteria of a well-organized ward. I would also consider it most probable that patient flows, staffing level, proportion of patients in the acute phase, etc most probably influence workloads and health outcomes or treatment times. It would be interesting to extend the model with such data and base the relations on interviews with both doctors and nurses.

The suitability of system dynamics for the problem at hand

Considering the non-dynamic nature of the results of the Cochrane study and the national stroke statistics, it is natural to question if system dynamics is a useful approach or not.

A critical issue would be to find how factors such as room design, patient flows, patient status tie into factors such as work load and what effect that in turn has on health outcomes, treatment times etc. These relationships need to be found by interviews and observations and interviews. Without such data system dynamics modeling does not answer the questions at hand.

It could also be interesting to combine system dynamics and agent based modeling, as is done in the program AnyLogic (XJ_Technologies). There it would be possible to test different spatial designs and use system dynamics logic to determine outcomes.

Extending the boundaries of the model

According to the national stroke register (Riks-Stroke 2002) the time between falling ill and being diagnosed and treated is a vital factor for health outcomes. The model could be extended to represent the differences in time to arrive at the hospital due living distance from the hospital, time for the ambulance to respond etc. Extensions should also allow for different conditions and policies in the emergency rooms.

About 30% of all stroke patients have a relapse. According to the national register this can be reduced by 10% by proper follow-up and interventions in primary care. This means that the model could be extended to include primary care policies and should include a loop of relapsing patients reentering the system.

Arrays

I have indicated several times that I had planned to rebuild the parallel patient flows into arrays. Due to the turbulence due to late data, the array model was never finalized. However, this is the outline of the model:

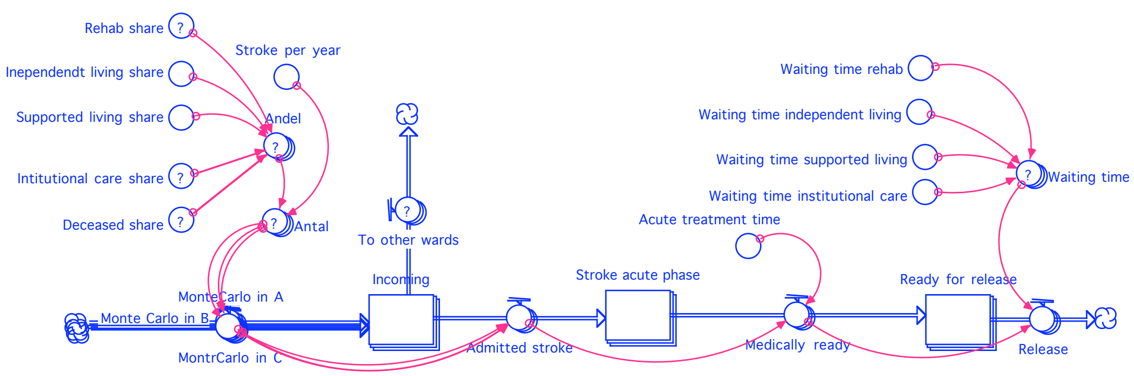


Figure 48 Model with arrays

References

Adizes, Ichak. 1992. *Mastering change : the power of mutual trust and respect in personal life, family life, business, and society*. Santa Monica, Calif.: Adizes Institute.

Andersen, David F., and George P. Richardson. 1997. Scripts for group model building. *System Dynamics Review* 13 (2):107-129.

Andersen, David F., George P. Richardson, and Jac A.M. Vennix. 1997. Group model building: ading more science to the craft. *System Dynamics Review* 13 (2):187-201.

Bateson, Gregory. 1987. *Steps to an ecology of mind : collected essays in anthropology, psychiatry, evolution, and epistemology*. Northvale, N.J.: Aronson.

Blake, Robert R., and Jane Srygley Mouton. 1986. *Consultation: A handbook for individual and organizational development*. 2nd ed: Reading, Massachusetts.

Brunsson, Nils, and Nancy Adler. 2002. *The organization of hypocrisy : talk, decisions and actions in organizations*. 2. ed. Malmö, Oslo, Copenhagen: Liber ekonomi; Abstrakt; Copenhagen Business School Press.

Cavana, Robert Y., Philip K. Davies, Rachel M. Robson, and Wilson Kenneth J. 1999. Drivers of Quality in Health Services: Different Worldviews of Clinicians and Policy Managers Revealed. *System Dynamics Review* 15:331-340.

Gergen, Kenneth, J. 1999. *An invitation to social construction*. Thousand Oaks, Calif. ; London: SAGE.

———. 2001. *Social construction in context*. London: SAGE.

Holmström, Paul, and Marie Elf. 2004. Staff retention and job satisfaction at a hospital clinic - a case study. Paper read at 22nd International Conference of the System Dynamics Society, at Oxford, U.K.

Petersen, Lars-Odd, Ellen Breddam, and Peder Jest. 2004. Improvement through organisational change – use of a consensus promoting method in planning stroke treatment. Paper read at European Health Management Organisation, at Gdansk.

Richardson, George P., and David F. Andersen. 1995. Teamwork in Group Model Building. *System Dynamics Review* 11:113-137.

Riks-Stroke, Styrgruppen för. 2002. Analyserande rapport från Riks-Stroke för helåren 1999-2000.

Schein, Edgar H. 1999. *Process consultation revisited : building the helping relationship*. Reading, Mass.: Addison-Wesley.

Sjölund, Arne. 1979. *Gruppsykologi*. 2nd ed. Stockholm: Rabén & Sjögren.

Socialstyrelsen. 2000. Nationella riktlinjer för strokesjukvård.

Sterman, John. 2000. *Business dynamics : systems thinking and modeling for a complex world*. Boston ; London: Irwin/McGraw-Hill.

Vennix, Jac A.M. 1996. *Group model building : facilitating team learning using system dynamics*. Chichester: John Wiley.

———. 1999. Group model building: tackling messy problems. *System Dynamics Review* 15 (4):379-401.

Vennix, Jac A.M., and Jan W. Gubbels. 1990. A Structured Approach to Knowledge Elicitation in Conceptual Model Building. *System Dynamics Review* 6:194-208.

Watzlawick, Paul. 1984. *The Invented reality : how do we know what we believe we know?* 1st ed ed. New York: Norton.

