THESIS FOR THE DEGREE OF LICENTIATE OF PHILOSOPHY

# Bringing System Dynamics into action research

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## ABSTRACT

System Dynamics simulation is a computer-aided approach to policy analysis and design, often carried out by external experts in simulation. System Dynamics is particularly useful in complicated and complex situations, such as healthcare. However, research has shown that few models in healthcare are implemented.

Within System Dynamics there are methods for group model building or participatory modelling, where simulation models generate insights for organizational learning. The aim of this thesis is to study how System Dynamics can be a useful tool for healthcare practitioners in action research settings, building more on the needs and issues of a group.

Thirteen cases are described in detail to illustrate the what is similar and different from a process / action research perspective, so that general conclusions can be made.

The thesis concludes that action research approaches are useful when more time is spent on initial stages identifying issues relevant to the participants. Using Causal Loop Diagrams creates shared maps and understanding of how issues are connected. The shared understanding is increased through experimentation and learning from simulation models so that the group can converge on solutions that they agree on and thus lower the threshold for implementation.

Keywords: System Dynamics, Operations Research, modelling, simulation, action research, process consultation, healthcare.

### Foreword

This has been a long journey, that started in 1999 when I read the Fifth Discipline Fieldbook and the section about using System Dynamics to test the robustness of strategies and as a tool for learning. That quickly lead to reading Morecroft and Sterman "Learning by Modelling" and travelling to York to attend a course in using iThink led by Richard Stevenson and professor Eric Wolstenholme. It seemed like a great tool and method but I did not know what to do with it until I took a master's course in "Business Modelling and Systems Thinking" at the IT University in Gothenburg. The rigour and the learning shared by professor Pål Davidsen was immense.

Marie Elf, a fellow student, and I got a paper accepted for the International System Dynamics Society in Oxford 2004. It was great listening to all inspiring presentations. Geoff McDonnell gave me great feedback after my presentation about first building a model, then spending as much time pruning it to half the size. Geoff's generous sharing over the years of his modelling in healthcare has been very valuable. At a later conference, Kim Warren said in a presentation that he often just builds "half a model" when working with a management team as there is no need to continue to build the ultimate model after they "have got it". Both made me consider what is the minimum viable model that leads to insight.

I completed my master thesis under the supervision of professor Hans Björnsson, who suggested that I continue with doctoral studies. As I basically am a self-employed management consultant I needed financing and we eventually got financing from Vinnvård for a project that allowed me to take some time off from my regular work. Very special thanks for that! My research has been intermittent, dependent of finding financed projects. Hans has been a very tolerant supervisor and very supportive when I sensed that projects did not seem to support my research question and managed to keep me on track.

The financing from Vinnvård led to me being affiliated with Centre for Health Care Improvement at Chalmers exposing me both to others working with healthcare and action research perspectives. Professor Bo Bergman and Dr Andreas Hellström have both been very supportive throughout the process. At a seminar, Dr Svante Lifvegren said that what I really was doing was running repeated plan-do-study-act cycles in the computer. That comment really made me sit up and realize that all the time I had been using System Dynamics in an action research process and allowed me to revisit my earlier work with new eyes. Special thanks to Nils Conradi, former director of the Regional Cancer Centre, who always has been better than me at explaining the usability of System Dynamics.

I would wish that other doctoral students could have attended as many conferences in the field as I have, in all 14. International System Dynamics Society conferences have given in depth knowledge and experience of modelling. Operations Society conferences have been interesting in their focus on solving client problems. UK chapter of the International System Dynamics Society conferences have been great bringing in strategic and policy perspectives. Of people that I have met at conferences I want to single out Douglas McKelvie as an inspiration having solved some very intricate issues in modelling healthcare and very generous in sharing his thinking.

Thanks to Dr Marie Elf, fellow student at the master's course, co-author of the Oxford paper. We have collaborated on four of my cases bringing System Dynamics into action research to uncover work processes in healthcare environments in early stages of architectural design.

Very special thanks to Stefan Hallberg, my long-term compatriot and collaborator in System Dynamics. We met after our master's course. During learning workshops with former students, we discovered our shared interest in and dedication to healthcare. We have worked together with several projects, some major and spanning over several years.

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# Summary

### Introduction

System Dynamics is particularly useful in the study of systems, which have characteristics often described as messy. Healthcare is a large sector which is both complex and complicated. SD has made significant contributions to healthcare in UK, USA and the Netherlands on policy levels as well as in local units. For decades, there have been concerns regarding very high increases in costs for healthcare providers, given demographic changes. System Dynamics and Operations Research have been used extensively in healthcare settings and show promising results in providing the analytical tools needed to address the issues facing healthcare.

The System Dynamics community has addressed both model quality and stakeholder engagement by developing methodology for group modelling, with the primary objective of building a model. However, research has shown that very few simulation models lead to actual implementation.

Action research builds on a group of stakeholders working to resolve a problem. This thesis studies how to include System Dynamics in such analytics and resolving such questions in a group, asking the question – *"Does integrating System Dynamics methodology into action research interventions create systems understanding and, the prerequisites for using the results in practise?*

### Theoretical background

The used theoretical approach is usually described as multi-methodology. The general approach is based on action research and a branch called Social Analysis, which allows itself to be usefully combined with System Dynamics approaches. Theories about efficient decision-making and implementation are also considered.

### Method

The work processes of thirteen cases are both summarized and described in detail. The general approach has been to work close to the clients and their problems. The variation and similarities between cases has given significant learning.

Methods used in the cases utilize

- a palette of group intervention from the process consultation literature
- the combination of work principles in System Dynamics and action research
- awareness of how shared meaning is created
- a generalized model for System Dynamics projects.

### Conclusions

It is shown that formal System Dynamics is a viable part of action research processes. It allows groups to test a variety of problem assumptions, hypotheses and solutions "in silico" first and then in reality. When a satisfactory model and simulation has been achieved, the simulation is part of the implementation process. Using System Dynamics in action research is useful in creating efficiencies at local process level as well as societal benefits at policy levels.

# Introduction

## My research interest

I worked as a specialist and manager in large international industries from 1973 to 1988, when I joined a management consultancy. I have often been engaged in large and complex implementation projects and part of that as process consultant. I developed deep interest in general systems theory and management cybernetics in the early nineties and became interested in System Dynamics as a method to combine analytics and complex system to test robustness of policies. I was very influenced by the book *Modeling for learning organizations* (*Morecroft & Sterman, 1994*), where I saw the power of using System Dynamics. I took a master's degree in Systems Thinking and Modelling 2004. Since 1996 I have done extensive work in the healthcare sector, initially organisational interventions and later System Dynamics modelling as described in this thesis. During my master's studies, I built a model based on one of my consultant interventions. I co-authored a paper (Paul Holmström & Elf, 2004) and presented it at the International System Dynamics Conference in 2004. At the conference, I was impressed by many of the models. However, I was puzzled that so few models led to implementation, which triggered my research interest. The issues that I observed regarding implementation were later described by Fone (*2003*).

In one of my first engagements in healthcare I included data from a public review of costs and financing of healthcare (SOU 1996:163), which showed very high cost increases for healthcare providers over the coming decades, given demographic changes. The cost increase has since then been highlighted in several reports. However, in a recent Swedish Government Official Report (*Stiernstedt, 2016*) the focus on cost has changed to that off efficiency.

Healthcare is a large sector which is both complex and complicated. Borgert (*1992*) describes decades of initiatives to organise and manage the sector. Nobody has updated Borgert's mapping but numerous authors refer to a continuation of initiatives.

There is both research and discussion into how system-wide improvements in healthcare can be done. The US Institute of Medicine and the National Academy of Engineering have produced a joint report (*Reid et al., 2005*) exploring how the engineering sciences can contribute to efficiency and quality improvement in healthcare at both local levels as well as at policy level. System Dynamics is one of the fields studied in the report. System Dynamics and Operations Research has been used extensively in healthcare settings and show promising results in providing the analytical tools needed to address the issues facing healthcare.

System Dynamics is particularly useful in the study of systems, which have characteristics often described as "messy". SD has made significant contributions to healthcare in UK, USA and the Netherlands on policy levels as well as in local units. The System Dynamics community has addressed both model quality and stakeholder engagement by developing methodology for group modelling. At International System Dynamics conferences 1976-2015 428 papers have been presented containing the phrase "group model" in the full text. In the reference library of the International System Dynamics Society there are 102 references with either "group modelling" or "participatory" in the title. There is a significant body of papers describing group-modelling methods.

Many group modelling interventions build on a System Dynamics model, to solve a problem. Action research builds on a group of stakeholders working to resolve a problem. This thesis studies how to include System Dynamics in the analytics and the resolving of questions in a group. Reason and Bradbury (*Reason & Bradbury, 2008*) writes "*Definitions of action research often emphasize an empirical and logical problem-solving process involving cycles of action and reflection.*". I have done a literature research to find papers in the intersection between System Dynamics, action research and healthcare using Medline, System Dynamics Society conferences and Web of Science, and found less than 20 papers, and none of these explicitly describing how the action research methodology was used.

Brailsford notes that many Operations Research models have been applied to a range of healthcare problems, but "*despite this proliferation of academic publications, and unlike manufacturing industry where a similar literature exists, there has been no widespread take-up of simulation by the healthcare industry."*

Fone (*2003*) carried out a literature search of papers published 1980-1999. Where 2226 abstracts were studied from which 990 full text papers were reviewed as to evidence of implementation. A total of 182 papers met the inclusion criteria and were appraised. The authors write: *"... we were unable to reach any conclusions on the value of modelling in health care because the evidence of implementation was so scant.*". In an analysis of the academic literature on simulation and modelling in health care Brailsford et al (*2009*) find that only 5,3% of simulation models led to actual use in practise.

Another paper (*S. Brailsford, 2005*) addresses the conflicting interests between users and modellers: "*The high prices charged by business consultancies has meant that much healthcare modelling work is carried out as research/consultancy projects by academics. However, academics and their clients work to different agendas. Academics need to publish in peer-reviewed journals and must thus demonstrate theoretical or methodological advances. This leads to complex, sophisticated models, in stark contrast with the objective of the end-user: a simple, easy-to-use model.*"

Jahangirian et al (*2015*) have studied the reasons for low stakeholder engagement in simulation projects in healthcare and listed the following highly significant primary causal factors:

- *Stakeholder's (e.g. clinician's) high workload*
- *Poor familiarity or awareness of simulation*
- *Communication gap between simulation and stakeholder groups*
- *Stakeholders' feeling that the project is not producing tangible and quick impact*
- *Poor management support*
- *Difficulties with understanding and working with simulation tools, techniques and models*
- *Lengthy project*
- *Healthcare problems are very complex to model*

I note that Jahangirian does not list the implementation planning, which I consider a topic that needs to be addressed. Brailsford (2005) states "*All models need data, and healthcare data are notoriously of poor quality*."

My research interest lies in applying process consultation / action research approaches to System Dynamics for several reasons:

- System Dynamics is a powerful methodology which can be democratised and made more powerful by putting it in the hands of people on the "shop floor".
- Action research approaches emphasises the concerns of the group. By addressing the issues of the participants', implementation should follow naturally.
- Many healthcare organisations have used action research or similar methods, which would gain in power by adding strong analytics.
- Healthcare is both complex and complicated, using Systems Thinking and System Dynamics to show and simulate such systems and systemic effects can be very valuable.
- Healthcare is always in operational mode with high resource utilization. There is little tolerance of experimentation on patient flows, etc. Experimenting by computer simulation allows discarding of alternatives that do not produce desired outcomes and can be seen as a less risky way to test new procedures etc.
- Working in such ways that results not only are conceptualised, but used in practice

## My research question

***Does integrating System Dynamics methodology into action research interventions, create systems understanding, and the prerequisites for using the results in practise?***

## Boundaries

This thesis explores intersections between action research and System Dynamics with the aim of improved implementation. It does not purport to be an in-depth study of either field. Here I explore the work processes before implementation.

# Theoretical background

## Multi-methodology

The research in this thesis is often described as multi-methodological, which in Wiley Encyclopaedia of Operations Research and Management Science is defined as:

*"Within the discipline of Operations Research and management science, many methods and techniques have been developed. Initially, these were generally based on mathematical or computer models. However, it was found in practice, particularly with complex, "wicked" problems, that many aspects of the situation, especially those concerning peoples' viewpoints and values, could not be represented mathematically. This led to the development of a range of non-quantitative, "soft" methods, which were, nevertheless, rigorous and systemic. Examples are soft systems methodology (SSM), cognitive mapping, strategic choice analysis, and strategic assumption surfacing and testing (SAST).*

*The question then became, which method should be used when? However, rather than using just a single method, theory and practice have demonstrated that most complex problems are better tackled using a combination of methods, both "hard" and "soft." This approach has been called **multi-methodology**."*

Multi-methodology is often a thread at both conferences in System Dynamics and Operations Research.

My research attempts to combine two major research fields and methodologies, those of System Dynamics and action research. Figure 1 builds on Alvesson and Sköldberg's (2008) image of a domain and extending the area of use and highlights the particular challenge of my research project.

System Dynamics is a methodology with applications in many fields. This is reflected in tracks at SD conferences and in journals and conferences. Group modelling has been developed, using techniques from process consultation.

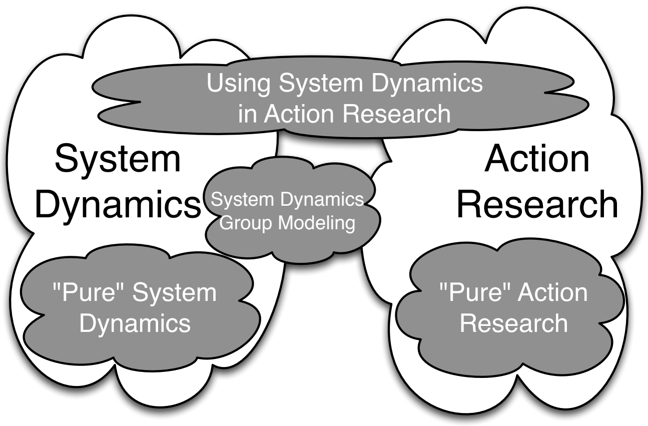



*Figure 1: Multi-methodology domains*

Group modelling is mainly focused on using a group to elicit information and build a simulation model. The focus of action research is the work of a group in exploring and developing their work. My research hypothesis builds on the possibility that there may be a difference between the two approaches and on the possibility that a successful and implemented model may be higher, using an action research approach.

Any reflective inquiry raises epistemological issues. What do we know? How is individual and shared understanding created? Process consultation and action research have the purpose to achieve action through participative group processes. This can involve conversation, reflection and analysis. In Figure 2, I map my understanding of the connections between the areas of knowledge on which I build my work. Each area is discussed below.

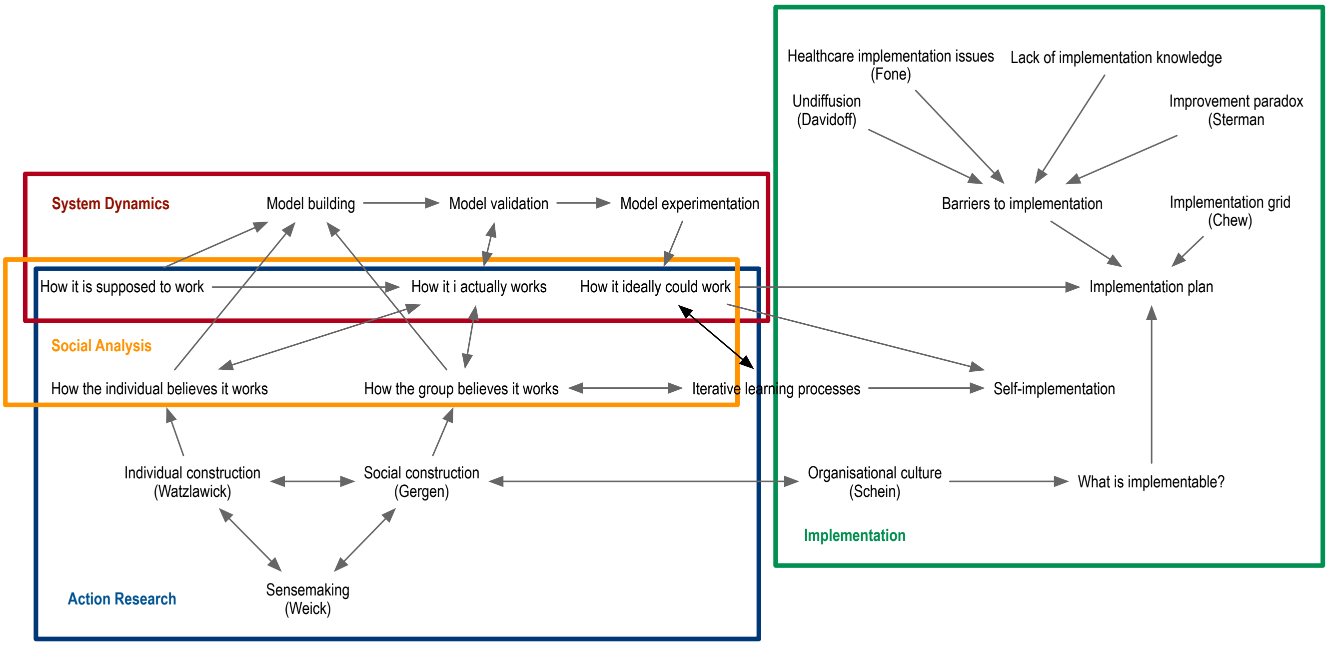



*Figure 2 Connections between areas of knowledge*

## System Dynamics

System Dynamics is method to understand the dynamics of complex systems over time. It is used to map and simulate interdependencies, feedback loops and interactions. Itis highly useful when the behaviour of a whole system cannot be explained by the behaviour of the parts. Causality is at the core of the method and models can solve problems of mutual causation by computing simultaneous interactions, which cannot be calculated in a spreadsheet. Healthcare is usually characterized by high variability in patient inflows, which System Dynamics is useful in analysing.

## System Dynamics group modelling

I have done a search in the reference database of the System Dynamics Society. There are 102 references with either “group modelling” or “participatory” in the title. Figure 3 shows the distribution over time. There is an increase over time and an early peak late nineties.

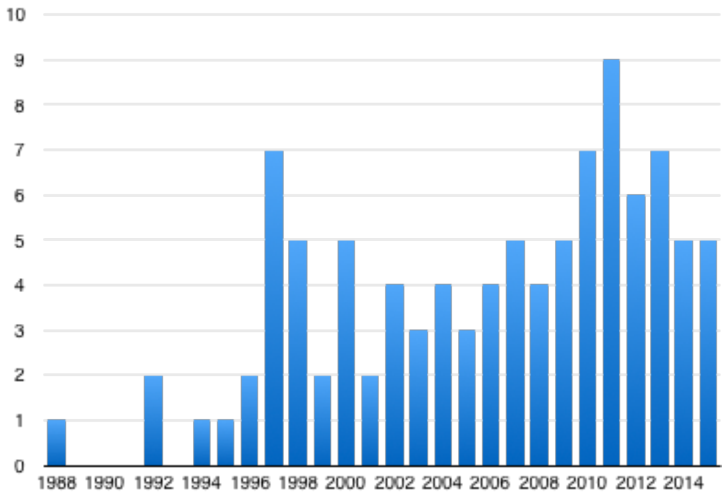



*Figure 3: Papers referring to group or participative modelling*

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 (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. Vennix describes this 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 modelling contains both procedure (structure and process (interaction among participants). Vennix states:

- *Group model building can be considered as an organizational intervention process.*
- *The goal of the intervention is not to build a System Dynamics model. The System Dynamics model is a means to achieve other ends.*
- *Model building serves the purpose of putting people in a position to learn about a messy problem.*
- *The learning process should create a shared social reality and result in a shared understanding of the problem and potential solutions.*

Many of the initial papers have a focus on knowledge elicitation and the contribution of participants to the building of a model. A slightly different perspective is taken by Rouwette (European Journal of Operations Research, 1992, Special Issue on Modelling for Learning). Rouwette focuses on how participative modelling contributes to learning. He argues that group model building works as mutual persuasion (2003). By creating shared maps and models the thinking of participants converges over time.

Participative, very much focus on how participants contribute to the building of a model. Over time a shared body of interventions is documented in “*Scriptapedia – a digital commons for documenting and sharing group model building scripts*” (Hovmand et al., 2011).

Eden and Ackermann (2004) (1998) have described tools and methods for strategy development. Their starting point is to let management teams use and arrange post-it notes to create shared understanding and meaning of their business situation and possibilities. They have created a software tool “Group modeller”, which allows for online collaboration in large groups to elicit, organise and prioritise. In final stages the tool can be used to create causal loop diagrams of the factors. I have been inspired by a paper they have co-authored describing how the software is used to brainstorm and create notes, organise them, add causality and finally build a stock and flow diagram in large groups (Fran Ackermann, Andersen, Eden, & Richardson, 2010).

# Action research

## Action research background

The term action research was first used by Kurt Lewin in his paper “*Action research and Minority Problems*” (1946), where he described action research as “*a comparative research on the conditions and effects of various forms of social action and research leading to social action*” that uses “*a spiral of steps, each of which is composed of a circle of planning, action and fact-finding about the result of the action*”.

Tavistock Institute was created in 1946 by a group of clinicians from the Tavistock Institute, including Elliot Jaques, later joined by Eric Trist and Frank Emery. Lewin's writings had an influence on Tavistock and he was invited by Trist and Wilson to found the Tavistock Journal of Human Relations.

At Tavistock a branch of action research called Sociotechnical Systems was developed, an approach to complex organizational *work design* that recognizes the interaction between *people* and *technology* in *workplaces*. The term also refers to the interaction between society's complex infrastructures and human behaviour (quoted from Wikipedia).

Elliot Jaques was engaged by the Glacier Metal Company in several major research projects, published in The changing culture of a factory” (Jaques, 1951) and ”Glacier Project Papers” (Brown, Jaques, & Jaques, 1965). Ralph Rowbottom was an internal consultant at Glacier and later joined Elliot Jaques at Brunel University when Jaques was made professor and invited to build a school of social studies. Jaques intention was to use tools and techniques in psychological analysis when studying organisations. He coined the expression Social Analysis, which became the title of Rowbottom's book describing the methodology (1977).

### Defining action research

"*Action research is a participatory process concerned with developing practical knowledge in the pursuit of worthwhile human purposes. It seeks to bring together action and reflection, theory and practise, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people, and more generally the flourishing of individual persons and their communities*". (Reason & Bradbury, 2008)

### Social Analysis

There are many different descriptions of the role of the facilitator in action research, ranging from a role mainly leading a reflective process to a role of equal participation in the process. I have found the description of the role in Social Analysis as particularly helpful in understanding the role when bringing System Dynamics into the action research process.

"*The social analyst's role is not a prescriptive one, but one which may more aptly be described as 'elucidatory'. It is within the role of the analyst to stimulate exploratory activity, to collect impressions and views, to analyse existing situations and problems and even to proffer alternative reconstructions."* (Rowbottom, 1977)

Rowbottom also describes four perspectives on organisation and organisational issues:

- **Expressed** – as formally described
- **Assumed** – as perceived
- **Extant** - as it actually is
- **Requisite** – as it ought to be

The four perspectives are well suited to System Dynamics processes. An SD process usually begins by capturing the expressed and assumed perspectives and building them into a formal model and simulation. A usual outcome is that the model does not reflect reality and needs to be modified. Participants' assumptions are challenged until the model captures that which is extant and shows results that correspond to reality. This is also the usual first step in validation a System Dynamics model. When the model is validated then the participants can understand the underlying issues and can begin to work with how things should be, by using the model to explore alternative futures.

### Process consultation

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 describes three categories of relation between a client and a consultant, which are useful in understanding different approaches to System Dynamics modelling:

- The Purchase of expertise model – where the System Dynamist builds a simulation model based on the problem definition and data given by the client. Such work can be done in a group modelling session, where the group is used for the elicitation of facts.
- The Doctor-Patient model – where the modeller analyses and defines the problem.
- The Process-Consultation Model – where the client and modeller actively work together using action research methods.

## Implementation

There is a significant body of literature in the field of implementation. The paper "On the Undiffusion of Established Practices" Davidoff (2015), specifically addresses issues of implementation in health care. As most healthcare organisations continuously work close to capacity, there is little space for experimentation. There is resistance to abandoning what works.

In the classic paper "Beating Murphy´s law" (Chew, Leonard-Burton, & Bohn, 1991) a number of failed implementations were studied. Many failures are ascribed an assumption that implementation is rational and instantaneous, just like changing the dvd in a video player. The man focus is on know-how of technical issues – "his is how to do it". The authors propose an "implementation grid" (Table 1) as a solution, where the starting point is the organisational know-why answering questions such as "what are our objectives" and "what problems are we trying to solve". This then has implications for how to organize (organisational know-how). The selection of technological platform also needs to be explained (technical know-why)

| | Technical knowledge | Organisational knowledge |
|---|---|---|
| **Know-How** Experience-based training in the technology | Operating rules, procedures for the new technical system | Impacts of the technology on organisational tasks and procedures |
| **Know-Why** Education in the theory underlying the technology | Architectural interdependencies with other technologies, other operating systems | Links to strategy (e.g. to manufacturing excellence, or total quality control) |

*Table 1 Implementation grid*

## Coalesced Authority, Power and Influence

Adizes (1992) states that Coalesced Authority, Power and Influence needs to be in place in the work group and/or reference group, for efficient work, decision-making and to lay the ground for implementation. Adizes defines *authority* 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.

## Group interventions

When running workshops, process consultation or action research interventions, there is a wide variety of well accepted group process methodologies that could be integrated with Systems Thinking and System Dynamics methods. These tools are well proven and accepted among group process researchers as well as practitioners.

In a conference paper (Paul Holmström & Elf, 2009) we carried out a scope review of the literature covering large group process interventions. A scoping review is distinct from a systematic review in purpose and approach. The review was based on specific literature that provided review and examination of large scale group interventions. A few such methods were selected and the purpose, method and outcomes for each of the methods were briefly described and it was considered how a particular method could be integrated with participatory SD group modelling.

The overview is summarized in Table 2.

It is important to recognize that there is a vast repertoire of interventions that can be used in group processes. When designing an actual process, inspiration may be drawn from several methods on the overall as well as detailed levels. It is important to be able to understand and analyse an on-going group process at every stage and select appropriate interventions that lead to the desired outcomes.

The intention of the scoping was to uncover a palette of group interventions that could be useful in the cases. The results were used both in planning of specific interventions and as ad-hoc interventions as group processes unfolded.

| | **World Café** | **Open space** | **Future Search** | **Strategy and cognitive mapping** | **Strategic visioning, Visual Thinking** |
|---|---|---|---|---|---|
| **Attributed to** | Juanita Brown and David Isaacs | Harrison Owen | Marvin Weisbord | Colin Eden and Fran Ackerman | David Sibbett |
| **Main reference(s)** | The World Cafe: Shaping Our Futures Through Conversations That Matter by Juanita Brown, David Isaacs)<br>http://www.theworldcafe.com/ | Open Space Technology: A Users Guide: A User's Guide by Harrison Owen<br>http://www.openspaceworld.org/ | Future Search: An Action Guide to Finding Common Ground in Organizations and Communities by Marvin Weisbord and Sandra Janoff | Making Strategy: The Journey of Strategic Management by Colin Eden, Fran Ackermann<br>The Practice of Making Strategy: A Step-By-Step Guide by Fran Ackermann, Colin Eden, Ian Brown<br>Decision Explorer®, http://banxia.com/dexplore | Strategic Visioning Overview, David Sibbett<br>Graphic Facilitation, David Sibbett<br>http://www.grove.com/ |
| **# participants** | >12 | 25-2000 | 60-80 | 5- | 5-30 |
| **Time required** | 2-3 hours | 3 hours – 3 days | 16 hours over 3 days | 1 day | 1-2 days |
| **Description** | Participants are seated at small tables, with large paper sheets, pencils and markers. People are asked to explore a wide, but well-defined question. The rules and etiquette of the World Café are introduced. After 20-30 minutes of conversation all but one at the table move to other tables and continuing the conversation with a new set of people. Three rounds are usually carried out.<br>Afterwards comments can be solicited from the tables or all sheets of paper are taped to the walls and people invited to walk around. | People are invited to an Open Space conference around a major topic or problem area. At the outset people are seated in concentric circles around the moderator who introduces the topic and methodology. People are invited to suggest subtopics and post them on a grid on a wall with available time slots and rooms. The conference self-organizes with people attending sessions that attracts them. Each session is responsible for documentation and computers, printers etc are made available. | Ideally participants consist of a representative intersection from an organization. Day one focuses on the past, individual and shared timelines are created. During the first day, present trends are identified. Day 2 concerns the effects of present trends and how they affect the future. During day 3 ideal future scenarios are developed and turned into action plans. | The original process builds on personal interviews and the creation of individual cognitive maps of important issues and using these as input for developing joint maps in small groups. By using Decision Explorer® the process can be used in large group, seated in clusters and bypassing the interview stage. Issues are clustered, connected and prioritized and then form the basis for the development of strategies and policies. | David Sibbett and Grove provides a facilitation process and graphical templates/posters for group processes and strategy development. Templates are available in different sizes from table-sized to 16 ft. (4,85 m) wall charts. Working with graphics creates other understanding and eases linking of concepts. As walls are papered with the entire process other levels of understanding are attained |

| | **World Café** | **Open space** | **Future Search** | **Strategy and cognitive mapping** | **Strategic visioning, Visual Thinking** |
|---|---|---|---|---|---|
| **Outcomes** | The expected outcome is a shared understanding of the main issues relating to the question at hand. People come away with sense of what is important and a convergence of ideas. | Each session is responsible for documentation. Relevant discussions and decisions are distributed. | Action plans for future | Interconnected and prioritized issues and issue clusters. | Graphical storyboard of strategic visioning process |
| **Suggested uses** | World Café can be useful in the early stages of a modelling process where divergent points of view can be expected. Even in homogenous groups a shared sense of what is important can create an efficient focus | Open Space is suitable for in-depth discussions, identifying and resolving issues and problems etc. We suggest that Open Space can be suitable mid-stages in a participatory modelling process, exploring identified issues, developing time-charts, policy exploration etc. | As Future Search is time oriented (past, present and future) it is probable that an interaction between Future Search and System Dynamics could be fruitful. Systems Thinking and causal diagrams could most probably help to create sense of the past and present. System Dynamics modelling could aid in formalizing trends and assessing their consequences. A model would also be useful in testing future policies and strategies. | When working with large groups and with diverse stakeholders, rapid issue identification and prioritization is important to gain momentum in the process, as the number of potential issues rapidly grow with the number of participants and stakeholder groups. Eden's and Ackerman's cognitive mapping methodology allows for combining speed with qualitative outcomes. | As Systems Thinking and System Dynamics themselves are graphical this could be a positive integration. Group graphics methodology would help to facilitate the group process itself. By using templates to kick off meetings, as intermediary steps in the group modelling process and finally in developing action plans an entire process can be secured including implementation. |

*Table 2 Overview of group interventions*

# Method

## Case methodology

I build on a series of cases. As my intention was to have a consultative approach building on the problems and issues facing each client I wanted to allow for different processes and outcomes and learn from that. Eisenhardt (1989) describes how theory evolves in a strikingly iterative way "*While an investigator may focus on one part of the process at a time, the process itself involves constant iteration backward and forward between steps***.**" She suggests, "*A priori specification of constructs can also help to shape the initial design of theory- building research*. "

## Coping with the problems of implementation and stakeholder engagement

While attending System Dynamics conferences I noted the implementation issues as described by Fone (Fone et al., 2003; Rowbottom, 1977) and decided to approach my research with a more consultative approach, seeing client outcomes as more important than building a complete model. I built in some of the assumptions later described by Jahangirian et al (Jahangirian et al., 2015). In consultancy work that I already had done in the healthcare sector I had noted the difficulty of accessing useful data as pointed out by Brailsford (S. Brailsford, 2005). In Table 3 I refer to problems according to Jahangirian and my intended approach.

| **Problem** (according to Jahangirian) | **My chosen approaches** |
|---|---|
| Clinician's high workload | Schedule meetings 4-6 weeks in between. More often could lead to perceived added workload. Less often could lead to losing continuity.<br>Short meetings, 2-3 hours, so as not to impinge on the workday. |
| Clients not knowledgeable about simulation and System Dynamics | Step-by-step approach, starting with a very small and basic model leading to "*aha, so this is System Dynamics*" and the client reformulating the problem, actively prioritising which parts to pursue. |
| Project not producing tangible results fast enough, i.e. client losing interest and dropping out. Risk for lengthy projects. | Rapid prototyping and selective modelling, allowing for discussing the important without spending much time on detail that may not be relevant. Iterative modelling process, each step leading to decisions what else to pursue. Build on the principles of cycles as used in action research. |
| Healthcare is complex and is characterized by high variability. | Build models that show the variability that the practitioners recognise. Cope with some of the complexity by identifying small number of sufficiently defined pathways and allow 10-20% of patient flows to be messy. |
| Lack of easily accessible data | Start small and basic using as much real data as possible and some guesstimates. Engage the participants so that they see the need to get data and help to find it. |

*Table 3: Problems and approaches*

## Social Analysis

I consider Rowbottom's (1977) description of the role of the social analyst as useful in understanding the role of the System Dynamics modeller:

*"The social analyst's role is not a prescriptive one, but one which may more aptly be described as 'elucidatory'. It is within the role of the analyst to stimulate exploratory activity, to collect impressions and views, to analyze existing situations and problems and even to proffer alternative reconstructions."*

There are Process Consulting and action research interventions when the role of the external process leader purely is to objectively facilitate the group in its work and help the group to learn through reflexivity. I see my role as a subjective facilitator, where I alternate between objective facilitation and suggesting interpretations of the results of simulations.

## Constructions and knowledge gaps

I address knowledge gaps as identified in action research (Reason & Bradbury, 2008):

- First person – the knowledge gaps of each of the participating individuals
- Second person – the knowledge gaps of and in the group
- Third person – my knowledge gaps in transcending from individual cases to generalized knowledge.

Watzlawick (1984) describe how each individual constructs his/her reality. As a facilitator one needs to understand that individuals in a group hold different constructs. The work of the facilitator is to bring them into the open, share them and support the group in creating a shared construct. This is addressing the first-person perspectives. There is a wide field of social constructivism with (Gergen, 2001) as one of the key writers. Weick (1995) addresses sense-making in organisations. Many process consultation and action research interventions concern this second person perspective. Rouwette (2003) shows how group modelling in System Dynamics leads to convergence of meaning over time.
The third person perspective is mine. By working through several cases I uncover gaps in my knowledge, which I can explore in the following cases and build generalized knowledge, as described by Eisenhardt (1989)

## Group interventions and project structure

As described in the theory section there is a significant body of work and articles in the field of group modelling in System Dynamics. Most of the interventions are intended to support the development of a System Dynamics model. At an early stage Elf and I scoped group interventions (2009), the main results shown in Table 2

In several cases resources were constrained, which meant that we had funds for 4-5 sessions of 2-3 hours for each case. This meant that we needed to both work at speed and high involvement of participants. Producing rapid deliverables to the group increases satisfaction (Fran Ackermann et al., 2010).

The basic structure for group interventions was

- Using process consultation interventions to elicit issues of importance to the participants
- Use causal loop diagramming to structure the issues and provide participants with a view of the system
- Build a System Dynamics model incorporating both qualitative and quantitative aspects and use the model for experimentation and learning in the group.

In several cases, we had Wolstenholme's project structure (2004) as background for considering general approaches (Figure 4 Generic project plan based on E. F. Wolstenholme et al., (2004))

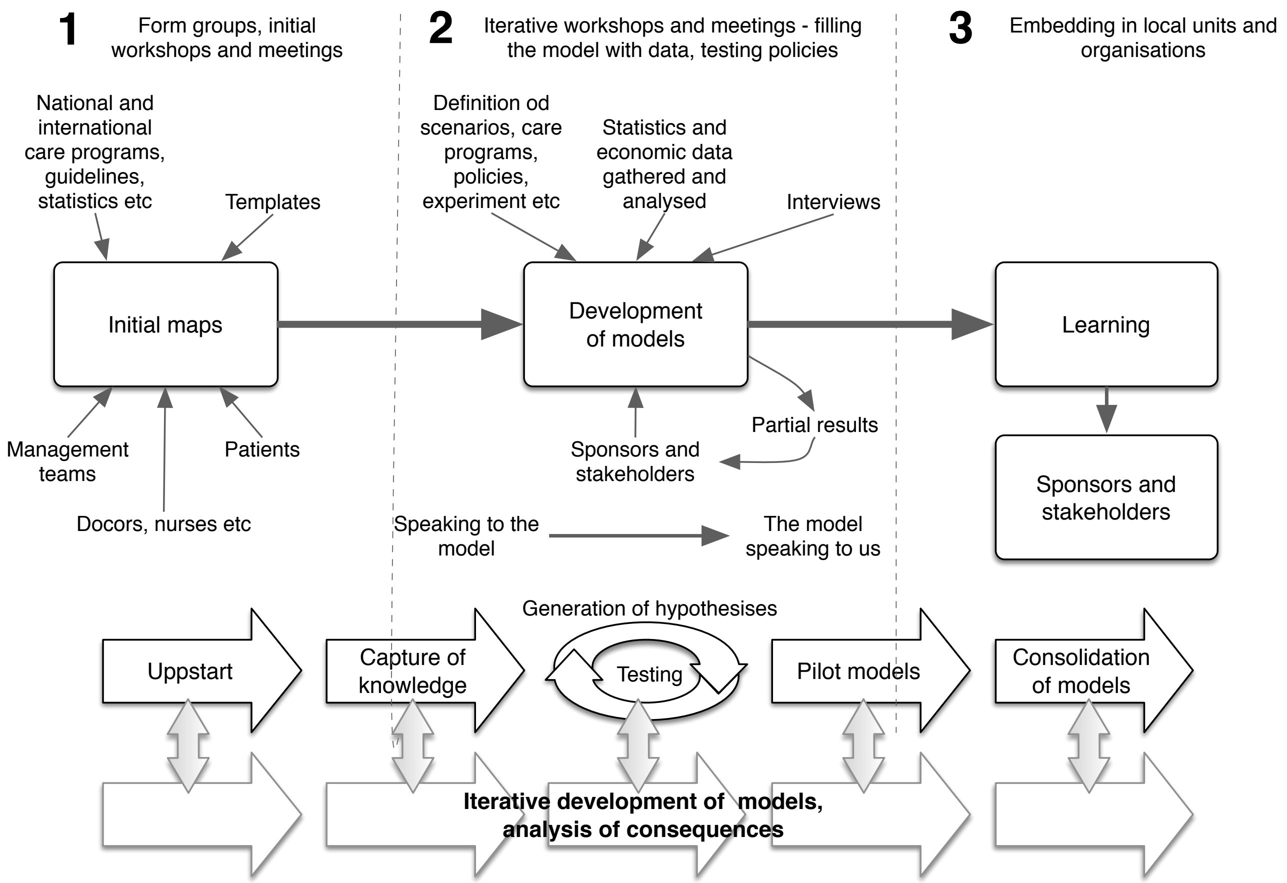



*Figure 4 Generic project plan based on E. F. Wolstenholme et al., (2004)*

# Results

I have carried out and analysed 13 cases involving Systems Thinking and System Dynamics. The work processes are described in detail and can be found in the appendix. An overview of main components is shown in the case matrix (Table 4). Each case is summarised in this section along with my insights and reflections.