Weick, Karl E. 1995. *Sensemaking in organizations*, *Foundations for organizational science,*. Thousand Oaks, Calif.: Sage.

Wolstenholme, Eric. 1999. A patient flow perspective of U.K. Health Services: Exploring the case for new "intermediate" care initiatives. *System Dynamics Review* 15 (3):253-271.

Wolstenholme, Eric, Douglas McKelvie, Gill Smith, and David Monk. 2004. Using System Dynamics in Modelling Health and Social Care Commissioning in the UK. Paper read at 22nd International Conference of the System Dynamics Society, at Oxford, u.k.

Wolstenholme, Eric, and Richard W. Stevenson. 1996. Process Design in UK Health Care and Social Services. Paper read at Designing organisations for change: Systems Thinking and Systems Modelling with ithink, 27-29 November 1996, at Harrogate, U.K.

XJ_Technologies. *AnyLogic 5.1.1* [cited. Available from http://www.xjtek.com/.

Equation appendix

Figure 12 Meeting 3 - initial simple model

```
Patients_in_ward(t) = Patients_in_ward(t - dt) + (Patient_inflow - Pa-
tient_release) * dt
INIT Patients_in_ward = 0
```

Figure 14 Meeting 3 - final model

```
INFLOWS:
Patient_inflow = Patients_per_year/365
OUTFLOWS:
Patient_release = Patients_in_ward/Average_treatment_time
Average_treatment_time = 4.2
Patients_per_year = 462
Acute_patients_in_ward(t) = Acute_patients_in_ward(t - dt) + (Pa-
tient_inflow - Patients_ready_for_release) * dt
INIT Acute_patients_in_ward = 4
INFLOWS:
Patient_inflow = Patients_per_year/365
OUTFLOWS:
Patients_ready_for_release =
Acute_patients_in_ward/Average_acute_treatment_time
Other_patients_in_ward(t) = Other_patients_in_ward(t - dt) +
(Other_patient_inflow - Other_patients_release) * dt
INIT Other_patients_in_ward = 4
INFLOWS:
Other_patient_inflow = Other_patients_per_year/365
OUTFLOWS:
Other_patients_release =
Other_patients_in_ward/Other_patient_treatment_time
Sorting_stock(t) = Sorting_stock(t - dt) + (Patients_ready_for_release
- Waiting_for_Community_Care - Waiting_for_rehab - Wait-
ing_for_Idependent_Living - Deceased) * dt
INIT Sorting_stock = 3
INFLOWS:
Patients_ready_for_release =
Acute_patients_in_ward/Average_acute_treatment_time
OUTFLOWS:
Waiting_for_Community_Care = Pa-
tients_ready_for_release*Community_Care_%
Waiting_for_rehab = Patients_ready_for_release*Rehab_%
Waiting_for_Idependent_Living = Pa-
tients_ready_for_release*Independent_Living_%
Deceased = Patients_ready_for_release*Deceased_%
Waiting_CC(t) = Waiting_CC(t - dt) + (Waiting_for_Community_Care - Re-
lease_to_CC) * dt
INIT Waiting_CC = 1
INFLOWS:
Waiting_for_Community_Care = Pa-
tients_ready_for_release*Community_Care_%
OUTFLOWS:
Release_to_CC = Waiting_CC/Waiting_time_for_CC
Waiting_IL(t) = Waiting_IL(t - dt) + (Waiting_for_Idependent_Living -
Release_to_IL) * dt
INIT Waiting_IL = 0
INFLOWS:
Waiting_for_Idependent_Living = Pa-
tients_ready_for_release*Independent_Living_%
OUTFLOWS:
Release_to_IL = Waiting_IL/Waiting_time_for_IL
```

```
Waiting_Rehab(t) = Waiting_Rehab(t - dt) + (Waiting_for_rehab - Re-
lease_to_Rehab) * dt
INIT Waiting_Rehab = 1
INFLOWS:
Waiting_for_rehab = Patients_ready_for_release*Rehab_%
OUTFLOWS:
Release_to_Rehab = Waiting_Rehab/Waiting_time_for_Rehab
Average_acute_treatment_time = 3
Community_Care_% = .14
Deceased_% = .12
Independent_Living_% = .42
Other_patients_per_year = 462
Other_patient_treatment_time = 4
Patients_per_year = 462
Rehab_% = .32
Total_all_patients = Other_patients_in_ward+Total_stroke_patients
Total_stroke_patients = Acute_patients_in_ward+Total_waiting
Total_waiting = Waiting_CC+Waiting_IL+Waiting_Rehab
Waiting_time_for_CC = 5
Waiting_time_for_IL = .5
Waiting_time_for_Rehab = 2
```