## Case matrix

| **Project steps/content** | **1 Obstetrics (1)** | **2 Stroke** | **3 Hospital reorg** | **4 Dementia care** | **5 Paediatrics (1)** | **6 A&E (1)** | **7 Gynaecological clinic** | **8 Paediatrics (2)** | **9 Obstetrics (2)** | **10 Malignant melano-ma** | **11 Lung cancer** | **12 Breast Cancer** | **13 A&E (2)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time spanned in project | 6 | 6 | 2 | 4m | 1m | 3m | 6m | 4m | 4m | 3y | 2y | 6m | 4m |
| Pre-project scoping meeting with client (C) or initiator (I) | C | I | C | I | I | I | C | I | I | C | C | C | C |
| Pre-project design | | X | X | X | X | X | | X | X | | | | |
| Initially planned number of meetings | n/a | 5 | n/a | 4 | n/a | 4 | n/a | 4 | 5 | - | - | n/a | 2 |
| Initial meeting(s) defining problem, scope, objectives | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Fact-finding phase | 1m | | 1m | | 1w | 1m | | 1m | 1m | 1y | 1y | 6m | 1m |
| In-depth qualitative problem/issue inventory | X | | X | X | X | X | | X | | | | | |
| Early introductory causal loop diagram | | | | X | X | X | | X | | | X | | |
| Small explorative System Dynamics Model (Early or Mid-project) | | E | | | E | E | | E | E | M | M | | |
| Causal loop diagram | | | X | X | X | X | | X | | | X | | X |
| Questionnaire leading to weighted qualitative CLD | | | | X | | X | | X | | | | | |
| Combining qualitative CLD based SD model and quantitative SD | X | | | | | X | | X | | | | | |
| SD model | X | X | | X | X | X | X | X | X | X | X | | X |
| Iterative SD model development | | X | | | X | X | | X | X | X | X | | X |
| Reference group meetings | X | | X | | | | X | | | X | X | | |
| Work group final SD model workshop(s) | | | | X | X | X | | X | X | X | X | | |
| Staff/Stakeholder workshop(s) | | | | | | | | | X | X | X | | |
| Staff presentation(s) | | | X | | | | | | X | | | | |
| Conference presentation, published paper(s) | 1 | 1 | | 2 | 1 | 1 | 1 | 1 | | 5 | 1 | | |
| Case description in appendix | X | | X | | X | X | | X | X | | X | | X |

*Table 4 Case matrix*

## Case summaries

### Case 1 Obstetrics (1)

**Problem/issue addressed**

Midwives experiencing heavy workload due to many newly employed. Strong dissatisfaction with work conditions and management. The manager considered himself overloaded by having 70 direct reports. I was engaged by the hospital director.

**Method**

22 in-depth interviews. Analysis of documents. Report to hospital director and staff followed by organisational interventions. SD model etc done post-project.

| Wow - insights | Reflections |
|---|---|
| Actually, very few newly employed. Interviews reflected vacation period, 9 weeks with 1/3 temps. | "Everybody" knows that the vacation period is a mess, but nobody prepares for it. |
| Seen as critical at interviews end of August, early September, "forgotten" in December. | Good example of "memory of" sub-model in System Dynamics. |

**Implementation**

A work group was formed consisting of a new manager, a group of midwives and other staff. The group had five meetings facilitated by me and led a reorganization of the department.

**Coalesced Authority, Power and Influence in the work group**

All factors were present in the work group.

**My role**

Organisation review, facilitated work group. Afterwards model building and co-authored paper.

**Publications**

Holmström, P. and M. Elf (2004). *Staff retention and job satisfaction at a hospital clinic - a case study*. International System Dynamics Conference, Oxford, System Dynamics Society.

### Case 2 Stroke unit

**Problem/issue addressed**

According to national guidelines, stroke patients should be treated at dedicated units. At this hospital only 55% were treated at the stroke unit. The doctor responsible for stroke considered the reason to be a shortage of beds. The hospital wanted to review if any change in facilities was needed.

**Method**

Group modelling, 5 meetings, 13 participants, representing stake-holders. Progression:

- Issue identification
- Causal loop diagram
- Patient flows in Sankey chart
- SD model built gradually and iterative

| Wow - insights | Reflections |
|---|---|
| Large group intended to be representative of stake-holders, no deep engagement. | Smaller group allows more personal engagement in work and outcomes. |
| The doctor responsible, was planned to be part of the group, but never participated. | Medical decisions taken by doctors have significant consequences for work and was necessary for effective decisions by the group. |
| Initial model did not reflect reality in the ward. Beds were filled with patients with other diagnoses. | Important for me to access my ignorance to be able to explore the system (Schein, 1999) |
| One third of patients with suspected stroke get other final diagnosis. | Organisation not truly aware of the consequences. |
| Participants initial hypothesis – more beds, does not solve the problem. | Getting the big picture – showing the system. The problem is elsewhere, the high bed utilization factor at the hospital making it difficult to cope with acute in-flows. |

**Implementation**

Unknown

**Coalesced Authority, Power and Influence in the work group**

The group was somewhat large and I perceived a few participants acting more as representatives of their stake-holder group than being active group members. There were two main groups of participants – caregivers and facilities management respectively. As the power of medical decisions have a strong influence the fact that a doctor did not participate was probably detrimental to outcomes.

**My role**

Group modelling facilitator, model building. Planning with project leader, Marie Elf. The project was financed by Formas.

**Publications**

Elf Marie, Putilova Maria, von Koch Lena, Öhrn Kerstin (2007). Using system dynamics for collaborative design: a case study". BMC Health Service Research, 2(7), 123.

Elf, M. (2006). Modelling of Care Processes. The use of Simulation Models for the Design of Health Care Environments, Institutionen för arkitektur Chalmers tekniska högskola.

Holmström, P. (2004). *Group Modeling in System Dynamics - a Case Study* Master thesis, IT-University of Göteborg.

This case is described in detail my master thesis and not included here.

## Case 3 Evaluation of hospital reorganisation

### Problem/issue addressed

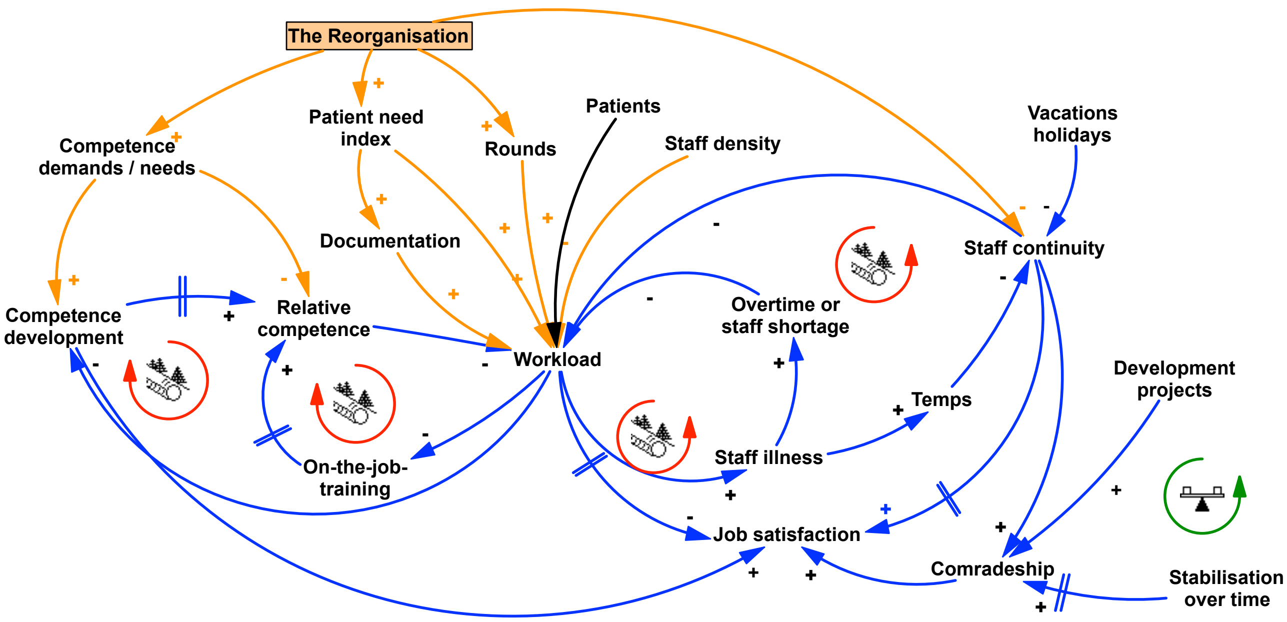
The hospital had 1 ½ years earlier been required by higher authorities to significantly cut costs. They then carried out a substantial reorganisation of 4 wards in surgery/gynaecology. The unions accepted the reorganisation after being promised an external evaluation, which I later was asked to do.

### Method

25 in-depth interviews. Analysis of documents. Report to first to the hospital director and managers of the two involved clinics, then to all staff. The presentation included causal loop diagram showing causation of issues.

| Wow - insights | Reflections |
|---|---|
| Strong negativity among staff, who wanted to go back to old organisation. "Laundry lists" of complaints. | Causal loop diagram showed the system, what had not worked and leverage points for next steps. |
| Weak analytical competence among ward managers led to highly narrative evaluations. | Recognise narratives, include numbers and show the system. |
| Particularity in complaints. | Addressed by showing the system. |
| The impact of showing the system in the form of a causal loop diagram, where the connections between particular issues was shown. | Showing the system is powerful and opens for very different solutions. |

### Causal loop diagram




### Implementation

The organisation was kept and action taken to counteract negative effects.

### Coalesced Authority, Power and Influence

Even if the hospital director and managers of the clinic held the formal authorities, it was vital to work and discuss results with all staff so that the power and influence vested there accepted the results. The causal loop diagram had a significant role in this.

### My role

Sole executor of project

### Publications

None

### Case 4 Dementia care

**Problem/issue addressed**

Dementia care unit to be reorganised and new work methods to be introduced. Facilities to be reorganised and rebuilt.

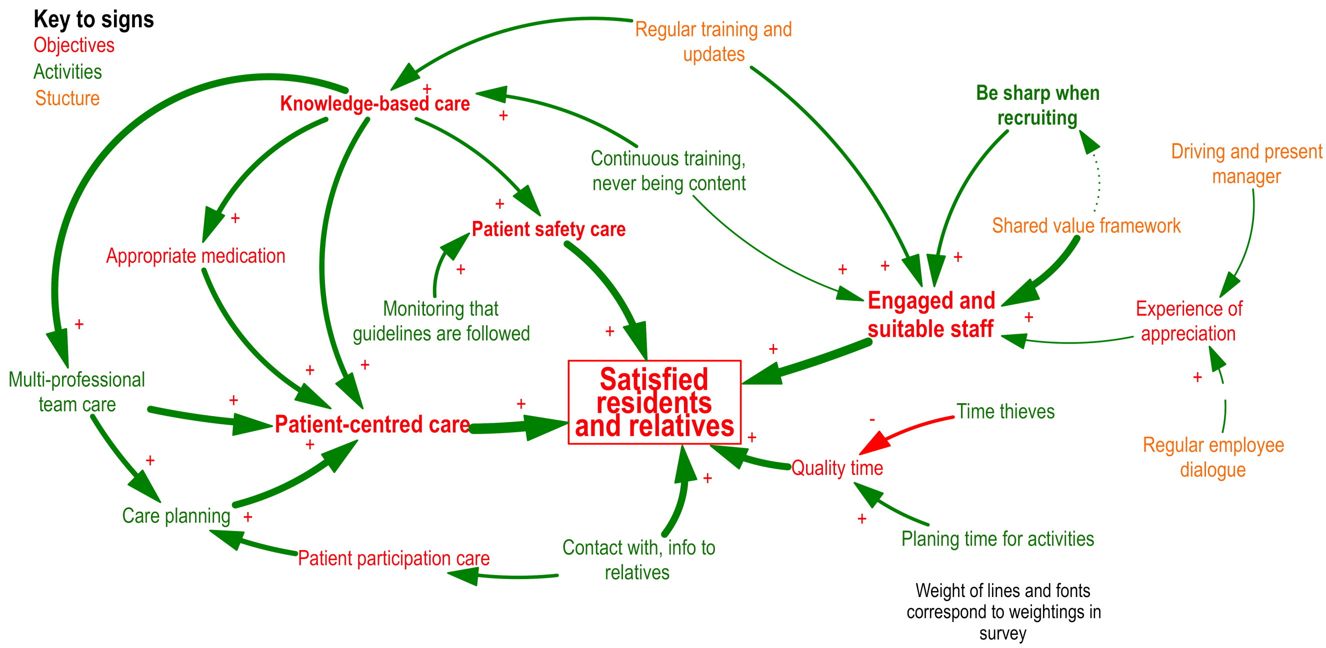
**Method**

- Process consultation interventions to elicit issues of importance to the participants
    - Desired outcome, process and structure
    - What should we do more of, less of, start doing or stop doing?
- Interactive causal loop diagramming to structure the issues and provide participants with a system view. Created a weighted diagram based on a questionnaire
- Built a System Dynamics model incorporating both qualitative and quantitative aspects and use the model for experimentation and learning in the group.

| Wow - insights | Reflections |
|---|---|
| Small group highly dedicated to the new objectives. All highly professional. | High engagement and involvement |
| Manager highly involved and giving context. | Reinforces purpose and meaning |
| Participants highly positive to having been heard | Listen, reproduce what is said, do not reinterpret. Show systemic connections. |

| Evaluation | Wow - insights | Reflections |
|---|---|---|
| Participants in cases 4-6, were interviewed by external researchers (Elf, Eldh, Malmqvist, Öhrn, & Koch, 2015) | Participants strongly felt that they were listened to and involved in the process | The process worked as intended, working with issues identified by the participants was helpful. |
| | Participants felt that they understood the modelling as we were working with it, but found it difficult to explain to others what had been done. | This concerns me. In other cases, we have made presentations to wider groups of colleagues and stakeholders. |

**Causal diagram**



**Implementation**

Led by the manager of elderly care.

**Coalesced Authority, Power and Influence in the work group**

Present

**My role**

Group facilitator, model building. Planning with project leader, Marie Elf. The project was financed by Formas.

**Publications**

Elf, M., P. Holmström, I. Malmqvist, K. Öhrn and L. v. Koch (2012). *Supporting pre-planning design phases of new dementia care environments through group-modeling*. OR54. Edinburgh, Operations Research Society.

## Case 5 Paediatrics (1)

**Problem/issue addressed**

Patient volumes have increased, facilities have become cramped. High concerns about patient safety and quality particularly considering expected reorganisation and additional patient volumes.

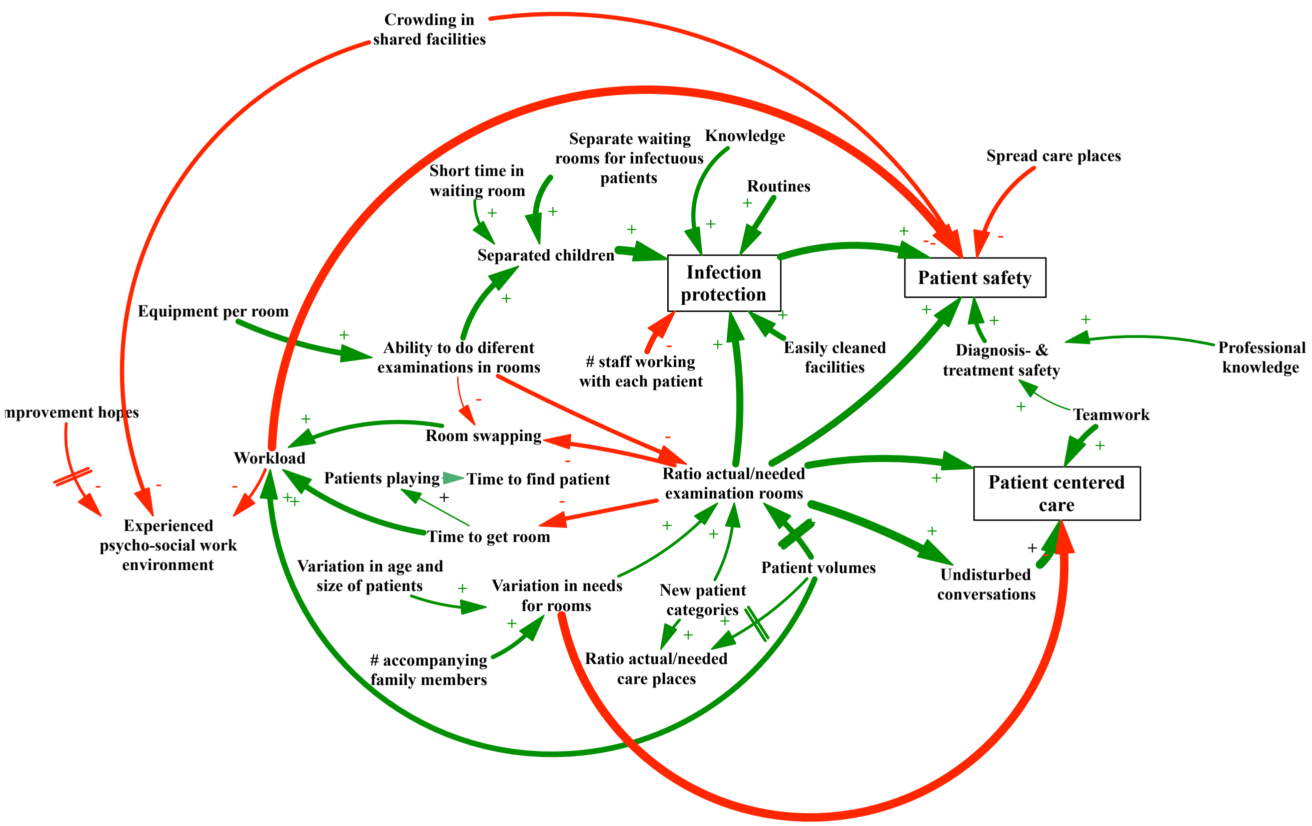
**Method**

- Process consultation interventions to elicit issues of importance to the participants
    - Desired outcome, process and structure
    - What should we do more of, less of, start doing or stop doing?
- Interactive causal loop diagramming to structure the issues and provide participants with a system view. Created a weighted diagram based on a questionnaire
- Built a System Dynamics model incorporating both qualitative and quantitative aspects and use the model for experimentation and learning in the group.

| **Wow - insights** | **Reflections** |
|---|---|
| Somewhat large multi-professional group. Manager present and active. | All participants highly engaged in spite of very cramped meeting room. High level of engagement. |
| All highly professional. Various professions gave different perspectives on issues. | Initial groups by profession, then mixed led to meaningful discussion. |
| Sense of urgency in problems gave high involvement and engagement | Working with real issues important |
| Moment of recognition when experimenting with model and group says, “this is exactly how it was when …” | Model that replicates the reality of the participants creates validation. |

Evaluation, see case 4

**Causal loop diagram**



**Implementation**

Unknown to me. Project leader was main contact.

**Coalesced Authority, Power and Influence in the work group**

Present. Group effective and able to take decisions.

**My role**

Group facilitator, model building. Planning with project leader, Marie Elf. The project was financed by Formas.

**Publications**

None

## Case 6 Accident and Emergencies (1)

**Problem/issue addressed**

Present facilities were overloaded several times per week. Concerns about patient safety and throughput times. New facilities to be considered.

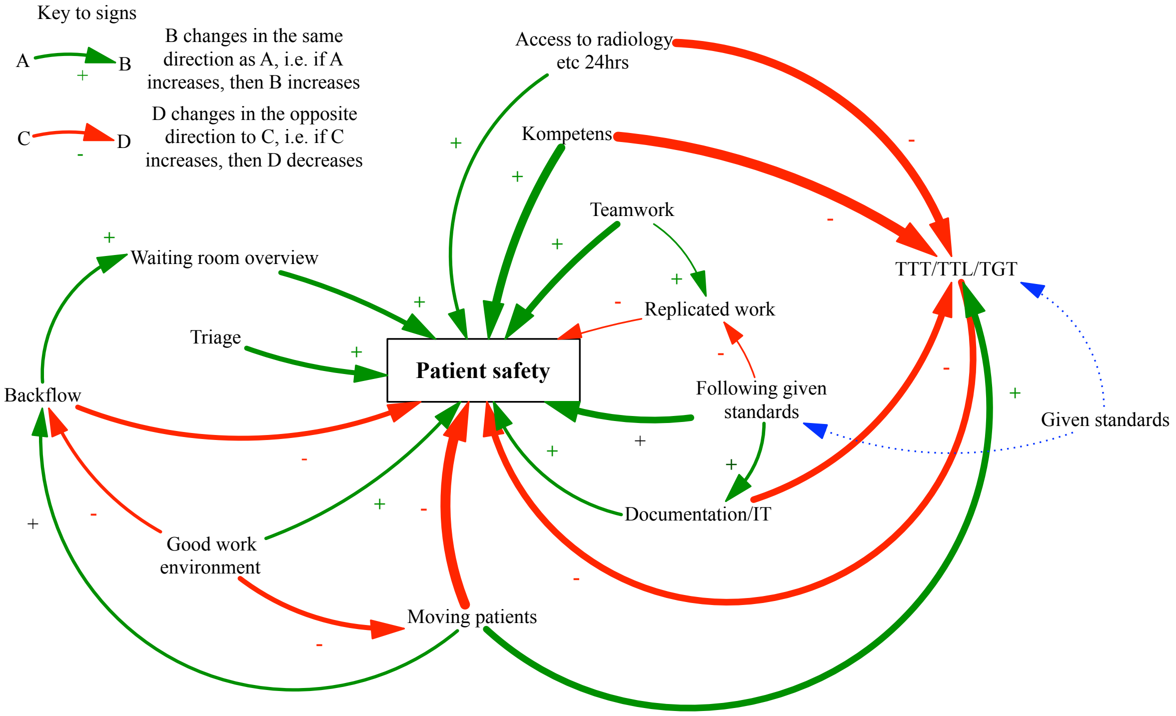
**Method**

- Process consultation interventions to elicit issues of importance to the participants
    - Desired outcome, process and structure
    - What should we do more of, less of, start doing or stop doing?
- Interactive causal loop diagramming to structure the issues and provide participants with a system view. Created a weighted diagram based on a questionnaire
- Built a System Dynamics model incorporating both qualitative and quantitative aspects and use the model for experimentation and learning in the group.

| Wow - insights | Reflections |
|---|---|
| Somewhat large multi-professional group. Manager present and active. | High level of engagement. |
| Various professions gave different perspectives on issues. | Meaningful discussion and considered reflection of different perspectives since main concerns shared. |
| Moment of recognition when experimenting with model and group says, "*this is exactly how it was when* …" | Model that replicates the reality of the participants creates validation. |
| Patient flows increasing. About half admitted to the hospital. Strong opinions that many patients should seek help in primary care instead. | Patients as good at self-referral as primary doctors as my experience is that only about half of doctors' referrals lead to the suspected diagnosis. |

Evaluation. see case 4

**Causal loop diagram**



**Implementation**

New facilities built some years later.

**Coalesced Authority, Power and Influence in the work group**

Present, group effective and able to take decisions.

**My role**

Group facilitator, model building. Planning with project leader, Marie Elf. The project was financed by Formas.

**Publications**

None

### Case 7 Gynaecological clinic

**Problem/issue addressed**

Waiting time between referral and first visit to doctor exceeded national guidelines. Receptionist overloaded with phone-calls. Patients and administrative staff highly dissatisfied

| Wow - insights | Reflections |
|---|---|
| Reactive scheduling of doctors gives time lag. | Simple logistics model where scheduling is based on incoming referrals cuts waiting times drastically |
| Lack of systemic understanding | Constant fixes. |

**Implementation**

Unknown

**Coalesced Authority, Power and Influence in the work group**

Not applicable

**My role**

This was a Master thesis where I supervised the System Dynamics perspectives. As the students were new to System Dynamics this involved some basic training, my main contribution was suggesting venues of inquiry, interpretation of data and suggesting model structures to reflect the present state and alternative solutions.

**Publications**

Acosta, R. and E. Rezvani (2009). *Managing Capacity and Quality, A search for the impact on service delivery in healthcare*. Masters, Chalmers University of Technology.

As I did not do the case work, no detailed description is included in the appendix.

### Case 8 Paediatrics (2)

**Problem/issue addressed**

I was initially asked to model how to plan the escalation of a specific service. This led to the development of two other models, one for preventing "over-consumers" of emergency visits and the other prevention of children on the path to obesity. The purpose of the models was to influence the commissioning authority to change the reimbursement systems to support preventative measures. This was planned as minimal pilot study, to test the viability of System Dynamics concepts.

**Method**

Simple, initial tentative model to show the possibilities of System Dynamics. Rapid development of models based on client interests and needs.

| Wow - insights | Reflections |
|---|---|
| A tentative minimal model of the planned service led to the reaction "*So this is System Dynamics, let's do this instead*" | Begin modelling processes with a minimal model to create understanding of usability, without locking into detail. |
| Even minimal models can create significant insights. | A complete and detailed model is not always necessary for insight and understanding. |

**Implementation**

The hospital director and manager of the clinic were very positive to the results and presented them at an international conference. We presented the results to the director of the commissioning authority, who was interested in the preventive concepts. However, the hospital director, who was the driving force, left shortly afterwards

**Coalesced Authority, Power and Influence in the work group**

As the purpose was to influence the commissioning unit, they probably should have been involved from the start.

**My role**

Sole executor of project

**Publications**

Olsson, M. and O. Panfilova (2009). *Lessons learned from designing innovative care*. EHMA Annual Conference. Innsbruck

### Case 9 Obstetrics (2)

**Problem/issue addressed**

Scheduling of follow-up after births was seen as problematic a, visitors do not show up at planned times. Staff stressed because of people waiting. Explore possibilities to move to drop-in.

**Method**

4 group meetings. First meeting identifying objectives, problems and issues.

Initial findings showed mismatch between scheduling needs and available time slots over a week. There was also a mismatch between when visitors wanted to come during a day and available resources.SD model build rapidly and iteratively. Model kept as small as possible to focus on key issues, without getting lost in detail. A flight simulator interface was built to iteratively explore possible solutions with different scenarios for patient flows and staff scheduling.

| **Wow - insights** | **Reflections** |
|---|---|
| Effective small group with key participants. | Group effective and able to take decisions. |
| Early analysis of data sharpened the definition of problems and issues. | Many in health care not used to explorative analytics. |
| "Flight simulator" interface allowed extensive iterative experimentation and testing of hypotheses. | High level of engagement and creativity in generating hypotheses. Iterations were like running plan-do-study-act cycles in computer. |
| Manager states "*The simulations made it exceptionally clear were the problems were*" | The method works. |

**Implementation**

Presentation and discussions at meetings with all staff. Roll-out tested, revised and implemented.

**Coalesced Authority, Power and Influence in the work group**

Present

**My role**

Group facilitator and model building in discussion with colleague.

**Publications**

None

### Case 10 Malignant melanoma

**Problem/issue addressed**

The clinic formulated the following issues:

- Analysis of patient flows.
- Effects of changes in care programs?
- Effects of continued increase of incidence?
- Prepare different scenarios for different incidence rates.
- How can prevention and early diagnostics affect disease trajectories?

**Method**

The project ran over several years with core project group working on basic action learning perspectives in iterative cycles, defining issues, searching for data and testing hypotheses. We had many and regular meetings with a reference group consisting of the manager of the clinic, the professor of dermatology and key clinicians. We used general Operations Research and analytical methodologies and stock-and-flow models. Both cases were financed as research projects and we used the generic approach described by Wolstenholme (Figure 4).

| Wow - insights | Reflections |
|---|---|
| Most medical research done to evaluate new treatments. Here opposite logic – which outcomes are desirable and feasible. | Struggle to make this “reverse logic” understood by clinicians outside the group. |
| On one hand an abundance of data in quality registers on the other hand lack of data in e.g. patient flows. | “Follow the numbers”, use available data, estimate other numbers, do sensitivity analysis to determine which data needs to be exact. |
| Health care defines incidence as the moment of diagnosis. When modelling the trajectory of a disease as cancer there is a moment of actual occurrence which may be months or years before “incidence”. | In some healthcare modelling this needs to be considered. |
| About 50% of referrals for suspected skin cancer actually have cancer. Lack of data and info for the benign cases. | The system is unaware of the many patients who do not get the diagnosis. But info on the patients needed to build a model replicating actual patient flows. |
| Cancer patients are rarely experimented on. Building a model replicating cancer growth allowed experimentation impossible in the real world. | System Dynamics can really contribute to learning otherwise impossible. |

**Implementation**

Key clinician and others created method supporting early diagnosis.

**Coalesced Authority, Power and Influence in the work group**

Present

**My role**

Analysis and models of patient flows, care programs and “flight simulator”. Colleague built “patient generator”

**Publications**

Holmström, P., M. Claeson and S. Hallberg (2012). *A System Dynamics 'Flight Simulator' for the Evaluation of Policy Interventions in Patient Pathways for Cutaneous Malignant Melanoma*. The Operations Research Society Conference 54, Edinburgh, OR Society.

Claeson, M., S. Hallberg, P. Holmström, A.-M. Wennberg Larkö, H. Gonzalez and J. Paoli. *“Modeling the future - System Dynamics in the health care pathway of cutaneous malignant melanoma”*. Poster at the 2nd International Conference on UV and Skin Cancer Prevention, Berlin 2013

Claeson, M., S. Hallberg, P. Holmström, A.-M. Wennberg Larkö, H. Gonzalez and J. Paoli (2015). *"Modelling the Future: System Dynamics in the Cutaneous Malignant Melanoma Care Pathway."* Acta Dermato-Venereologica 96(2): 5.

Hallberg, S., M. Claeson, P. Holmström, J. Paoli, A.-M. Wennberg Larkö and H. Gonzalez (2015). *"Developing a simulation model for the patient pathway of cutaneous malignant melanoma."* Operations Research for Health Care, 6: 23-30.

M. Claeson, "Modeling the future - System dynamics in the health care pathway of cutaneous malignant melanoma". Invited speaker at the conference "Facts and consensus about skin cancer prevention", Vadstena, Sweden, 2016.

M Claeson, P Holmström, S Hallberg, H Gonzalez, A-M Wennberg, J Paoli*, Multiple primary melanomas in Western Sweden; 1990-2013*, Poster at the 3rd International Conference on UV and Skin Cancer Prevention, Melbourne 2016

Multiple primary melanomas: A common occurrence in Western Sweden. Claeson M, Holmström P, Hallberg S, Gillstedt M, Wennberg A-M, Paoli J. Accepted for publication in Acta Derm Venereol 2016*

## Case 11 Lung cancer

### Problem/issue addressed

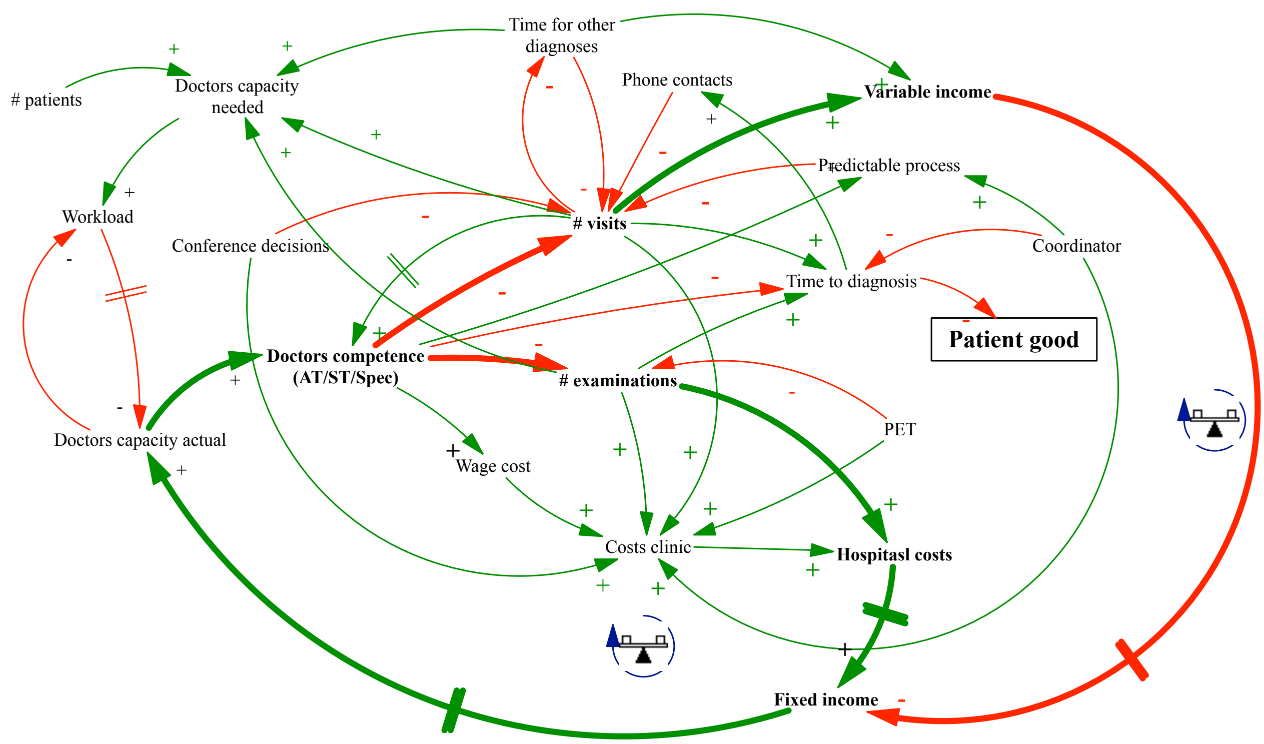
Multi-year project to study how reimbursement systems can incentivise shorter time to diagnosis.

### Method case

The project ran over several years with core project group working on basic action learning perspectives in iterative cycles, definition of issues, search for data and test of hypotheses. We used general Operations Research and analytical methodologies as well as causal loop diagramming and stock-and-flow models. We met irregularly with a large reference group of interested stakeholders in the region. We used the generic approach described by Wolstenholme (Figure 4).

| Wow - insights | Reflections |
|---|---|
| Workshop – causal loop diagrams as large worksheets. | Relevant insight in group. Worksheets good method. Highly relevant discussion and feedback. |
| "Small data" approach with manual analysis of patient records provided data and insights otherwise unavailable. | Important to work in ways so that people involved really want to dig out the data themselves. |
| Mapping and understanding the system shows where improvements can be carried within given resources. | System understanding and going beyond quick fixes important. |
| Reimbursement systems shown to be rigid and not having intended effects. | People state that results reflect the facts, but the system is too rigid to change. |
| High level of engagement in workshops for clinical staff. | Confidence in the model enables to isolate specific factors and leads to insights that changes in how to work gives more effect than additional resources. |

### Causal loop diagram



**Implementation**

The process owner at the clinic was a driving force in the analytics and used his insights as they were uncovered to improve the process and significantly cut the time to diagnosis. As a next stage, he needed to involve other staff, so we ran workshops with hands-on experimentation with models to share our insights.

**Coalesced Authority, Power and Influence in the work group**

The process owner had the authority to make significant changes, but to go further workshops were needed to engage people with power and influence.

**My role**

Co-lead of group with process leader. Led reference group meetings. Built causal loop in discussion with colleague. Built models for analysis of reimbursement systems. Colleague built model for analysing patient flows

**Publications**

Holmström, P., B. Bergman, S. Hallberg and C. Ridderbjelke (2013). *Ersättningsformer och processeffektivitet – modellering för styrning i ett komplext system*. Nationell konferens SKL. Stockholm.

## Case 12 Breast Cancer

**Problem/issue addressed**

The Regional Cancer Centre saw the lung cancer project as successful and asked us to do an initial study to assess if “big data” analysis could be used in similar ways.

**Method**

Analysis and structuring of very large amounts of data.

| **Wow - insights** | **Reflections** |
|---|---|
| Patterns in patient flows could be identified for most patients. | Big data useful as it shows actual patterns. |
| Deviations from standardized care processes could not be explained using the available data. | For improvement processes deviations need to be understood. |
| Huge amounts of data, but difficult to interpret without studying individual patient records | Big data approaches should be supplemented by stratified randomized studies of patient records. |

**Implementation**

None. The results were not clear enough and the process owner at the involved in clinic was highly engaged in a major value-based-care project.

I have included this case as confirmation of Brailsford’s (2005) comment on the quality of data in healthcare. I have experienced cases where it has been difficult to get any data. In other cases, I have had access to amount of high quality data. In this case an abundance of data, which needed additional work to interpret.

**Coalesced Authority, Power and Influence in the work group**

Not applicable

**My role**

Participant in work group with SD colleague and health statistician. Colleague analysed data from patient flow and SD perspectives

**Publications**

None

## Case 13 Accident & Emergencies (2)

### Problem/issue addressed

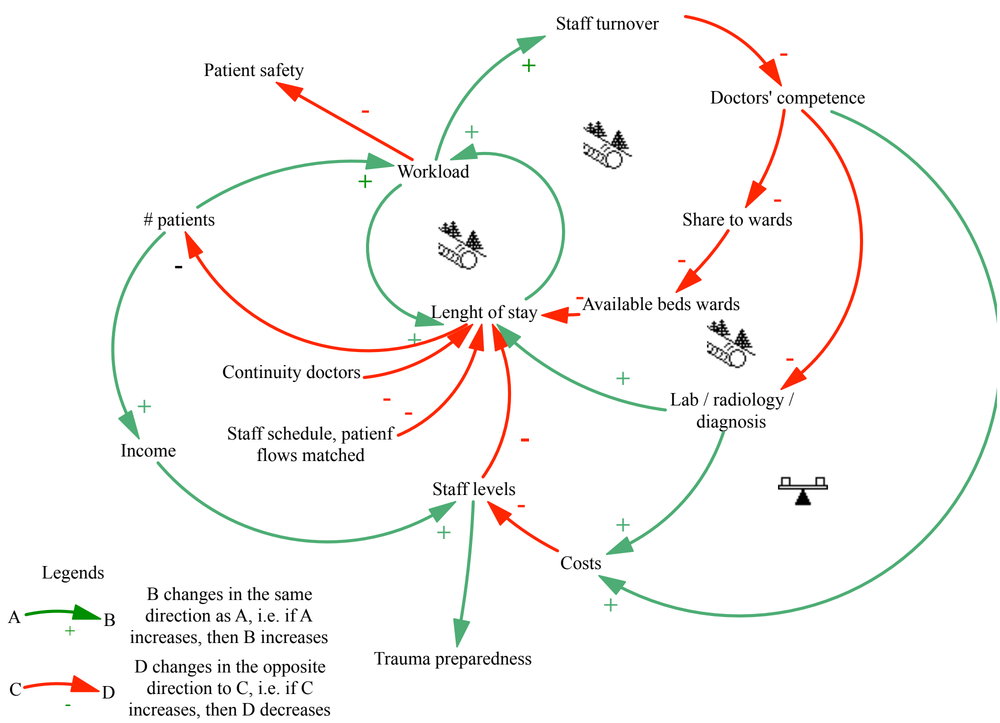
National study addressing causes of long wait and throughput times in A&E. I was asked to contribute with systemic views.

### Method

Desk study based on available data and info from my earlier studies of A&E departments. Focus on building a causal loop diagram to show the systemic issues and build minimal System Dynamics models to show what I had identified as core issues.

| Wow - insights | Reflections |
|---|---|
| Causal loop model accepted, but many still did not see the implications on a systems level. | How to get people to see leverage points for action instead of being overwhelmed by the system. Many are used to working with lists of issues and ticking each problem off. |
| Main study based on traditional statistics - correlation deeply rooted, but does not provide answers as the system is the problem. | Strongest correlation was that patients arriving by ambulance have the shortest throughput time, which says nothing about how to organise. The simulation shows that queues accumulate as there is a mismatch between predictable patient flows and staff scheduling, but everybody “knows” that scheduling can’t be changed and even if one could, patient flows are not that predictable. |
| I built minimal simulation models to show important general phenomena. Understood and accepted, but participants saw a need to build a detailed model for their respective units. | Need to consider how to move from general system understanding to actually organising work. |

### Causal loop diagram



**Implementation**

Not included in final report of the national study

**Coalesced Authority, Power and Influence in the work group**

I presented my results for a large group consisting of project leaders for the national study as well as representatives for the involved hospitals. The authority to include results was with the project leaders. I had been engaged by their manager. Ideally resources should have been available to work close to the project leaders. Also, data collection had begun late so project management were very short of time.

**My role**

Sole executor of systems study.

**Publications**

None

# Conclusions

I have described thirteen cases to illustrate the what is similar and different from a process / action research perspective, so that general conclusions can be made.