Figure 17 Model prepared for meeting 4

```
Acute_patients_in_ward(t) = Acute_patients_in_ward(t - dt) +
(To_stroke_unit - Patients_ready_for_release) * dt
INIT Acute_patients_in_ward = 2
INFLOWS:
To_stroke_unit = Min(Vacant_beds,Patient_inflow)
OUTFLOWS:
Patients_ready_for_release =
Acute_patients_in_ward/Average_acute_treatment_time
Kidney_patients_in_ward(t) = Kidney_patients_in_ward(t - dt) + (Kid-
ney_patient_inflow - Kidney_patients_release) * dt
INIT Kidney_patients_in_ward = 10
INFLOWS:
Kidney_patient_inflow = Kid-
ney_patients_per_year*Round(Pink_noise_KP)/365
OUTFLOWS:
Kidney_patients_release = Kid-
ney_patients_in_ward/Kidney_patient_treatment_time
Other_patients_in_ward(t) = Other_patients_in_ward(t - dt) +
(Other_patient_inflow - Other_patients_release) * dt
INIT Other_patients_in_ward = 2
INFLOWS:
Other_patient_inflow = Round(Vacant_beds-Reserved_beds)
OUTFLOWS:
Other_patients_release =
Other_patients_in_ward/Other_patient_treatment_time
Sorting_stock(t) = Sorting_stock(t - dt) + (Patients_ready_for_release
- Waiting_for_Community_Care - Waiting_for_rehab - Wait-
ing_for_Idependent_Living - Deceased) * dt
INIT Sorting_stock = 3
INFLOWS:
Patients_ready_for_release =
Acute_patients_in_ward/Average_acute_treatment_time
OUTFLOWS:
Waiting_for_Community_Care = Pa-
tients_ready_for_release*Community_Care_%
Waiting_for_rehab = Patients_ready_for_release*Rehab_%
Waiting_for_Idependent_Living = Pa-
tients_ready_for_release*Independent_Living_%
Deceased = Patients_ready_for_release*Deceased_%
Stroke_patients_other_wards(t) = Stroke_patients_other_wards(t - dt) +
(To_other_wards - Ready_OW) * dt
```

```
INIT Stroke_patients_other_wards = 3
INFLOWS:
To_other_wards = Patient_inflow-To_stroke_unit
OUTFLOWS:
Ready_OW = Stroke_patients_other_wards/Treatment_time_OW
Stroke_to_be_placed(t) = Stroke_to_be_placed(t - dt) + (Patient_inflow
- To_stroke_unit - To_other_wards) * dt
INIT Stroke_to_be_placed = 0
INFLOWS:
Patient_inflow = Stroke_patients_per_year*ROUND(Pink_noise)/365
OUTFLOWS:
To_stroke_unit = Min(Vacant_beds,Patient_inflow)
To_other_wards = Patient_inflow-To_stroke_unit
Susp_stroke_patients_in_ward(t) = Susp_stroke_patients_in_ward(t - dt)
+ (Susp_stroke_patient_inflow - Susp_stroke_patients_release) * dt
INIT Susp_stroke_patients_in_ward = 4
INFLOWS:
Susp_stroke_patient_inflow =
Susp_stroke_patients_per_year*ROUND(Pink_noise_SS)/365
OUTFLOWS:
Susp_stroke_patients_release =
Susp_stroke_patients_in_ward/Susp_stroke_patient_treatment_time
To_be_released_OW(t) = To_be_released_OW(t - dt) + (Ready_OW - Re-
leased_OW - Deceased_OW) * dt
INIT To_be_released_OW = 0
INFLOWS:
Ready_OW = Stroke_patients_other_wards/Treatment_time_OW
OUTFLOWS:
Released_OW = Ready_OW*(1-Deceased_%_OW)
Deceased_OW = Ready_OW*Deceased_%_OW
Waiting_CC(t) = Waiting_CC(t - dt) + (Waiting_for_Community_Care - Re-
lease_to_CC) * dt
INIT Waiting_CC = 1
INFLOWS:
Waiting_for_Community_Care = Pa-
tients_ready_for_release*Community_Care_%
OUTFLOWS:
Release_to_CC = Waiting_CC/Waiting_time_for_CC
Waiting_IL(t) = Waiting_IL(t - dt) + (Waiting_for_Idependent_Living -
Release_to_IL) * dt
INIT Waiting_IL = 0
INFLOWS:
Waiting_for_Idependent_Living = Pa-
tients_ready_for_release*Independent_Living_%
OUTFLOWS:
Release_to_IL = Waiting_IL/Waiting_time_for_IL
Waiting_Rehab(t) = Waiting_Rehab(t - dt) + (Waiting_for_rehab - Re-
lease_to_Rehab) * dt
INIT Waiting_Rehab = 1
INFLOWS:
Waiting_for_rehab = Patients_ready_for_release*Rehab_%
OUTFLOWS:
Release_to_Rehab = Waiting_Rehab/Waiting_time_for_Rehab
Average_acute_treatment_time = 3
Community_Care_% = .14
Deceased_% = .12
Deceased_%_OW = .12
Independent_Living_% = .42
Kidney_patients_per_year = 600
Kidney_patient_treatment_time = 6.5
Other_patient_treatment_time = 4
Pink_noise = NORMAL(1,0.4)
Pink_noise_KP = NORMAL(1,0.4)
Pink_noise_SS = NORMAL(1,0.4)
Rehab_% = .32
```

```
Reserved_beds = 0
Stroke_patients_per_year = 462
Susp_stroke_patients_per_year = 400
Susp_stroke_patient_treatment_time = 5
Total_number_of_beds = 22
Total_patients_in_ward = Kid-
ney_patients_in_ward+Other_patients_in_ward+Susp_stroke_patients_in_wa
rd+Tot_stroke_p_in_ward
Tot_stroke_p_in_ward =
Acute_patients_in_ward+Waiting_CC+Waiting_IL+Waiting_Rehab
Treatment_time_OW = 4.2
Vacant_beds = Total_number_of_beds-Total_patients_in_ward
Waiting_time_for_CC = 5
Waiting_time_for_IL = .5
Waiting_time_for_Rehab = 2
```

Figure 20 Generic sub model

```
In_ward(t) = In_ward(t - dt) + (Out - Released) * dt
INIT In_ward = 0
INFLOWS:
Out = Out'
OUTFLOWS:
Released = DELAY(Out,NORMAL(4,2),0)
Number_per_year = 462
Inflow = Intermediate_A + Intermediate_B
INFLOWS:
In = Number_per_year/365
OUTFLOWS:
Out = Out'
Intermediate_A(t) = Intermediate_A(t - dt) + (In' - MCB - MCC - MCA) *
dt
INIT Intermediate_A = 100
INFLOWS:
In' = In
OUTFLOWS:
MCB = MONTECARLO((Number_per_year*100)/(365*3))/DT
MCC = MONTECARLO((Number_per_year*100)/(365*3))/DT
MCA = MONTECARLO((Number_per_year*100)/(365*3))/DT
Intermediate_B(t) = Intermediate_B(t - dt) + (MCB + MCC + MCA - Out')
* dt
INIT Intermediate_B = 0
INFLOWS:
MCB = MONTECARLO((Number_per_year*100)/(365*3))/DT
MCC = MONTECARLO((Number_per_year*100)/(365*3))/DT
MCA = MONTECARLO((Number_per_year*100)/(365*3))/DT
OUTFLOWS:
Out' = MCB+MCC+MCA
```