I conclude that on the use of an action research approach is useful when time is spent on initial stages identifying issues relevant to the participants. In most of my cases I have facilitated the group to describe objectives and issues. During this process we have used the structure described in Social Analysis (Rowbottom, 1977). We brought forward descriptions of that which is manifest, i.e. how processes formally are described as well as each participant's assumptions of how things actually work. As participants shared their perspectives a shared understanding of how things actually are, was created. The result was a System Dynamics model having passed the first step of validation – showing the current state of the system. I conclude that working from and using issues as directly described by participants leads to high engagement and in the active exploration of the resulting models.

In most cases, we used Causal Loop Diagrams to create shared maps and understanding of how issues are connected. The shared understanding was increased through experimentation and learning from simulation models so that the group can converge on solutions that they agree on and thus lower the threshold for implementation.

From a System Dynamics perspective building on the words and the issues of participants and working with these, instead of rephrasing them to fit the needs of a model leads to a very high degree of identification with the resulting model and thus increasing the chances for actual implementation.

What I can see in many of my cases is that creating system maps, starting by causal loop diagrams, significantly changed the conversation. Participants see how their views do not "compete" with the views of others, as the interaction between perspectives is shown. This is an important shift from individual to shared constructs (Gergen, 2001), building on the methods of Social Analysis (Rowbottom, 1977).

It has long been considered good practise to identify and name sub-loops in a causal loop diagram. This combined with discussion and identification of leverage points for change can have significant effects in overcoming what some considers to be overwhelming complexity. In three of my cases I have used questionnaires to build weighted causal loop diagrams, which also allowed for defining areas that have higher effects on intended results.

My planned approaches as described in *Table 3: Problems and approaches,* worked as intended. However, I now conclude that two perspectives are missing in Jahangirian's analysis, i.e. selection of participants and the issues of the very implementation.

### Selection of participants

In most of my cases Coalesced Authority, Power and Influence (Adizes, 1992) was in place among the participants of the work group and/or reference group, for efficient work, decision-making and laying the ground for implementation. Adizes defines *authority* 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.

### Implementation

Neither Jahangirian (2015) or Brailsford (2005) discuss the lack of a plan for implementation, when discussing the failure of implementation. I interpret this through the lens of Chew et al (1991), i.e. it is as if a simulation model is seen as self-implementing. When reviewing the action research literature, I find few references to the issue of implementation, it is raised only when the action research group is small in comparison to the larger organisational unit into which the results are to be implemented. I understand this as action research projects being "self-implementing" as participants have worked out solutions themselves, whereas an expert System Dynamics model needs an implementation plan. The roll-out of model that has been built with a partial group of those involved needs to have an implementation plan where the research group has an important role. In Table 5 I map my approaches on the structure of the implementation grid.

| | Technical knowledge | Organisational knowledge |
|---|---|---|
| **Know-How**<br>Experience-based training in the technology | Step 3<br>Define new operating rules, processes etc | Step 2<br>Model experimentation and learning |
| **Know-Why**<br>Education in the theory underlying the technology | Step 4<br>What technological platform(s) can support our new ways of working? | Step 1<br>What are our objectives? Which problems do we see and want to resolve? |

*Table 5 Proposed use of implementation grid*

In some of the cases there has been a roll-out to a larger group of people. In these cases, I have followed the basic principle as suggested in the implementation grid:

- What are the organisational objectives that we want to reach?
- What problems have we seen in the present ways of working?
- Introduction of a systems dynamics model and running through a selection of scenarios to show what we have learned.
- Introduction of proposed solutions

My conclusion as to my research question *Does integrating System Dynamics methodology into action research interventions create systems understanding and, the prerequisites for using the results in practise?*: is that the following steps should be followed in order to obtain a favourable result:

- Start by listing objectives and issues identified by the participants
- Create system maps using words and issues from the participants
- Introduce System Dynamics gradually, start with small models
- Experiment with the model in the group for discovery and learning
- Expand the model as suggested by the group, iterate experimentation
- Work with the group to prioritise and make an implementation plan

## Future research

- How to explicitly use Systems Thinking and System Dynamics in implementation, i.e. to move from an understanding of a system, to reorganising the existing system by changing its constituent parts.
- Action research builds on the involvement of those who "own" the issues at hand, how can ST/SD support them when they in turn involve colleagues?
- How to support implementation of SD/ST action research projects through workshops, documentation etc. An additional reason for the lack of implementation (S. Brailsford, 2005) could be that the modeller "abandons" the project either through lack of funding or the lack of implementation knowledge.
- How to make System Dynamics easier to use for novices?

# Appendices

## Case 1 – Obstetrics (1)

### Project context

I was asked to review obstetrics and postnatal wards with a staff of about 125. The unit had severe cost overruns and strong staff dissatisfaction. I interviewed 22 persons and studied documents and data. The key issues required no systems mapping or modelling, but the methods informed my analysis and insights and I co-authored a paper on my systems insights.

Here I describe the major insights that have influenced me and inspired the paper.

### Variability in patient flows

Patient flows are highly variable as can be seen in Figure 5, showing births per day over a year. With such variations, daily or seasonal patterns are not easily recognisable, neither are changes in trends. I have seen the same variability not only in births, but in arrivals at A&E and referrals from primary care. My important insight is that any simulation models should show such variation to be considered credible by the staff.

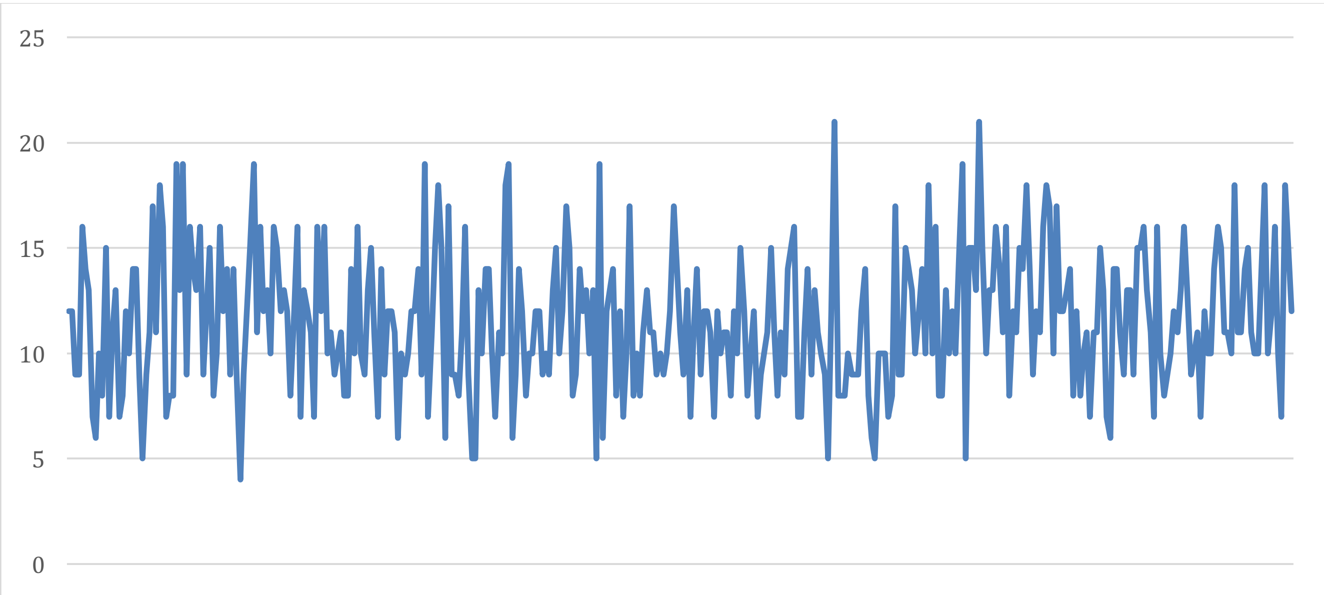



*Figure 5 Variability in patient flows*

### Coping with variability

Daily variation in clinical referrals are usually smoothed when subject to rolling average on a 7-14-day basis, i.e. the system copes with variation by queuing referrals. A&E units' cope with variation by triage and queuing patients in waiting rooms. What I find particularly interesting is how one can cope with variation in obstetrics. Expectant mothers arrive with significant variation and give birth immediately or up to several days later. It is not possible to queue the babies. In case of overload, expectant mothers can be referred to other hospitals.

What stood out in the interviews was how midwives themselves absorb the variation. A shift with many births may be followed by a shift with fewer births. This department had merged birthing and post-natal, so midwives would do one shift at one unit and the next at the other unit. Working in post-natal was seen as one way to absorb a high workload in birthing.

In the model that I built for the subsequent paper I modelled the dynamics of the perceived workload. When the actual workload increased the perceived workload also increased rapidly, but the memory would remain longer. My conclusion is that this kind of analysis could be very valuable when determining staff levels as dimensioning based on averages probably will lead to perceived overload.

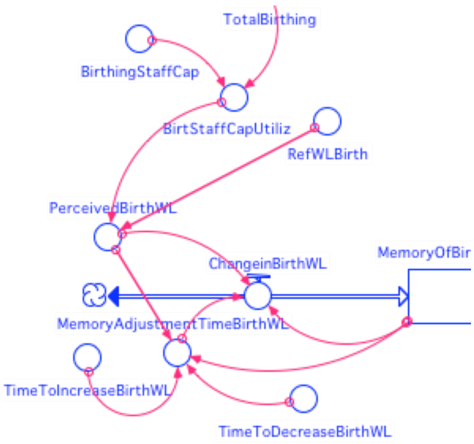



*Figure 6 "Memory of" module*


*Figure 7 Workload and memory of workload*

### The "vacation problem"

Three years before my study the hospital had been asked by the regional authorities to increase its obstetrics capacity by 30% and had been given sufficient resources for the task. I conducted my interviews in late August to early September. Many of those interviewed complained about the high number of newly employed staff. When checking with the personnel department I could see that very few new persons had been hired since the increase. My conclusion was that the perception must have been due to the vacation period, when one third of the staff goes on vacation for a three-week period, and there is a nine-week period with temps, usually newly examined midwives. My hypothesis was that a similar "memory of" disruption took place over the vacation period. This was confirmed when the organisation project moved into its second phase in November-December when it seemed as though everybody had forgotten the summer.

In the published paper, I explored what I call issues of perceived continuity, where there was a one-third drop in staff continuity over the vacation period. Regular staff would quickly feel the loss of continuity in their daily work as they would have to support inexperienced staff and it would take months for that experience to subside.

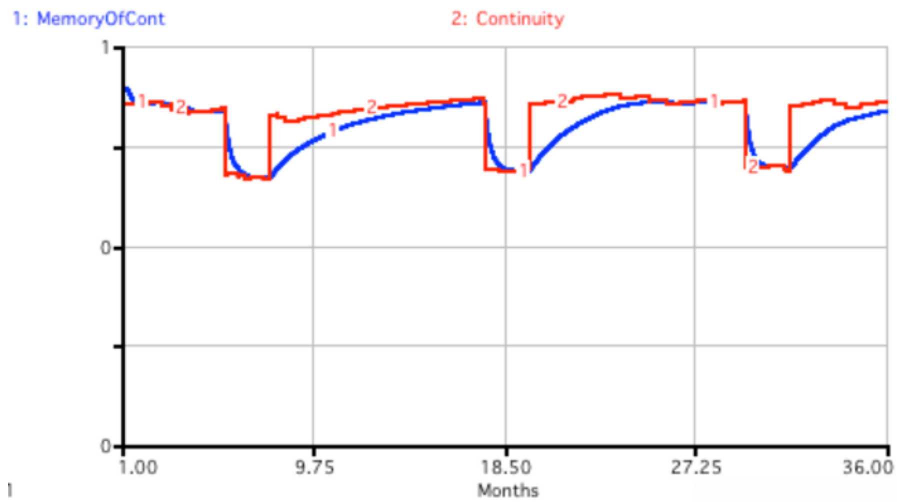



*Figure 8 Continuity and memory of continuity*

### Academic presentation

I built a model and co-authored a paper as a project during my master studies. I presented the paper at the annual conference of the System Dynamics Society in Oxford 2004.

Holmström, P. and M. Elf (2004). *Staff retention and job satisfaction at a hospital clinic - a case study*. International System Dynamics Conference, Oxford, System Dynamics Society

## Case 3 – Evaluation of hospital reorganisation

### Project context

The study involves a hospital with about 1000 employees. The regional council demanded that it cut costs by 50 million SEK in one year or be shut down. The hospital management rapidly found a way to reorganise, which involved two clinics and four wards. The unions understood the urgency but demanded a review to be carried out one year later. I carried out that review. As part of the project, I interviewed a cross-sample of 25 employees from different wards and professions, and studied data and qualitative analysis done by the ward manager.

### Results

While staff understood the need for the reorganisation they were dissatisfied. Instead of organising wards by medical sub-speciality they were now organised by patient flows. Specialist doctors doing rounds needed to visit several wards. Nurses assigned to a specific ward needed to develop their competencies to work with patients with other diagnoses. Two wards no longer were open 24/7. Those open all the time had increased staffing levels, but staff felt that workload had increased.

In my report and presentations to management and staff I summarized what I had heard in my interviews and what I had seen in the data. Many who I interviewed were exasperated and wanted to go back to the old organisation. There was a lot of focus on specific detailed issues but little understanding of the systemic consequences of the reorganisation. I addressed this by drawing a causal loop diagram (Figure 9), which I presented step by step.

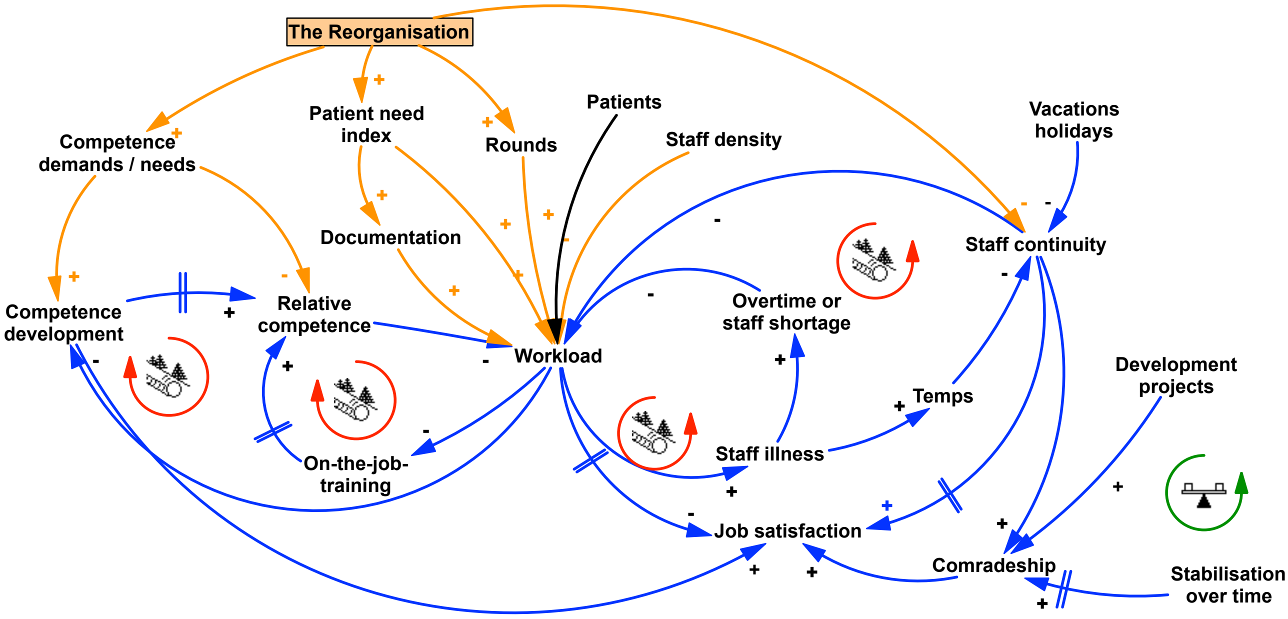



*Figure 9 Causal loop diagram reorganisation*

Nurses experienced a significant increase in workload. Partly due to them being exposed to three additional sub-specialities that they had not worked with previously. The managers of the involved clinics had planned initial training programs to address this, but few could participate as three of four ward managers considered it difficult if not impossible to hire temps. Some nurses fell ill due to stress and overwork, which in turn increased the workload of others. Ward managers had also, due to cost concerns, eliminated work meetings for development purposes, which lead to difficulties in engaging staff in how to solve the issues.

In connection with the reorganisation urology specialists had been reassigned from surgery to initial meetings with patients. This had the effect of eliminating queues for first visit but building a waiting list for surgery. I illustrated the long-term effect with a simple stock and flow model (Figure 10).

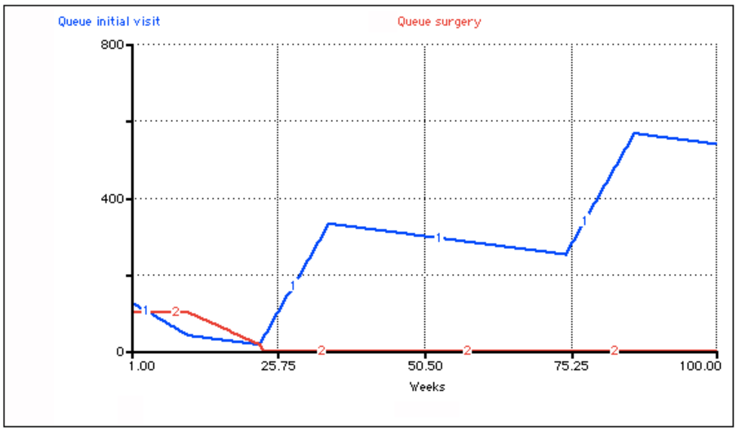



*Figure 10 Queue effects*

As I knew that the hospital management considered it impossible to wind back the reorganisation and the cost savings it brought, I needed to show leverage points for improvement in the system (Figure 11).

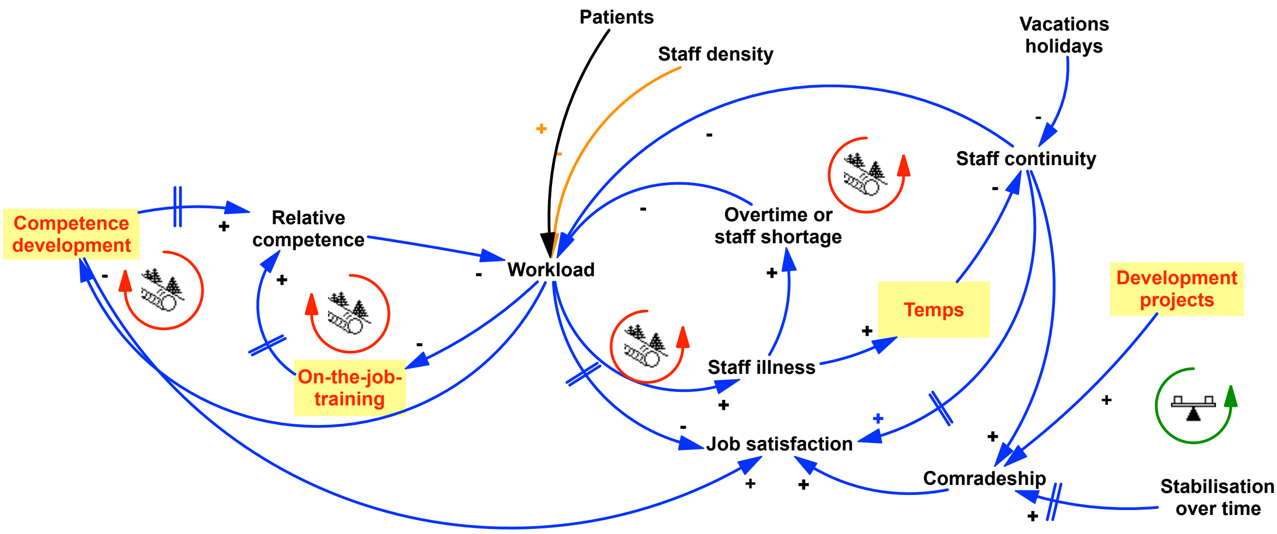



*Figure 11 Levers for change*

One of the ward managers could show that it was a myth that temps were not available. They and the managers of the clinic agreed that temps should be used not only to ease staff workload, but also since it was cost neutral to ordering overtime. I also suggested that the planned initial training programs should be run again, this time taking in temps so that staff actually could attend. Finally, it was accepted to reinstate development meetings to allow the staff to participate in analysis and problem-solving. It was agreed that the negative effects of stress and perceived workload were higher than the costs of having such meetings.