Figure 23 Model meeting 5

```
Other patients in ward
Dialysis_patients(t) = Dialysis_patients(t - dt) + (Entered_dialysis -
Released_dialysis) * dt
INIT Dialysis_patients = 0
INFLOWS:
Entered_dialysis = Entered_dialysis'
OUTFLOWS:
Released_dialysis = DELAY(Entered_dialysis,Treatment_time_dialysis,0)
Kidneypatients(t) = Kidneypatients(t - dt) + (Entered_kidney - Re-
leased_kidney) * dt
INIT Kidneypatients = 0
INFLOWS:
Entered_kidney = Entered_kidney'
```

```
OUTFLOWS:
Released_kidney = DELAY(Entered_kidney,Treatment_time_kidney,0)
Other_patients(t) = Other_patients(t - dt) + (Incoming_other_patients
- Released_others) * dt
INIT Other_patients = 0
INFLOWS:
Incoming_other_patients = ROUND(Free_beds-Reserved_beds)/DT
OUTFLOWS:
Released_others = DE-
LAY(Incoming_other_patients,NORMAL(Treatment_time_others,1),1)
Stroke_in_wards_Inst_Care(t) = Stroke_in_wards_Inst_Care(t - dt) +
(Entered_stroke_Inst_Care - Releaseable_Inst_Care) * dt
INIT Stroke_in_wards_Inst_Care = 1
INFLOWS:
Entered_stroke_Inst_Care      (IN SECTOR:  Stroke patients in stroke
ward)
OUTFLOWS:
Releaseable_Inst_Care   (IN SECTOR:  Stroke patients in stroke ward)
Suspected_stroke_in_ward(t) = Suspected_stroke_in_ward(t - dt) + (En-
tered_susp_stroke - Release_suspected) * dt
INIT Suspected_stroke_in_ward = 2
INFLOWS:
Entered_susp_stroke = Entered_susp_stroke'
OUTFLOWS:
Release_suspected = DE-
LAY(Entered_susp_stroke,NORMAL(Treatment_time_susp,1),.5)
Average_dialysis = SMTH1(Dialysis_patients,20)
Average_kidney = SMTH1(Kidneypatients,20)
Average_suspected = SMTH1(Suspected_stroke_in_ward,20)
Dialysis_and_kidney = Dialysis_patients+Kidneypatients
Dialysis_per_year = 104
Kidney_pat_per_year = 320
Medelv_njur_dialys = SMTH1(Dialysis_and_kidney,20)
Reserved_beds = 100
Room_and_assesment = 1
Suspected_stroke_per_year = 684
Treatment_time_dialysis = 4.6
Treatment_time_kidney = 8.8
Treatment_time_others = 4.2
Treatment_time_susp = 5.3
Dialysis_under_way = MellanA_3 + MellanB_3
INFLOWS:
Incoming_dialysis = Dialysis_per_year/365
OUTFLOWS:
Entered_dialysis = Entered_dialysis'
MellanA_3(t) = MellanA_3(t - dt) + (Incoming_dialysis' - MCB_3 - MCC_3
- MCA_3) * dt
INIT MellanA_3 = 100
INFLOWS:
Incoming_dialysis' = Incoming_dialysis
OUTFLOWS:
MCB_3 = MONTECARLO((Dialysis_per_year*100)/(365*3),2200)/DT
MCC_3 = MONTECARLO((Dialysis_per_year*100)/(365*3),3003)/DT
MCA_3 = MONTECARLO((Dialysis_per_year*100)/(365*3),1010)/DT
MellanB_3(t) = MellanB_3(t - dt) + (MCB_3 + MCC_3 + MCA_3 - En-
tered_dialysis') * dt
INIT MellanB_3 = 0
INFLOWS:
MCB_3 = MONTECARLO((Dialysis_per_year*100)/(365*3),2200)/DT
MCC_3 = MONTECARLO((Dialysis_per_year*100)/(365*3),3003)/DT
MCA_3 = MONTECARLO((Dialysis_per_year*100)/(365*3),1010)/DT
OUTFLOWS:
Entered_dialysis' = MCB_3+MCC_3+MCA_3
Kidney_under_way = MellanA + MellanB
INFLOWS:
```

```
Incoming_kidney = Kidney_pat_per_year/365
OUTFLOWS:
Entered_kidney = Entered_kidney'
MellanA(t) = MellanA(t - dt) + (Incoming_kidney' - MCB - MCC - MCA) *
dt
INIT MellanA = 100
INFLOWS:
Incoming_kidney' = Incoming_kidney
OUTFLOWS:
MCB = MONTECARLO((Kidney_pat_per_year*100)/(365*3),2000)/DT
MCC = MONTECARLO((Kidney_pat_per_year*100)/(365*3),3000)/DT
MCA = MONTECARLO((Kidney_pat_per_year*100)/(365*3),1000)/DT
MellanB(t) = MellanB(t - dt) + (MCB + MCC + MCA - Entered_kidney') *
dt
INIT MellanB = 0
INFLOWS:
MCB = MONTECARLO((Kidney_pat_per_year*100)/(365*3),2000)/DT
MCC = MONTECARLO((Kidney_pat_per_year*100)/(365*3),3000)/DT
MCA = MONTECARLO((Kidney_pat_per_year*100)/(365*3),1000)/DT
OUTFLOWS:
Entered_kidney' = MCB+MCC+MCA
Susp_stroke_on_way = MellanA_2 + MellanB_2
INFLOWS:
Incoming_susp_stroke = (Suspected_stroke_per_year-
Antal_stroke_per_år)/365
OUTFLOWS:
Entered_susp_stroke = Entered_susp_stroke'
MellanA_2(t) = MellanA_2(t - dt) + (Incoming_susp_stroke' - MCB_2 -
MCC_2 - MCA_2) * dt
INIT MellanA_2 = 100
INFLOWS:
Incoming_susp_stroke' = Incoming_susp_stroke
OUTFLOWS:
MCB_2 = MONTECARLO((Suspected_stroke_per_year*100)/(365*3))/DT
MCC_2 = MONTECARLO((Suspected_stroke_per_year*100)/(365*3))/DT
MCA_2 = MONTECARLO((Suspected_stroke_per_year*100)/(365*3))/DT
MellanB_2(t) = MellanB_2(t - dt) + (MCB_2 + MCC_2 + MCA_2 - En-
tered_susp_stroke') * dt
INIT MellanB_2 = 0
INFLOWS:
MCB_2 = MONTECARLO((Suspected_stroke_per_year*100)/(365*3))/DT
MCC_2 = MONTECARLO((Suspected_stroke_per_year*100)/(365*3))/DT
MCA_2 = MONTECARLO((Suspected_stroke_per_year*100)/(365*3))/DT
OUTFLOWS:
Entered_susp_stroke' = IF ((MCA_2+MCB_2+MCC_2)>0)
THEN MIN((MCA_2+MCB_2+MCC_2),ROUND(Free_beds)/DT)
ELSE 0
```

Figure 33 Qualitative model

```
Interdisciplinary_teamwork = 1
Patients_and_relatives_influence = 1
Room_and_team = 1
Room_quality = 1
Share_deceased = Share_deceased_Ref*Vårdeffekter
Share_deceased_Ref = .12
Share_Ind_Liv = .42
Share_Inst_Care = Share_Inst_Care_Ref*Vårdeffekter
Share_Inst_Care_Ref = .14
Share_rehab = .32
Systematic_assessment_and_planning = 1
Treatment_time_stroke = Treat-
ment_time_stroke_Ref*Vårdeffekter*Room_effect*Walking_effect
Treatment_time_stroke_Ref = 3.5
```

```
Vårdeffekter = Influ-
ence_effect*Systematic_effect*RoomTeam_effect*Team_effect*RoomAsses_ef
fect
Walking_factor = 1
Influence_effect = GRAPH(Patients_and_relatives_influence)
(0.00, 0.8), (0.2, 0.8), (0.4, 0.8), (0.6, 0.81), (0.8, 0.86), (1.00,
1.00), (1.20, 1.10), (1.40, 1.18), (1.60, 1.20), (1.80, 1.20), (2.00,
1.20)
RoomAsses_effect = GRAPH(Room_and_assesment)
(0.00, 0.8), (0.2, 0.8), (0.4, 0.8), (0.6, 0.81), (0.8, 0.86), (1.00,
1.00), (1.20, 1.10), (1.40, 1.18), (1.60, 1.20), (1.80, 1.20), (2.00,
1.20)
RoomTeam_effect = GRAPH(Room_and_team)
(0.00, 0.8), (0.2, 0.8), (0.4, 0.8), (0.6, 0.81), (0.8, 0.86), (1.00,
1.00), (1.20, 1.10), (1.40, 1.18), (1.60, 1.20), (1.80, 1.20), (2.00,
1.20)
Room_effect = GRAPH(Room_quality)
(0.00, 0.8), (0.2, 0.8), (0.4, 0.8), (0.6, 0.81), (0.8, 0.86), (1.00,
1.00), (1.20, 1.10), (1.40, 1.18), (1.60, 1.20), (1.80, 1.20), (2.00,
1.20)
Systematic_effect = GRAPH(Systematic_assessment_and_planning)
(0.00, 0.8), (0.2, 0.8), (0.4, 0.8), (0.6, 0.81), (0.8, 0.86), (1.00,
1.00), (1.20, 1.10), (1.40, 1.18), (1.60, 1.20), (1.80, 1.20), (2.00,
1.20)
Team_effect = GRAPH(Interdisciplinary_teamwork)
(0.00, 0.8), (0.2, 0.8), (0.4, 0.8), (0.6, 0.81), (0.8, 0.86), (1.00,
1.00), (1.20, 1.10), (1.40, 1.18), (1.60, 1.20), (1.80, 1.20), (2.00,
1.20)
Walking_effect = GRAPH(Walking_factor)
(0.00, 0.8), (0.2, 0.8), (0.4, 0.8), (0.6, 0.81), (0.8, 0.86), (1.00,
1.00), (1.20, 1.10), (1.40, 1.18), (1.60, 1.20), (1.80, 1.20), (2.00,
1.20)
Stroke patients at other units
Sorting(t) = Sorting(t - dt) + (Ready_fore_releasde_OW -
To_wait_Inst_Care_OW - To_wait_rehab_OW - To_wait_Ind_Liv_OW - Av-
lidna_utp) * dt
INIT Sorting = 0
INFLOWS:
Ready_fore_releasde_OW = DE-
LAY(Stroke_till_andra_avdelningar_A,NORMAL(Treatment_time_stroke_OW,1)
,1)+DELAY(Stroke_to_other_units_Ind_Liv,NORMAL(Treatment_time_stroke_O
W,1),1)+
DE-
LAY(Stroke_to_other_wards_Inst_care,NORMAL(Treatment_time_stroke_OW,1)
,1)+
DE-
LAY(Stroke_to_other_wards_Rehab,NORMAL(Treatment_time_stroke_OW,1),1)
OUTFLOWS:
To_wait_Inst_Care_OW = Ready_fore_releasde_OW*Inst_Care_share_OW
To_wait_rehab_OW = Ready_fore_releasde_OW*Rehab_share_OW
To_wait_Ind_Liv_OW = Ready_fore_releasde_OW*Ind_Liv_share_OW
Avlidna_utp = Ready_fore_releasde_OW*Deceased_OW
Stroke_patients_other_wards(t) = Stroke_patients_other_wards(t - dt) +
(Stroke_to_other_wards_Inst_care + Stroke_to_other_wards_Rehab +
Stroke_to_other_units_Ind_Liv + Stroke_till_andra_avdelningar_A -
Ready_fore_releasde_OW) * dt
INIT Stroke_patients_other_wards = 0
INFLOWS:
Stroke_to_other_wards_Inst_care = Stroke_to_other_wards_Inst_care'
Stroke_to_other_wards_Rehab = Stroke_to_other_wards_Rehab'
Stroke_to_other_units_Ind_Liv = Stroke_to_other_units_Ind_Liv'
Stroke_till_andra_avdelningar_A     (IN SECTOR:  Stroke patients in
stroke ward)
OUTFLOWS:
```

```
Ready_fore_releasde_OW = DE-
LAY(Stroke_till_andra_avdelningar_A,NORMAL(Treatment_time_stroke_OW,1)
,1)+DELAY(Stroke_to_other_units_Ind_Liv,NORMAL(Treatment_time_stroke_O
W,1),1)+
DE-
LAY(Stroke_to_other_wards_Inst_care,NORMAL(Treatment_time_stroke_OW,1)
,1)+
DE-
LAY(Stroke_to_other_wards_Rehab,NORMAL(Treatment_time_stroke_OW,1),1)
Waiting_Ind_Liv_OW(t) = Waiting_Ind_Liv_OW(t - dt) +