## Case 4 – Dementia Care

### Project context

This was my first collaboration with a research project carried out at the institution of Architecture at Chalmers. Marie Elf was project leader and it was financed by Formas. The overall purpose of the project was to study the usability of System Dynamics to support pre-planning processes. My brief was to use System Dynamics group modelling to explore mainly qualitative, but also quantitative aspects of work processes to engage the group into considering development of work processes before specifying future needs of premises.

Here a dementia care unit in a municipality in a rural area was studied. The council elderly care manager was lead on the client side. They were in a major transition from dementia care as ”storage units” to revitalizing environments and care. Prior to the intervention many staff members had taken academic credits in dementia care at the nearest university. They were about to change their organisation and move into the pre-planning phase for the nursing home. The purpose of the manager was to move the group from discussions around traditional building programming and engage them in exploratory discussions of their work. A nearby municipality was seen as a warning example, where they had invested substantially in a new building, but not changed the work methods or care itself.

### Project outline

As the purpose of the project was to use System Dynamics group modelling in the pre-planning phase and open up for discussions about work processes, a small number of meetings were planned were the conversations under way were to be more important than any final models.

The academic project group contained a nurse/architecture researcher, an architecture researcher and me as modeller. Our general plan was as follows. The first meeting would set the project context, express the participants' objectives and introduce System Dynamics concepts. The second meeting was to delve deeper into qualitative analysis of work processes and focus on improvements. The third meeting would introduce tentative System Dynamics models based on prior discussions and outline how to improve the model. The fourth meeting would present a deeper iteration of the model with a flight simulator interface and ask the model questions and see where priorities for future work should lie.

The project took place over a period of 4 months with four three-hour meetings with the local group and intermediary meetings in the academic group. The local group consisted of the elderly care manager and six caregivers.

### Meeting 1

At the first meeting, we had mutual introductions. The researchers and the staff at the dementia care unit shared their purposes and desired outcomes. Their major objective was “We will build the best dementia care in Sweden”. Donabedian's structure (1988) was introduced and the participants first worked individually and then in pairs to discuss and describe the desired outcome, processes and structure. They wrote on large adhesive notes and presented and discussed their results. The notes were then clustered according to theme and the participants were allotted a small number of coloured adhesive dots to stick to the notes to indicate their personal priorities.

A sample of desired objectives

- Satisfied residents and relatives
- Knowledge-based care
- Safe and secure care
- Individually adapted care
- Participative care
- Reduced medication
- Satisfied and engaged staff

### Meeting with the council elderly care manager

The academic project group met with the manager who described the overall purpose and objective of the change project. The intention was to concentrate all local dementia care to this unit. Present residents that do not have dementia would be moved to other units over the coming months. Patients at other units with dementia would be gradually moved there. 50% of all elderly patients in council services have dementia or cognitive impairment.

Staff interested and willing to take part in the change had taken university credit courses in dementia care. The combination of extensive experience and new knowledge was to be driving the change. The staff would be working both night and day shifts to ensure knowledge sharing.

Some staff problematize that patients are awake and move around at night. The premises are presently U-shaped but will be modified to be circular, which in combination with lighting, painting and furnishing will encourage residents to walk and be more active during daytime and achieve a more normal day-night rhythm.

### Meeting 2

The chairman of the council committee for social services began the meeting by sharing challenges and objectives for the care of the elderly:

- Improving the quality of care actions
- Improving patient safety
- Centring care around individuals
- Attracting staff. There are difficulties in recruiting staff and some report burnout
- The care environment can be a factor in attracting staff. A distinct and clear environment can reduce the need for escort and allow time for care and communication.
- Change and development is progressing rapidly
- Technology development to give caregivers more time for patients and their needs. Technology needs to be embedded and harmonize with a homelike environment. Technology and methodological improvement can reduce time for cleaning and other chores beside the actual care.

The meeting moved on to organise and elaborate on the output from the first meeting

- What are our *objectives*? (pink notes)
- What activities are required to achieve the objectives, i.e. *process*? (green notes)
- What needs to be in place to achieve the objectives, like staff levels, physical environment, suitable indoor and outdoor facilities ..., i.e. *structure?* (yellow notes)

**Objectives**

Individually adapted care
Satisfied residents and relatives
Best dementia care and living in Sweden
Reduced or minimal use of medication
Suitable and satisfied staff
A new attitude to work – we must adapt to the residents

**Processes and activities**

Self-supporting ways of work
Ongoing exploration of life histories – create knowledge about the patient
Make use of the needs and abilities of individuals
Activities that suits the individuals
Meaningful everyday activities with activity, not passivity
Adapted activities together with staff
Sharply sensitive
Good teamwork
Manager and staff at the same level, all are important
All staff to follow the same principles and direction
All staff and management working in the same direction towards shared objectives
Regular medication reviews
Dare to phase out medicines
Continuous development, never at ease
Dare to try methods, dare to fail
Check that guidelines are followed

Contact with and training of relatives
Develop cooperation with outside organisations e.g. pensioner groups
Contact with and information to relatives

**Structure**

Continuous training and updates for relatives and staff
Engaged manager
Suitable premises
Adapted outdoors environment
Calm and harmonious environment
Patients have a sense of security and feeling at home
Continuous supervision
Listen carefully when recruiting staff
Regular feedback to staff

At this point both the manager and participants expressed great satisfaction having come so far. They expressed that having worked through and discussed the priorities they had a shared sense of purpose that would guide them through their coming work.

When the notes had been rearranged and discussed, we asked which note was primary and should be the focus of a causal diagram that we would be building together. They selected “satisfied residents and relatives”. Next, we asked which other notes had a direct influence on that objective. Those notes were moved closer to the focus note and we gradually built a causal diagram by taking a note, discussing how it fitted into the causality, pasted it on the wall with an appropriate arrow showing the causality (Figure 12). I felt slight frustration at this point as we had not uncovered any loop mechanisms, all was straightforward linear causality. I made a mental note that that was my “problem”, it was not a problem for the participants as they were very happy about the causal diagram as it stood.


*Figure 12: Building the causal loop diagram*

### Before meeting 3

I built a formal causal loop diagram based on the outcome of meeting 2 (Figure 13)

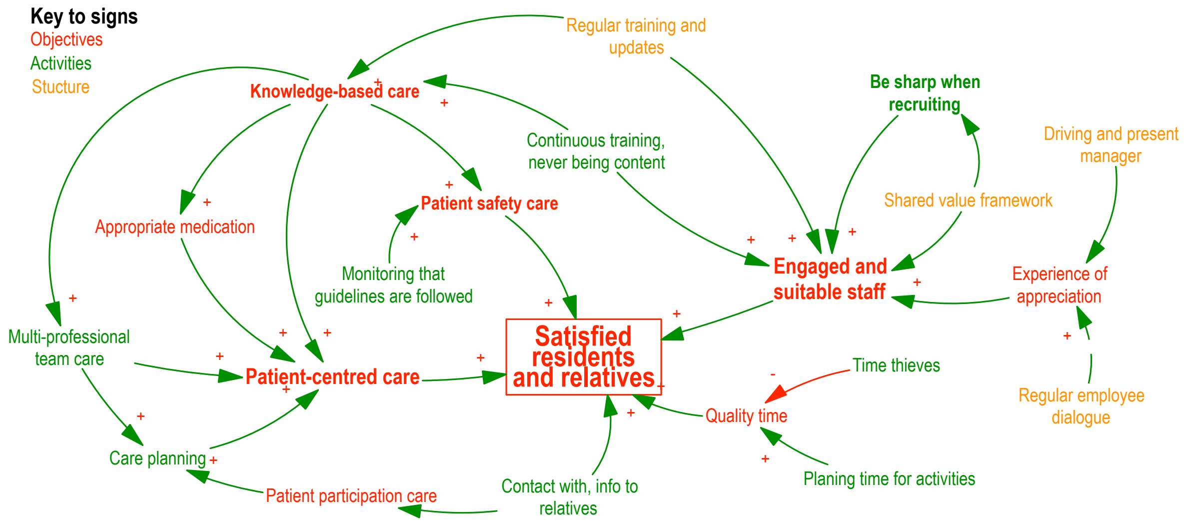



*Figure 13: Initial causal diagram*

### Meeting 3

In the research team's discussions prior to the meeting we felt that the work group were to a degree talking about generalities. We wanted to get them more into specifics and consequences. We had constructed the causal diagram using Vensim and walked through it with the group and discussed it. We then asked, given this causality and the main objectives:

- what do we need to do more of?
- what do we need to do less of?
- what should we stop doing?
- what should we start doing?

The participants worked in smaller groups, wrote on large adhesive notes and presented their findings, examples below:

**What should we start doing?**

- More "personal" time with the residents
- Utilize seasonal changes in weather
- Schedule activities
- Schedule staff to work with activities
- Better/more contact between doctors and assistant nurses
- Schedule work meetings and take minutes (for safe care)
- Involve janitors in outdoor activities
- Reminiscence
- Spa activities, sensory room
- Café
- Pedagogical meals

**What should we do more of?**

- More natural seating places outdoors and indoors
- Consider colouring, leads to calmer living and cheerfulness
- Room for shouters (silence for others)
- Evening activities, being up later. Leads to less medicine, better sleep, less anxiety, fewer falls, better appetite)
- Outdoor activities, garden

- Consider clerical visits at a natural level (hospital priest)
- Early and structured welcome conversations, with resident, relatives and contact person
- Develop the work of contact persons to involve patients in their care
- Culture (film, music, theatre)
- Belief in the abilities of each patient.
- Reflect over what we do and how we do it
- Staff needs to adapt to the residents, not the other way around
- Life stories (for individual care)
- Capture and use the moments, capture
- More group discussions -> decisions > agreement -> clarity. Decisions need to be followed to ensure safe care

**What should we do less of?**

- Less territorial thinking
- Change washing and cleaning routines
- Less time spent on scheduling
- Clean less
- Fewer fixed routines, spend more on quality time
- More responsibility to the contact persons
- Follow decisions of health care workers on care levels

**What should we stop doing?**

- Work in unstructured ways (follow routines)
- Spend time on activities unrelated to the patients
- Interfering in the work of contact persons

The group found that they had uncovered a lot of relevant issues which were very meaningful for them. They would continue the discussion at a staff meeting later in the year when they are to work with care philosophy, guidelines and work organisation. They saw clearly that they want to get better at individually adapting care through guidelines and individual care plans. The realised that the care plan is an important instrument in developing individual care. The group repeatedly returned to the necessity of good leadership and a manager who is present.

My reflection was that the council elderly care manager was very inspirational. In our side discussions, he shared his deep knowledge of the care of the elderly and cognitively impaired in general. Even if he is responsible for a larger area than this care unit, he is involving himself heavily.

We ended the meeting by telling that we would be develop and send them a questionnaire to investigate the causal diagram.

### Survey and model

Between meeting 3 and 4 I developed a survey with the intention of weighting all the inputs of the causal diagram and estimating the present rating of each variable in the diagram. The output was a revised causal diagram showing the relative weights using different line thicknesses and font sizes. A sample node question is shown in Figure 14.

**Satisfied residents and relatives**


Distribute in total 10 points between the incoming variables (e.g. 4, 1, 2, 1, 1. Check that the sum is 10)

| Points | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Patient-centered care | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Patient safety care | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Engaged and suitable staff | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Quality time | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Contact with, info to relatives | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

*Figure 14: Survey question example*

The causal diagram had also been translated into a System Dynamics model where it was possible to simulate the effects of changing a variable on the following variables. Here the relative weightings of the different inputs were used and the present rating was used as the default state of the model (Figure 15). Assumptions were made about how long it would take for any change to have an effect.

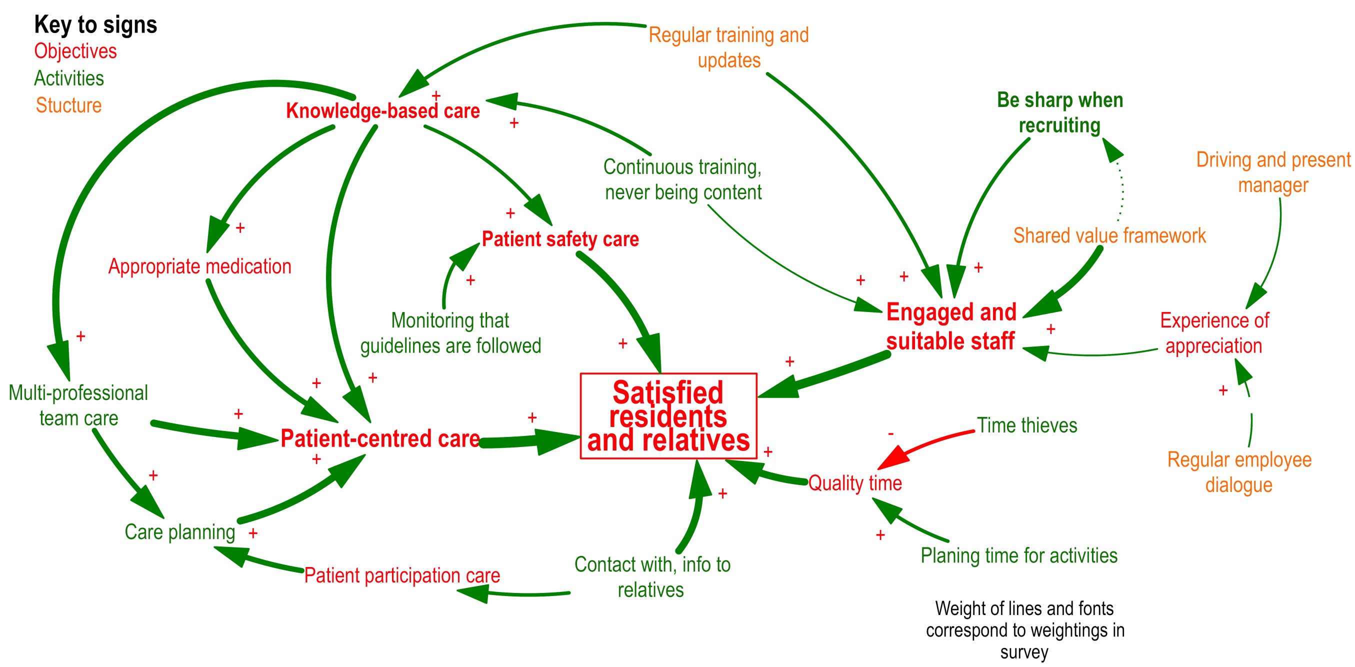



*Figure 15: Weighted causal diagram*

### Meeting 4

At the fourth meeting the weighted causal diagram was introduced and discussed to ensure that it was understood and shared by all. We then reviewed the responses to the survey. I then introduced a System Dynamics model to study the impact of changes on the main objective. I had built the model in a runtime version so we could leave it behind for continued experimentation (Figure 16).

The default settings of the model are based on the survey results with differing speeds of change. One can then test the effects of individual or combined activities. An organisation cannot change all parameters at once, so the purpose of the model is to test and discuss where to start to achieve maximum initial effects. The group had very good discussions.

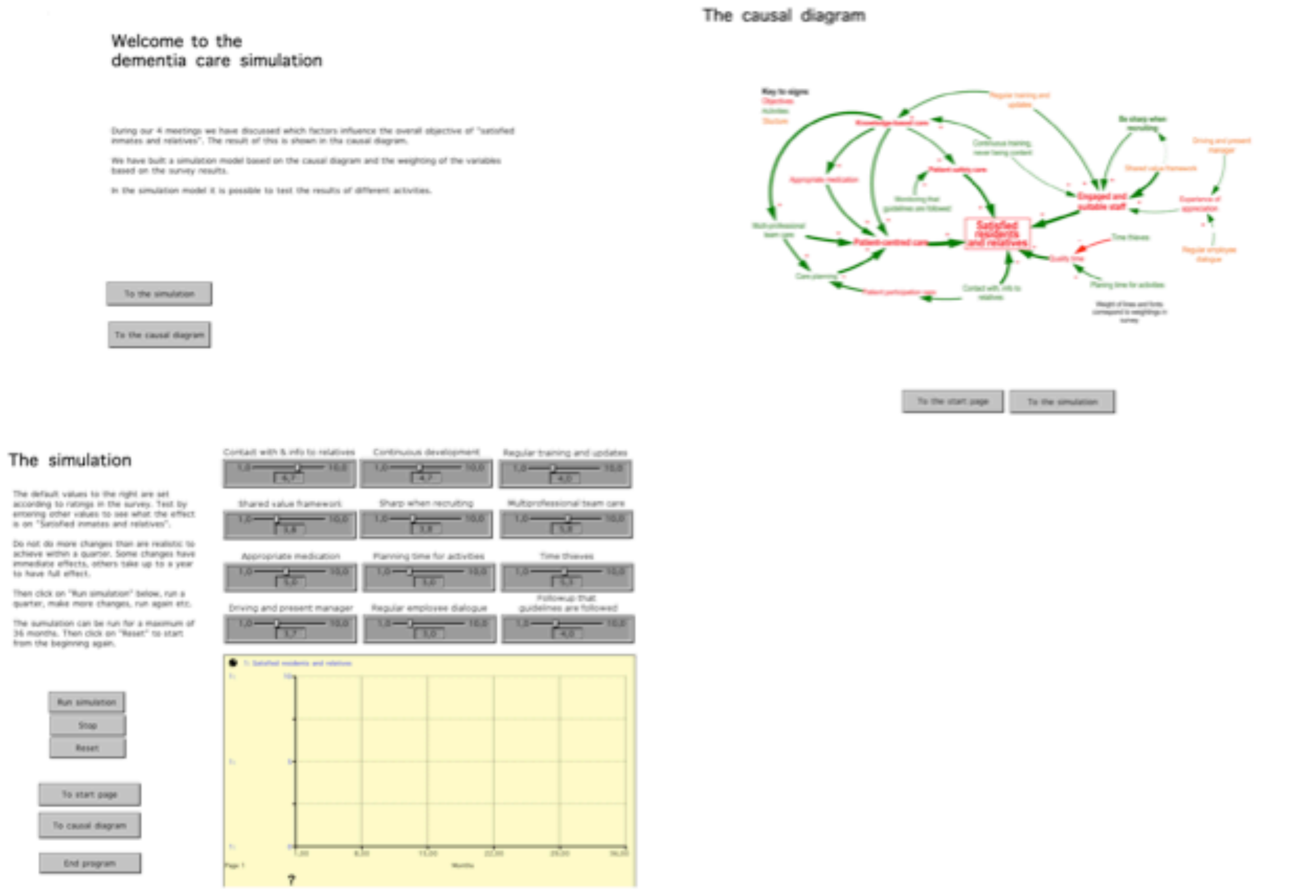



*Figure 16: Run-time interface*

### The most important outcomes

The purpose of the intervention was to move the group beyond traditional building programming and to engage them in an exploratory discussion of their work in the light of higher objectives. Although there was a rough plan at the outset, the detailed interventions were designed under way to facilitate a learning process.

The group was highly committed to the overall purposes and very engaged in their discussions. They found the process most useful and gained insights which they found very useful in their own process of redesigning their work. This allowed them to move from discussions of room functionality and square meters to an understanding of the work to be done in the rooms and thus having an entirely different discussion.

The prioritization process and the final model built on the survey results led to significant insights about everything not being equally important, but that some activities have more impact than others.

### Formal evaluation

The project has been evaluated together with five other System Dynamics cases in the main project (Elf et al., 2015). The main conclusions are discussed in the thesis.

### Academic presentation

Highlights of this case were presented at OR54 and are included in this thesis (Elf, Holmström, Malmqvist, Öhrn, & Koch, 2012).