(To_wait_Ind_Liv_OW - Release_to_Ind_Liv_OW) * dt
INIT Waiting_Ind_Liv_OW = 0
INFLOWS:
To_wait_Ind_Liv_OW = Ready_fore_releasde_OW*Ind_Liv_share_OW
OUTFLOWS:
Release_to_Ind_Liv_OW = DE-
LAY(Waiting_time_Ind_Liv,NORMAL(To_wait_Ind_Liv_OW,1),1)
Waiting_Inst_Care_OW(t) = Waiting_Inst_Care_OW(t - dt) +
(To_wait_Inst_Care_OW - Release_to_Inst_Care_OW) * dt
INIT Waiting_Inst_Care_OW = 0
INFLOWS:
To_wait_Inst_Care_OW = Ready_fore_releasde_OW*Inst_Care_share_OW
OUTFLOWS:
Release_to_Inst_Care_OW = DE-
LAY(To_wait_Inst_Care_OW,NORMAL(Waiting_time_Inst_care,2),1)
Waiting_Rehab_OW(t) = Waiting_Rehab_OW(t - dt) + (To_wait_rehab_OW -
Release_to_rehab_OW) * dt
INIT Waiting_Rehab_OW = 0
INFLOWS:
To_wait_rehab_OW = Ready_fore_releasde_OW*Rehab_share_OW
OUTFLOWS:
Release_to_rehab_OW = DE-
LAY(To_wait_rehab_OW,NORMAL(Wait_time_rehab,1),1)
Average_outplaced = SMTH1(Share_outplaced,20)
Deceased_OW = .15
Ind_Liv_share_OW = .39
Inst_Care_share_OW = .17
Rehab_share_OW = .29
Share_outplaced = IF (Sum_placed_other_wards<=0) THEN 0 ELSE
((Sum_placed_other_wards*100)/(Sum_placed_other_wards+Stroke_pat_at_st
roke_ward))
Sum_placed_other_wards = Wait-
ing_Inst_Care_OW+Waiting_Rehab_OW+Stroke_patients_other_wards+Sorting+
Waiting_Ind_Liv_OW
Treatment_time_stroke_OW = 3
Stroke patients in stroke ward
Stroke_in_ward_Dec(t) = Stroke_in_ward_Dec(t - dt) + (En-
tered_stroke_Dec - Deceased) * dt
INIT Stroke_in_ward_Dec = 0
INFLOWS:
Entered_stroke_Dec = Entered_stroke_Dec'
OUTFLOWS:
Deceased = DELAY(Entered_stroke_Dec,NORMAL(Treatment_time_stroke,1),0)
Stroke_in_ward_Ind_Liv(t) = Stroke_in_ward_Ind_Liv(t - dt) + (En-
tered_stroke_Ind_Liv - Releaseable_Ind_Liv) * dt
INIT Stroke_in_ward_Ind_Liv = 2
INFLOWS:
Entered_stroke_Ind_Liv = Entered_stroke_Ind_Liv'
OUTFLOWS:
Releaseable_Ind_Liv = DE-
LAY(Entered_stroke_Ind_Liv,NORMAL(Treatment_time_stroke,1),.5)
Stroke_in_ward_Rehab(t) = Stroke_in_ward_Rehab(t - dt) + (En-
tered_stroke_Rehab - Releaseable_Rehab) * dt
INIT Stroke_in_ward_Rehab = 1
INFLOWS:
```

```
Entered_stroke_Rehab = Entered_stroke_Rehab'
OUTFLOWS:
Releaseable_Rehab = DE-
LAY(Entered_stroke_Rehab,NORMAL(Treatment_time_stroke,1),.25)
Waiting_Ind_Liv(t) = Waiting_Ind_Liv(t - dt) + (Releaseable_Ind_Liv -
To_Ind_Liv) * dt
INIT Waiting_Ind_Liv = .3
INFLOWS:
Releaseable_Ind_Liv = DE-
LAY(Entered_stroke_Ind_Liv,NORMAL(Treatment_time_stroke,1),.5)
OUTFLOWS:
To_Ind_Liv = DE-
LAY(Releaseable_Ind_Liv,NORMAL(Waiting_time_Ind_Liv,1),1)
Waiting_Inst_Care(t) = Waiting_Inst_Care(t - dt) + (Release-
able_Inst_Care - To_Inst_Care) * dt
INIT Waiting_Inst_Care = 1
INFLOWS:
Releaseable_Inst_Care = DE-
LAY(Entered_stroke_Inst_Care,NORMAL(Treatment_time_stroke,1),.25)
OUTFLOWS:
To_Inst_Care = DE-
LAY(Releaseable_Inst_Care,NORMAL(Waiting_time_Inst_care,3),1)
Waiting_Rehab(t) = Waiting_Rehab(t - dt) + (Releaseable_Rehab -
To_rehab) * dt
INIT Waiting_Rehab = 0
INFLOWS:
Releaseable_Rehab = DE-
LAY(Entered_stroke_Rehab,NORMAL(Treatment_time_stroke,1),.25)
OUTFLOWS:
To_rehab = DELAY(Releaseable_Rehab,NORMAL(Wait_time_rehab,1),1)
Antal_stroke_per_år = 462
Average_stroke_at_ward = SMTH1(Stroke_at_ward,20)
Average_susp_styroke = SMTH1(Stroke_and_suspected,20)
Average_total_pat = SMTH1(Total_pat_at_ward,20)
Average_waiting = SMTH1(Total_waiting,20)
Free_beds = Total_beds-Total_pat_at_ward
Medelv_stroke_plus_vänt = SMTH1(Stroke_pat_at_stroke_ward,20)
Stroke_and_suspected =
Stroke_pat_at_stroke_ward+Suspected_stroke_in_ward
Stroke_at_ward =
Stroke_in_wards_Inst_Care+Stroke_in_ward_Dec+Stroke_in_ward_Ind_Liv+St
roke_in_ward_Rehab
Stroke_pat_at_stroke_ward = Stroke_at_ward+Total_waiting
Total_beds = 22
Total_pat_at_ward = Sus-
pected_stroke_in_ward+Kidneypatients+Other_patients+Stroke_pat_at_stro
ke_ward+Dialysis_patients
Total_waiting = Waiting_Inst_Care+Waiting_Rehab+Waiting_Ind_Liv
Used_beds = 22-Total_pat_at_ward
Waiting_time_Ind_Liv = .5
Waiting_time_Inst_care = 5
Wait_time_rehab = 2
Stroke_under_way_Dec = Mellan_A_A + Mellan_BA
INFLOWS:
Incoming_stroke_Dec = Antal_stroke_per_år*Share_deceased/365
OUTFLOWS:
Entered_stroke_Dec = Entered_stroke_Dec'
Stroke_till_andra_avdelningar_A = Stroke_till_andra_avdelningar_A'
Mellan_A_A(t) = Mellan_A_A(t - dt) + (Incoming_stroke_Dec' - MCB_A -
MCC_A - MCA_A) * dt
INIT Mellan_A_A = 100
INFLOWS:
Incoming_stroke_Dec' = Incoming_stroke_Dec
OUTFLOWS:
MCB_A = MONTECARLO((Antal_avlidna*100)/(365*3))/DT
```

```
MCC_A = MONTECARLO((Antal_avlidna*100)/(365*3))/DT
MCA_A = MONTECARLO((Antal_avlidna*100)/(365*3))/DT
Mellan_BA(t) = Mellan_BA(t - dt) + (MCB_A + MCC_A + MCA_A - En-
tered_stroke_Dec' - Stroke_till_andra_avdelningar_A') * dt
INIT Mellan_BA = 0
INFLOWS:
MCB_A = MONTECARLO((Antal_avlidna*100)/(365*3))/DT
MCC_A = MONTECARLO((Antal_avlidna*100)/(365*3))/DT
MCA_A = MONTECARLO((Antal_avlidna*100)/(365*3))/DT
OUTFLOWS:
Entered_stroke_Dec' = IF ((MCB_A+MCC_A+MCA_A)>0)
THEN MIN((MCB_A+MCC_A+MCA_A),ROUND(Free_beds)/DT)
ELSE 0
Stroke_till_andra_avdelningar_A' = (MCA_A+MCB_A+MCC_A)-
Entered_stroke_Dec'
Antal_avlidna = Antal_stroke_per_år*Share_deceased
Stroke_under_way_Ind_Liv = MellanA_5 + Mellan_B_EB
INFLOWS:
Incoming_stroke_Ind_Liv = Antal_stroke_per_år*Share_Ind_Liv/365
OUTFLOWS:
Entered_stroke_Ind_Liv = Entered_stroke_Ind_Liv'
Stroke_to_other_units_Ind_Liv (IN SECTOR:  Stroke patients at other
units)
MellanA_5(t) = MellanA_5(t - dt) + (Incoming_stroke_Ind_Liv' - MCB_EB
- MCC_EB - MCA_EB) * dt
INIT MellanA_5 = 100
INFLOWS:
Incoming_stroke_Ind_Liv' = Incoming_stroke_Ind_Liv
OUTFLOWS:
MCB_EB = MONTECARLO((Antal_eget_boende*100)/(365*3))/DT
MCC_EB = MONTECARLO((Antal_eget_boende*100)/(365*3))/DT
MCA_EB = MONTECARLO((Antal_eget_boende*100)/(365*3))/DT
Mellan_B_EB(t) = Mellan_B_EB(t - dt) + (MCB_EB + MCC_EB + MCA_EB - En-
tered_stroke_Ind_Liv' - Stroke_to_other_units_Ind_Liv') * dt
INIT Mellan_B_EB = 0
INFLOWS:
MCB_EB = MONTECARLO((Antal_eget_boende*100)/(365*3))/DT
MCC_EB = MONTECARLO((Antal_eget_boende*100)/(365*3))/DT
MCA_EB = MONTECARLO((Antal_eget_boende*100)/(365*3))/DT
OUTFLOWS:
Entered_stroke_Ind_Liv' = IF ((MCB_EB+MCC_EB+MCA_EB)>0)
THEN MIN((MCB_EB+MCC_EB+MCA_EB),ROUND(Free_beds)/DT)
ELSE 0
Stroke_to_other_units_Ind_Liv' = (MCA_EB+MCB_EB+MCC_EB)-
Entered_stroke_Ind_Liv'
Antal_eget_boende = Antal_stroke_per_år*Share_Ind_Liv
Stroke_under_way_Inst_Care = Mellan_A_K + Mellan_B_K
INFLOWS:
Incoming_stroke_Inst_Care = Antal_stroke_per_år*Share_Inst_Care/365
OUTFLOWS:
Entered_stroke_Inst_Care = Entered_stroke_Inst_Care'
Stroke_to_other_wards_Inst_care     (IN SECTOR:  Stroke patients at
other units)
Mellan_A_K(t) = Mellan_A_K(t - dt) + (Incoming_stroke_Inst_Care' -
MCB_K - MCC_K - MCA_K) * dt
INIT Mellan_A_K = 100
INFLOWS:
Incoming_stroke_Inst_Care' = Incoming_stroke_Inst_Care
OUTFLOWS:
MCB_K = MONTECARLO((Antal_komm_år*100)/(365*3))/DT
MCC_K = MONTECARLO((Antal_komm_år*100)/(365*3))/DT
MCA_K = MONTECARLO((Antal_komm_år*100)/(365*3))/DT
Mellan_B_K(t) = Mellan_B_K(t - dt) + (MCB_K + MCC_K + MCA_K - En-
tered_stroke_Inst_Care' - Stroke_to_other_wards_Inst_care') * dt
INIT Mellan_B_K = 0
```

```
INFLOWS:
MCB_K = MONTECARLO((Antal_komm_år*100)/(365*3))/DT
MCC_K = MONTECARLO((Antal_komm_år*100)/(365*3))/DT
MCA_K = MONTECARLO((Antal_komm_år*100)/(365*3))/DT
OUTFLOWS:
Entered_stroke_Inst_Care' = IF ((MCB_K+MCC_K+MCA_K)>0)
THEN MIN((MCB_K+MCC_K+MCA_K),ROUND(Free_beds)/DT)
ELSE  0
Stroke_to_other_wards_Inst_care' = (MCA_K+MCB_K+MCC_K)-
Entered_stroke_Inst_Care'