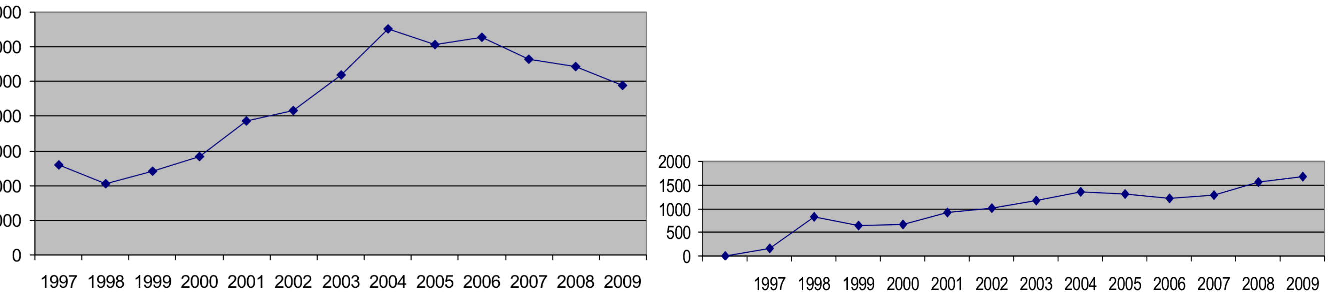
## Case 5 – Paediatrics (1)

### Project context

This was my second collaboration with a research project carried out at the institution of Architecture at Chalmers. Marie Elf was project leader and it was financed by Formas. The overall purpose of the project was to study the usability of System Dynamics to support pre-planning processes. My brief was to use System Dynamics group modelling to explore mainly qualitative, but also quantitative aspects of work processes to engage the group into considering development of work processes before specifying future needs of premises.

Here a child care clinic in a town with 25 000 inhabitants was studied. The clinic was housed at the local hospital, but organisationally was part of the major hospital in the district. The clinic in its turn had a small satellite unit in a small municipality. They considered their premises too small for their needs. A situation which would be exacerbated as the doctor at the satellite would be retiring and its patients be allocated to the main clinic.

The clinic moved into its present premises in 1996 and they are not up to date with present requirements for hygiene, disease control and efficient patient processes. Figure 17 shows how the number of patient visits to doctors and nurses respectively has developed over the years. In addition to this are 1500 annual visits to the satellite clinic. Visits to welfare officers, dieticians and psychologists have also increased. More doctors in training also attend the clinic. All this leads to a shortage of work space and examination rooms. Additionally, birth rates in the take-up area have increased, which will lead to even more visits.




*To doctors* *To nurses*

*Figure 17: Visits to the main clinic*

### Project outline

As the purpose of the project was to System Dynamics use group modelling in the pre-planning phase and open up for discussions about work processes, a small number of meetings were planned were the conversations under way were to be more important than any final models. The academic project group contained a nurse/architecture researcher, an architecture researcher and me as modeller. Our general plan was as follows. The first meeting would set the project context, express the participants' objectives and introduce System Dynamics concepts. As the clinic was about to begin writing a program for future premises it was decided to begin the process by doing an inventory of its needs. The second meeting was to delve deeper into qualitative analysis of work processes and focus on improvements. The third meeting would introduce tentative System Dynamics models based on prior discussions and outline how to improve the model. The fourth meeting would present a deeper iteration of the model with a flight simulator interface and ask the model questions and see where priorities for future work should lie.

As discussions were intense and time-consuming a fifth meeting was needed. The project took place over a period of 8 months with five three-hour meetings with the local group and intermediary meetings in the academic group. The local group consisted of the manager of the clinic, doctors, nurses and other staff.

### Meeting 1

All participants introduced themselves and the overall research project was presented. We began by splitting them up into specialist sub-groups and had them write post-it notes expressing their needs as objectives, e.g. "The clinic needs rooms to separate infected children in the waiting room and examination rooms".

Secretaries

Objective: 0-vision, i.e. no patient records waiting to be registered. To achieve this objective, we need:

- Personal work rooms with daylight for efficiency and reduced noise
- Archive of patient records and storage of office materials

Play therapy

Objective: Sufficient space to carry out pedagogical activities. To achieve this objective, we need:

- Large playroom with space for different needs (hospital play, kitchen play, carpentry, mischief with pillows, bikes and wet area. (Equipment: heated floor for the toddlers)
- Teenage room or –corner with cosy corner, TV, DVD etc, also in the inpatient area
- Office for the play therapist
- Large storage room
- Outdoor space
- Interview/meeting rooms close to play therapy for meetings with parents
- Information room for preparations
- Parents' corner

Doctor and nurse

Objective: Good child care, reduce spread of infection by having enough rooms and two waiting rooms. To achieve this objective, we need:

- Sufficient examination rooms to maintain high patient flow
- Infection-free waiting areas for patients and families
- Possibility for undisturbed patient work, administrative work and supervision
- Access to family rooms for interviews/meetings
- Undisturbed phone advice
- Closeness to surgery, radiology and emergency services
- Area for staff meetings, training with seating for all, undisturbed at meal times
- Possibility for secretaries to work undisturbed
- Avoid queues for weighing/measurement as well as testing/inhalation room
- Ability to separate infectious and non-infectious children
- Maintain privacy throughout the care chain

Doctor and nurse (day care)

- More and larger interview rooms
- Larger staff room for meetings, lunch etc.
- Rest room
- More beds and/or rooms for day care
- Waiting room with more seats and ability to separate infectious and non-infectious children
- Allergy nurse office with two desks
- More doctor's offices and examination rooms
- Supervised area for older children to be in during treatment
- Separate room with good ventilation for spirometry and SPT
- Separate room for allergy and oxygen tube
- Daylight in examination rooms
- Cupboard for informational materials

Two child nurses

- Patient room

### Meeting 2

We began the meeting by putting up the post-it notes from the first meeting. They had been slightly edited to conform to steering documents. The objectives were discussed at length and rephrased for clarity e.g. “Improve diagnostic precision” was changed to “High diagnostic precision” and “Reduce incorrect assessments” to “Correct assessments”. The group added an objective for a patient record system to be integrated into the care chain for higher patient safety.

We presented graphs of patient numbers and their future development. The numbers had been taken from a document regarding facility needs. Many felt that actual increases in patient visits were not accurately reflected in the data as visit registration was not fully reliable. Many visits to nurses had not been registered.

We then divided the participants into three groups to discuss activities in relation to the objectives:

- What do we need to do more of?
- What do we need to do less of?
- What should we start doing?
- What should we stop doing?

Do more of

- Nurse visits
- Review staff utilisation
- Planning further into the future
- Undisturbed interviews/meetings
- Care for those who are afraid of treatment
- Groups (**)
- Relaxing
- Infection control (***)
- Privacy (**)
- Training

Do less of

- Search for information and training materials
- More parental responsibility for booked times (***)
- No-show (*)
- Search for available rooms, equipment
- Disturb each other (**)

Start doing

- Outdoor activities
- Teenager activities (*)
- Videoconferences
- More diagnostic groups
- Train new/young staff
- Sort in patient records
- More time with patients, less “surround” time

Stop doing

- Others work
- Neuropsychological examinations (*)
- Being IT technicians
- Queueing (**)
- Standing at staff meetings

After putting up the post-it notes each participant got a small number of coloured adhesive dots to put on the notes reflecting their personal priorities. The asterisks in the list above reflect the combined priorities.

We then began assembling a causal loop diagram (Figure 18) where we placed “infection control” as one of the top priorities in the centre. (The notes are not translated; the photo is included to show how we worked.)

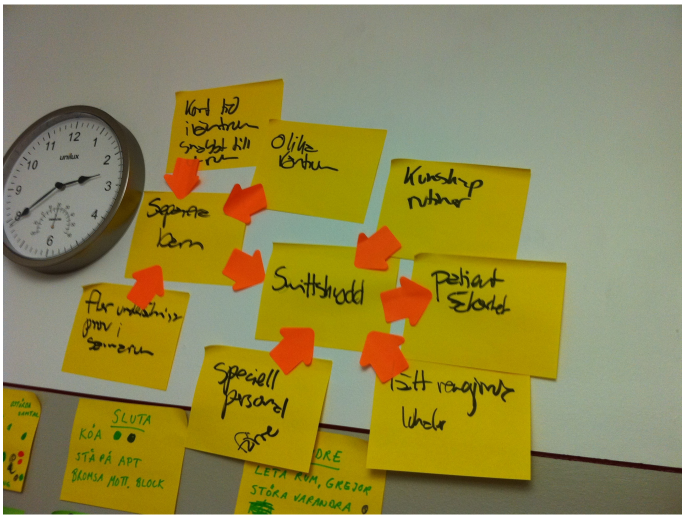


*Figure 18: Initial causal loop diagram*

### Between meeting 2 and 3

I converted the initial causal loop diagram from post-it notes to a formal diagram to show such a diagram and explain the notation (Figure 19).

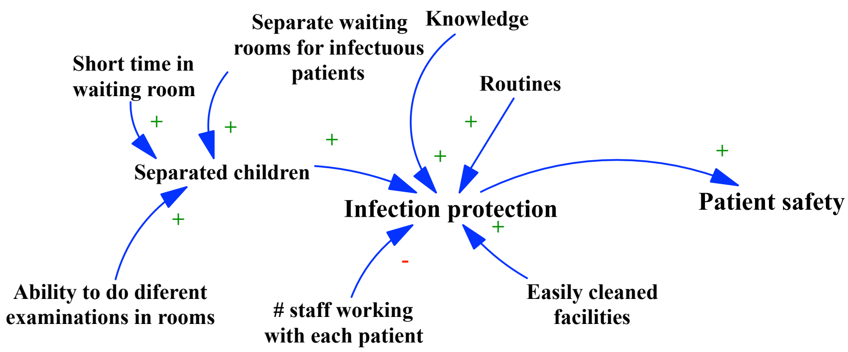



*Figure 19: Initial formal causal loop diagram*

### Meeting 3

We began by discussing patient volumes in relation to capacity and noted that it is not easy to describe the increase in patient volume in a useful way. When the clinic was built, the unit had 2000 visits to doctors and 900 visits to nurses, but now totals 7000 visits. Additional patient categories will be added, such as rheumatic children, anesthetized patients waking up after simple surgeries etc. Visits are not recorded in a statistically useful way.

We revisited the discussion of the objectives. The participants asked about the purpose. Given the historical record many of the staff have grown resigned, as the space shortage has worsened over the years and they have not felt that they have been listened to, leading to a negative psychosocial work environment.

We then continued building the causal loop diagram using the remaining post-it notes (Figure 20). (The notes are not translated; the photo is included to show how we worked.)

*Figure 20: Expanded causal loop diagram*

### Between meeting 3 and 4

I converted the completed causal loop diagram from post-it notes to a formal diagram and altered the notation by adding colours to the [+] and [-] arrows to make it easier to understand for non-specialists (Figure 21).

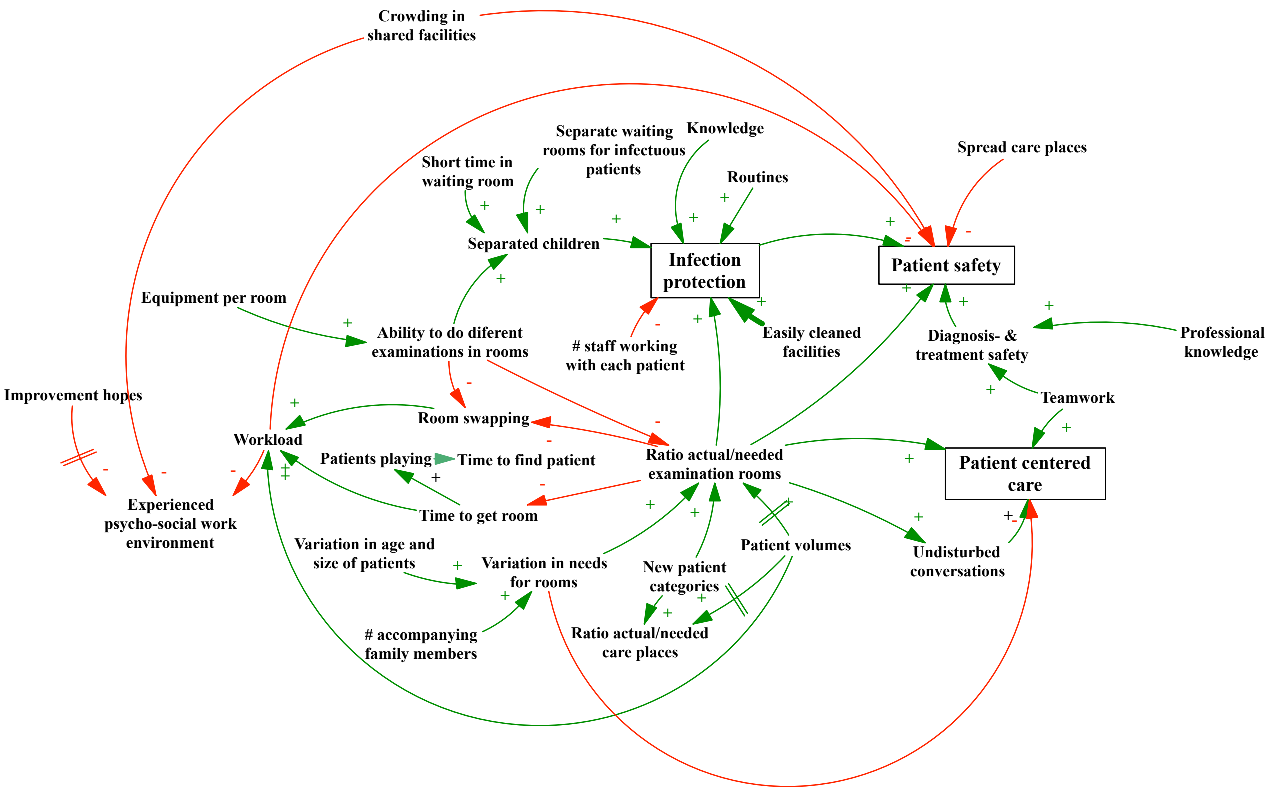



*Figure 21: Formal expanded causal loop diagram*

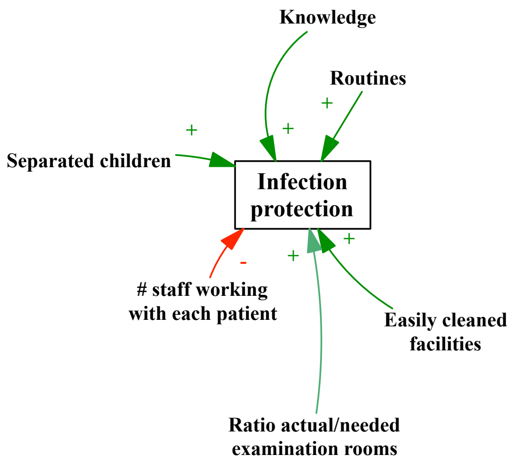
### Meeting 4

We began the meeting by revisiting the purpose of the research project. It was becoming clearer and clearer to me that on one hand the group was very engaged in the work that we were doing, but on the other hand their experience over the years of having their needs ignored meant that their motivation occasionally sagged.

I had prepared a set of PowerPoint slides that built up the causal loop diagram step-by-step. We worked through the diagram and kept asking if it was correct. We made corrections as we worked through the presentation, adjusting names of variables as well as relations.

### Between meeting 4 and 5

I built a survey with the purpose of exploring the strengths and weighting of the relations as well as initial key state variables. Figure 22 shows an example of a node and its question.




We have determined that the following variables influence infection protection.
Estimate how much each variable influences patient safety - You can distribute 10 points (e.g. 3, 1, 2, 1, 1, 2. Add up and make sure that the sum is 10.

| | 1 point | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| # staff working with each patient | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Ratio actual/needed examination rooms | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Knowledge | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Easily cleaned facilities | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Routines | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Separated children | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

*Figure 22: Survey question example*

Based on the results I redrew the diagram so that the thickness of the lines reflected their weight in the respective relations (Figure 23).

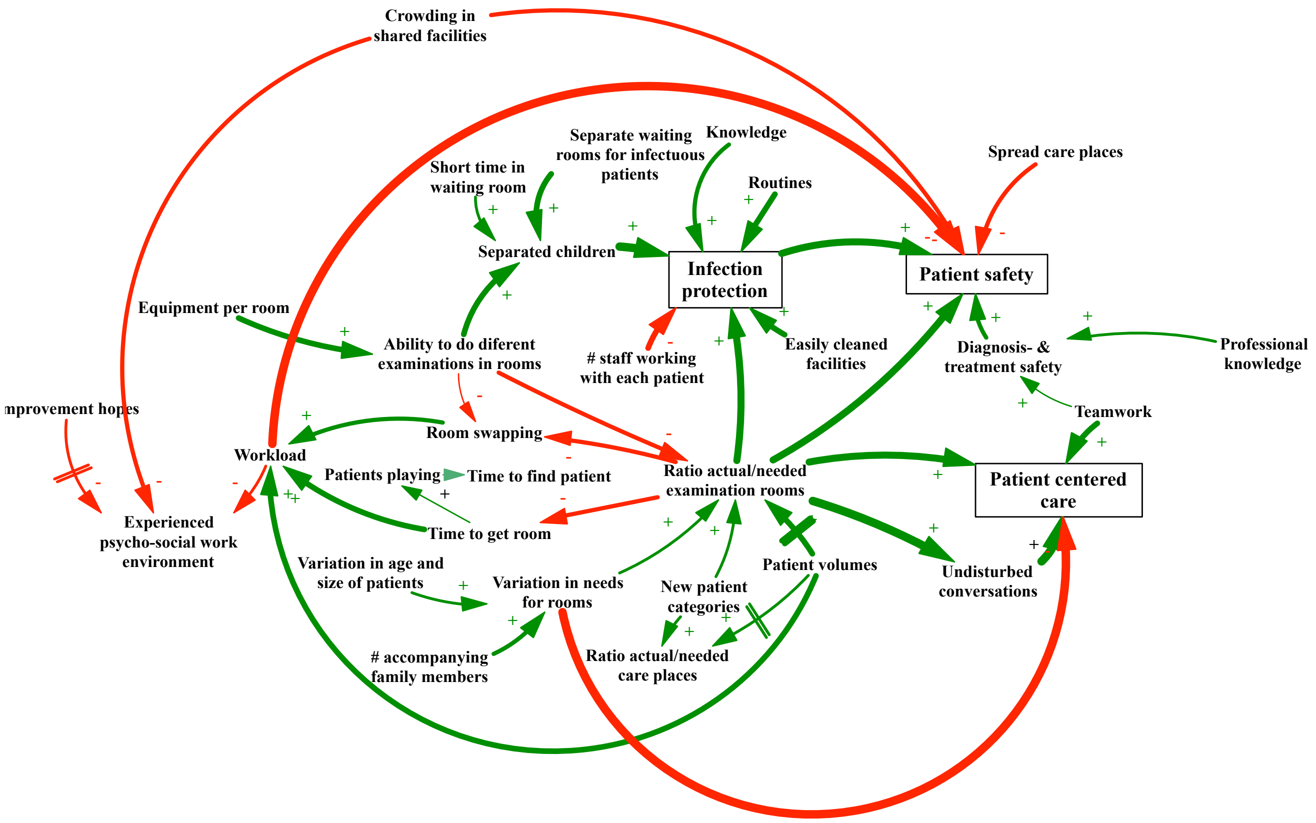



*Figure 23: Weighted causal loop diagram*

I then built a stock and flow model based on the causal loop diagram to experiment with different activities and see and discuss their effects on the main objectives (Figure 24). The initial state of the model was derived from the survey. I made assumptions about the time to affect changes to any variable. I also built a user interface where key parameters could be changed and the results of the simulation be shown (Figure 25).