Antal_komm_år = Antal_stroke_per_år*Share_Inst_Care
Stroke_under_way_Rehab = Mellan_A_R + Mellan_B_R
INFLOWS:
Incoming_stroke_Rehab = Antal_stroke_per_år*Share_rehab/365
OUTFLOWS:
Entered_stroke_Rehab = Entered_stroke_Rehab'
Stroke_to_other_wards_Rehab   (IN SECTOR:  Stroke patients at other
units)
Mellan_A_R(t) = Mellan_A_R(t - dt) + (Incoming_stroke_Rehab' - MCB_R -
MCC_R - MCA_R) * dt
INIT Mellan_A_R = 100
INFLOWS:
Incoming_stroke_Rehab' = Incoming_stroke_Rehab
OUTFLOWS:
MCB_R = MONTECARLO((Antal_rehab*100)/(365*3))/DT
MCC_R = MONTECARLO((Antal_rehab*100)/(365*3))/DT
MCA_R = MONTECARLO((Antal_rehab*100)/(365*3))/DT
Mellan_B_R(t) = Mellan_B_R(t - dt) + (MCB_R + MCC_R + MCA_R - En-
tered_stroke_Rehab' - Stroke_to_other_wards_Rehab') * dt
INIT Mellan_B_R = 0
INFLOWS:
MCB_R = MONTECARLO((Antal_rehab*100)/(365*3))/DT
MCC_R = MONTECARLO((Antal_rehab*100)/(365*3))/DT
MCA_R = MONTECARLO((Antal_rehab*100)/(365*3))/DT
OUTFLOWS:
Entered_stroke_Rehab' = IF ((MCB_R+MCC_R+MCA_R)>0)
THEN MIN((MCB_R+MCC_R+MCA_R),ROUND(Free_beds)/DT)
ELSE 0
Stroke_to_other_wards_Rehab' = (MCA_R+MCB_R+MCC_R)-
Entered_stroke_Rehab'
Antal_rehab = Antal_stroke_per_år*Share_rehab
Not in a sector
At_Rehab(t) = At_Rehab(t - dt) + (To_rehab - Released_from_Rehab) * dt
INIT At_Rehab = 10
INFLOWS:
To_rehab    (IN SECTOR:  Stroke patients in stroke ward)
OUTFLOWS:
Released_from_Rehab = DELAY(To_rehab,NORMAL(Rehab_time,5),.3)
Average_stroke_incl_Rehab = SMTH1(Stroke_incl_Rehab,20)
Medelv_rehab = SMTH1(At_Rehab,20)
Rehab_time = 30
Stroke_incl_Rehab = Stroke_and_suspected+At_Rehab
Effect_Ind_Liv = 35/3
Effect_lethality = 11/3
Interdisciplinary_teamwork = 1
Lethality_ref = .12
Participation_weight = 3.4
Patients_relatives_participation = 1
Ratio_Rehab_Inst_Care =
Share_in_Rehab_ref/(Share_Inst_Care_ref+Share_in_Rehab_ref)
RoomAsses_weight = 4.5
RoomQual_weight = 5.4
Room_and_assessment = 1
Room_quality = 1
Share_dead = (1/
```

```
(1+(Total_effect-1)/Effect_lethality)
)*Lethality_ref
Share_idependent_living = Share_independent_livin_ref*
(1+(Total_effect-1)/Effect_Ind_Liv)
Share_independent_livin_ref = .42
Share_Inst_Care = (1-Ratio_Rehab_Inst_Care)*(1-Andel_avlidna-
Share_idependent_living)
Share_Inst_Care_ref = .14
Share_in_REhab = Ratio_Rehab_Inst_Care*(1-Andel_avlidna-
Share_idependent_living)
Share_in_Rehab_ref = .32
Share_Support_Living_ref = .09
Share_with_Supported_living = Share_Support_Living_ref
Systematic_assessment_and_planning = 1
Systematic_weight = 1.7
Team_weight = 1.5
Total_effect = (((Participation_effect-1)/Participation_weight)+1)*
(((RoomAssses_Effect-1)/RoomAsses_weight)+1)*
(((RoomQual_effect-1)/RoomQual_weight)+1)*
(((Systematic_effect-1)/Systematic_weight)+1)*
(((Team_effect-1)/Team_weight)+1)
Participation_effect = GRAPH(Patients_relatives_participation)
(0.00, 0.8), (0.2, 0.8), (0.4, 0.8), (0.6, 0.81), (0.8, 0.86), (1.00,
1.00), (1.20, 1.10), (1.40, 1.18), (1.60, 1.20), (1.80, 1.20), (2.00,
1.20)
RoomAssses_Effect = GRAPH(Room_and_assessment)
(0.00, 0.8), (0.2, 0.8), (0.4, 0.8), (0.6, 0.81), (0.8, 0.86), (1.00,
1.00), (1.20, 1.10), (1.40, 1.18), (1.60, 1.20), (1.80, 1.20), (2.00,
1.20)
RoomQual_effect = GRAPH(Room_quality)
(0.00, 0.8), (0.2, 0.8), (0.4, 0.8), (0.6, 0.81), (0.8, 0.86), (1.00,
1.00), (1.20, 1.10), (1.40, 1.18), (1.60, 1.20), (1.80, 1.20), (2.00,
1.20)
Systematic_effect = GRAPH(Systematic_assessment_and_planning)
(0.00, 0.8), (0.2, 0.8), (0.4, 0.8), (0.6, 0.81), (0.8, 0.86), (1.00,
1.00), (1.20, 1.10), (1.40, 1.18), (1.60, 1.20), (1.80, 1.20), (2.00,
1.20)
Team_effect = GRAPH(Interdisciplinary_teamwork)
(0.00, 0.8), (0.2, 0.8), (0.4, 0.8), (0.6, 0.81), (0.8, 0.86), (1.00,
1.00), (1.20, 1.10), (1.40, 1.18), (1.60, 1.20), (1.80, 1.20), (2.00,
1.20)
```