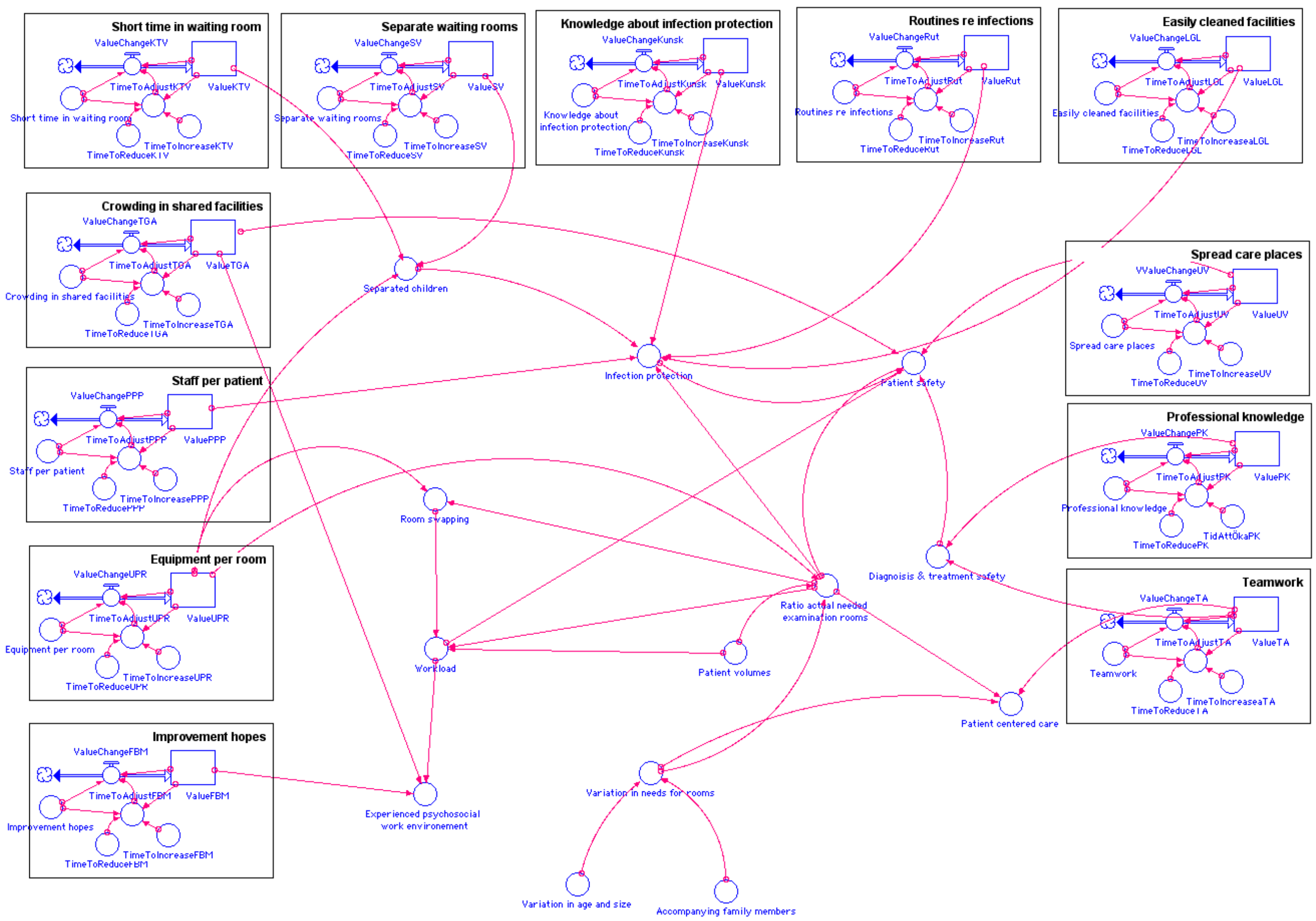


*Figure 24: Underlying model*

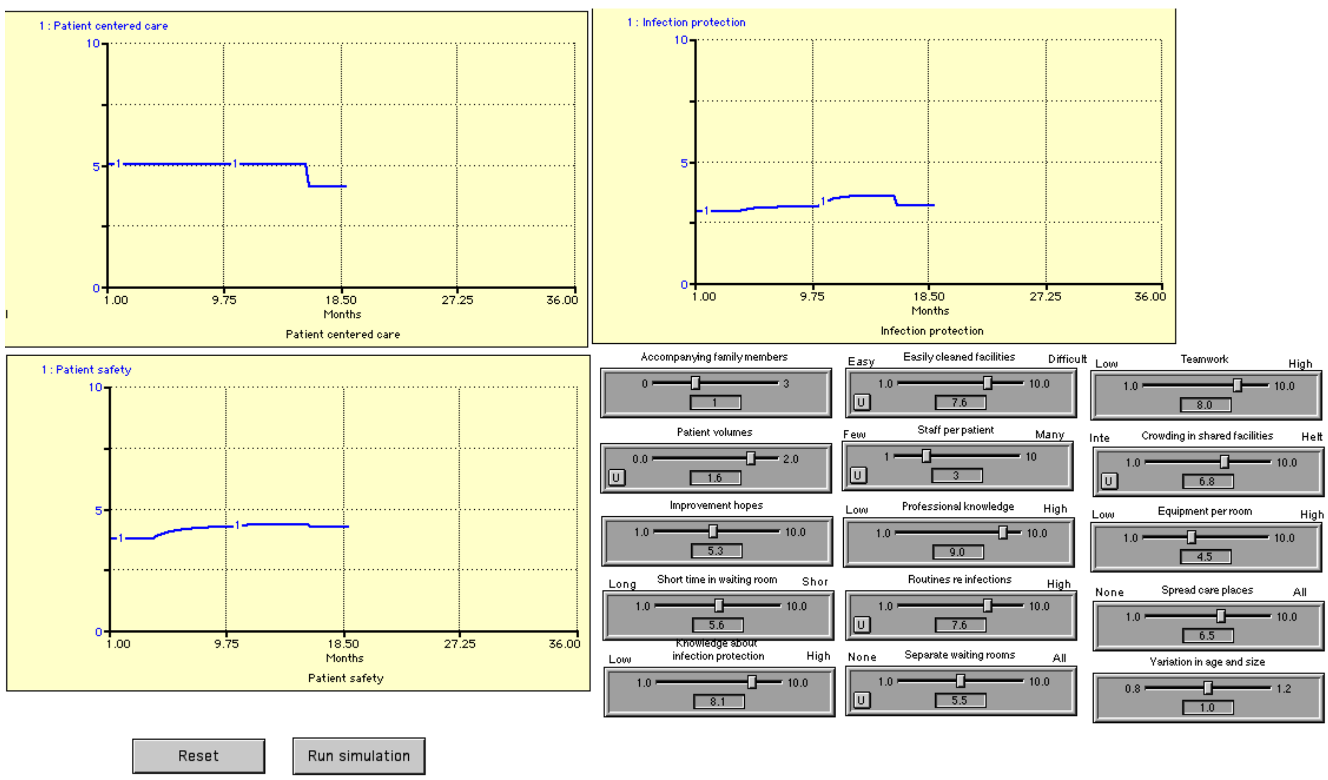


*Figure 25: User interface*

### Meeting 5

I introduced the interface of the stock and flow model, the initial state was based on the survey results and the concept of time to achieve change. I then ran some sample assumptions and changes after which we opened up for discussion and spent considerable time running the model according to the suggestions of the group.

The breakthrough understanding of the model and its explanatory value came when the inflow was doubled, patients were not separated and had to wait a long time – peak crowding. The group said that this was exactly how it had been last winter when HRSV peaked. At that point, the group felt that the model was validated and spent quite some time experimenting with it.

## Case 6 – Accident and Emergency (1)

### Project context

This was my third collaboration with a research project carried out at the institution of Architecture at Chalmers. Marie Elf was project leader and it was financed by Formas. The overall purpose of the project was to study the usability of System Dynamics to support pre-planning processes. My brief was to use System Dynamics group modelling to explore mainly qualitative, but also quantitative aspects of work processes to engage the group into considering development of work processes before specifying future needs of premises.

Here an Accident and Emergency department is studied. They have about 50 000 visitors per year and consider their premises too constrained to ensure proper patient safety.

### Project outline

As the purpose of the project was to use System Dynamics group modelling in a pre-planning phase and open up for discussions about work processes, a small number of meetings were planned were the conversations under way were to be more important than any final models.

The same general plan was to be followed as in earlier projects. The first meeting would set the project context, express the participants' objectives and introduce System Dynamics concepts. The second meeting was to delve deeper into qualitative analysis of work processes and focus on improvements. The third meeting would introduce tentative System Dynamics models based on prior discussions and outline how to improve the model. The fourth meeting would present a deeper iteration of the model with a flight simulator interface and ask the model questions and see where priorities for future work should lie.

The project took place over a period of 5 months including the summer vacation period.

### Project group

There were three participants from Chalmers: a nurse/architecture researcher, an architecture researcher and me as modeller. Nine persons from the hospital took part: a facilities controller, the A&E manager and key staff representatives.

### Meeting 1

After general introductions and presentation of the overall research project the participants were split into three groups and used post-it notes to identify problem areas etc:

Problems

- Primary care closed on evenings and weekends
- Insufficient space for all patients
- Too few doctors
- Too much movement within the premises
- High noise levels
- Time to triage, time to doctor and time to ready are not optimal

Effects

- Patient safety and integrity impaired
- Work environment impaired
- More patients, longer waiting times
- Tired, disappointed patients
- Tired staff
- Higher competence needed
- Dependent on other units

What can be done

- More doctors
- Primary care unit at the hospital with longer opening hours
- New premises.

I briefly showed three models to introduce different aspects of System Dynamics modelling

- Obese children as an example of pure quantitative modelling and optimisation of resources
- Stroke unit as a complicated quantitative model with multiple interfering pathways
- Obstetrics as an example of the effect of quantitative variability on job satisfaction

Personal reflections.

Somewhat concerned about the large number of people in the group. According to my experience from an earlier group modelling project, it is difficult to have good discussions in large groups. Hoping that we would be able to compensate by breaking up into smaller groups.

Initial impression from the problem identification was that this could develop into a model with an interesting mix of qualitative and quantitative. High variation in patient numbers with effects on throughput times and possible effects on patient safety and job satisfaction.

### Prior to meeting 2

During meeting 1, I asked for basic quantitative data for the unit and received score cards and annual reports. I decided to build an initial minimal model (Figure 26) both to use as an introduction to System Dynamics and to explore the effects of variable patient inflows on throughput and waiting times. I assumed that there are adequate resources in place to treat all patients over time. My experience is that even minor changes in inflows can lead to major fluxes. The model below uses the number of annual visitors as a base for constant treatment resources and applies a randomization on the same number for patient inflows. A timer is set on the inflow and time is measured until the patient leaves the system. The simulation was run for a week and yielded the results I expected. The variation creates queues and waiting times. In reality this should be handled by adding staff resources. Usually doctors are stationed at clinics and come to A&E in bursts. Increased variability is coped with by balancing the needs of patients in the clinic and in A&E.

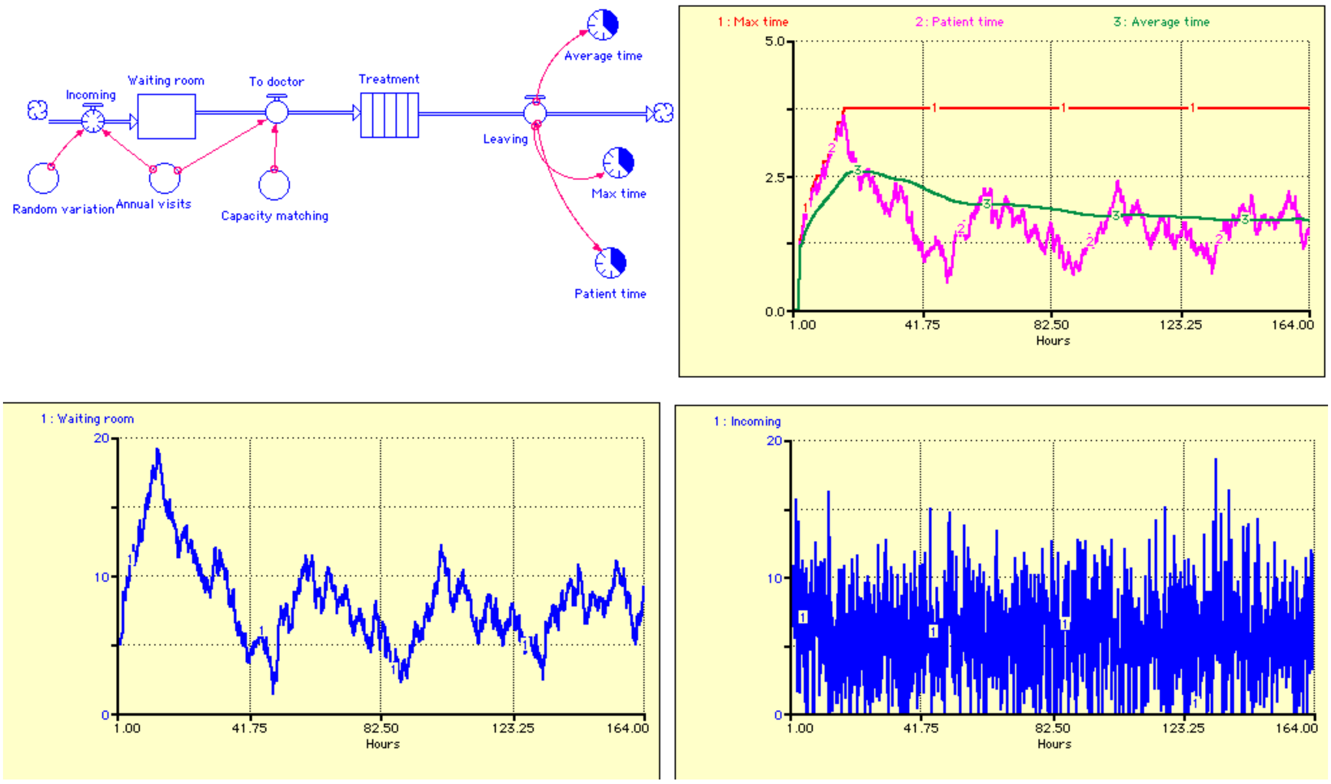



*Figure 26: An example of a simulation model*

### Meeting 2

We began the meeting with a recap of the first meeting and me running my introductory model. This led to a discussion about how in reality capacity is variable by bringing in additional specialist time from the hospital. It was also discussed how triage ensures that truly acute patients are handled as soon as possible.

We recapitulated the objectives stated during the first meeting, split the participants into groups and asked them to list on post-it notes, given the objectives:

- What they need to do more of
- What they need to do less of
- What they should stop doing
- What they should start doing.

Based on this, we interactively created an initial causal loop diagram (Figure 27). (The notes are not translated; the photo is included to show how we worked.)


*Figure 27: Initial causal loop diagram*

It was decided that I would make a separate visit to the clinic for fact-finding and clarifying the loops. A usual complaint in A&E departments is that many patients could or should go to primary care instead. Here I asked the group roughly what proportion of patients should be seen by an A&E generalist rather than doctors from sub-specialties. The group suggested around 80%.

### Fact-finding meeting

At the fact-finding meeting, I gathered data on patient numbers by triage, department etc. as well as patient flows, staffing levels etc. I summed up the patient flows in Figure 28, where the arrow width is proportional to patient numbers.

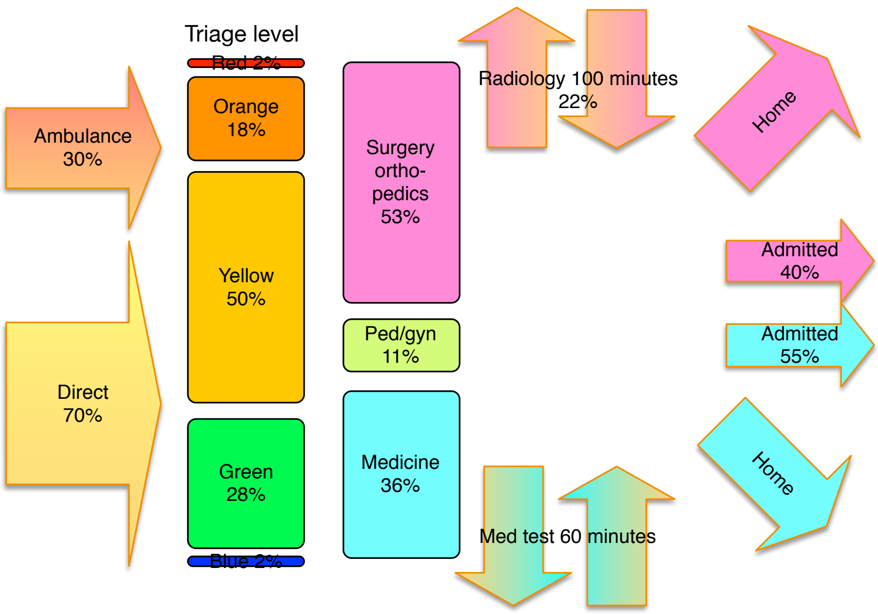



*Figure 28: Basic patient flows*

I also asked for an estimate of how many relatives etc. accompanied the patients. Estimates were about 1 person per 2 patients. This is an interesting factor to consider when planning space requirements. The number of patients in the system usually peaks at around 50, which means that there are another 25 in the rooms.

Given the opinion that too many patients come to A&E it is interesting to note that 40% of patients seen by a surgical specialist are admitted to the hospital and 55 % of those seen by a medical specialist. This is in line with what I have noted in several hospital studies, that around 50% of patients referred to the hospital are eventually diagnosed as expected.

### Prior to meeting 3

I drew a formal causal loop diagram based on the work during meeting 2 (Figure 29). I used the +/- notation and made it more explicit by using red and green arrows and adding an explanatory note.

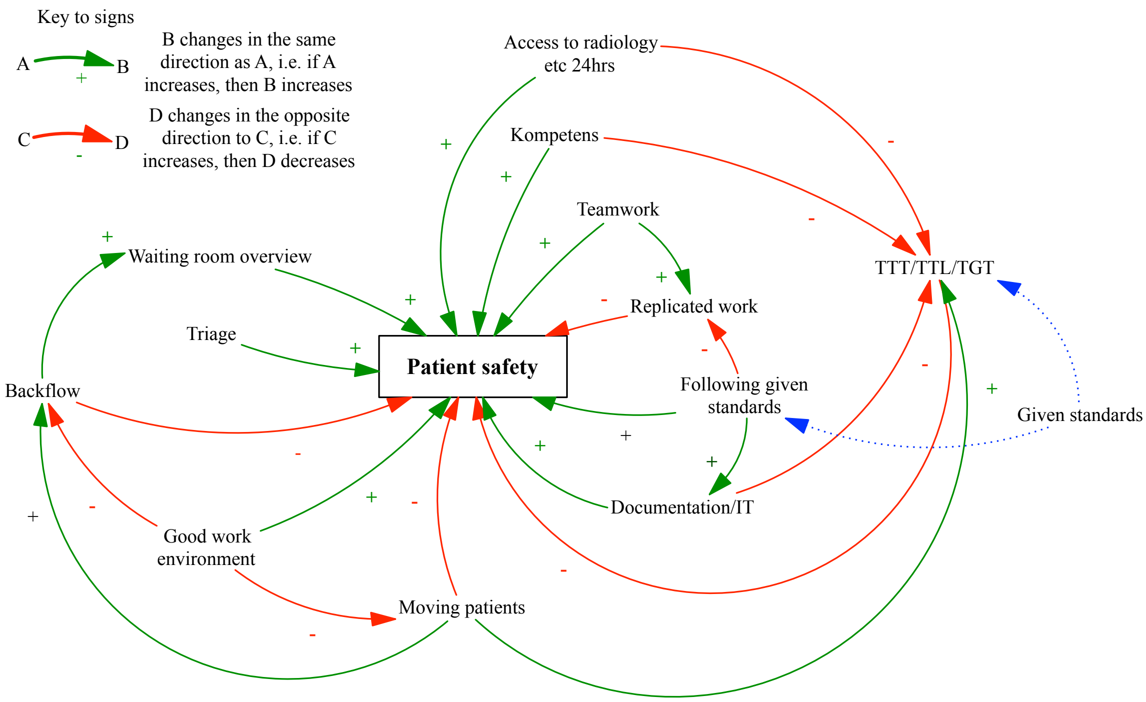



*Figure 29: Formal initial causal loop diagram*

Based on the discussion of the introductory model presented at the first meeting and the fact-finding meeting I extended the model (Figure 30) to describe three patient groups.

- Red triage group, i.e. those who are taken care of immediately and given top priority over all other patients. This category is rapidly taken into surgery or admitted to the hospital for immediate treatment.
- Patients that need lab testing or radiology, which means that they are subjected to additional queues, first waiting for testing, then waiting for results and seeing a doctor again.
- All other patients.

Studying the effects of this model highlights that the additional queues for patients subject to testing/radiology can add substantial time. As radiology closes between midnight and morning for all but critical patients this adds time as well. I also built a user interface (Figure 31).

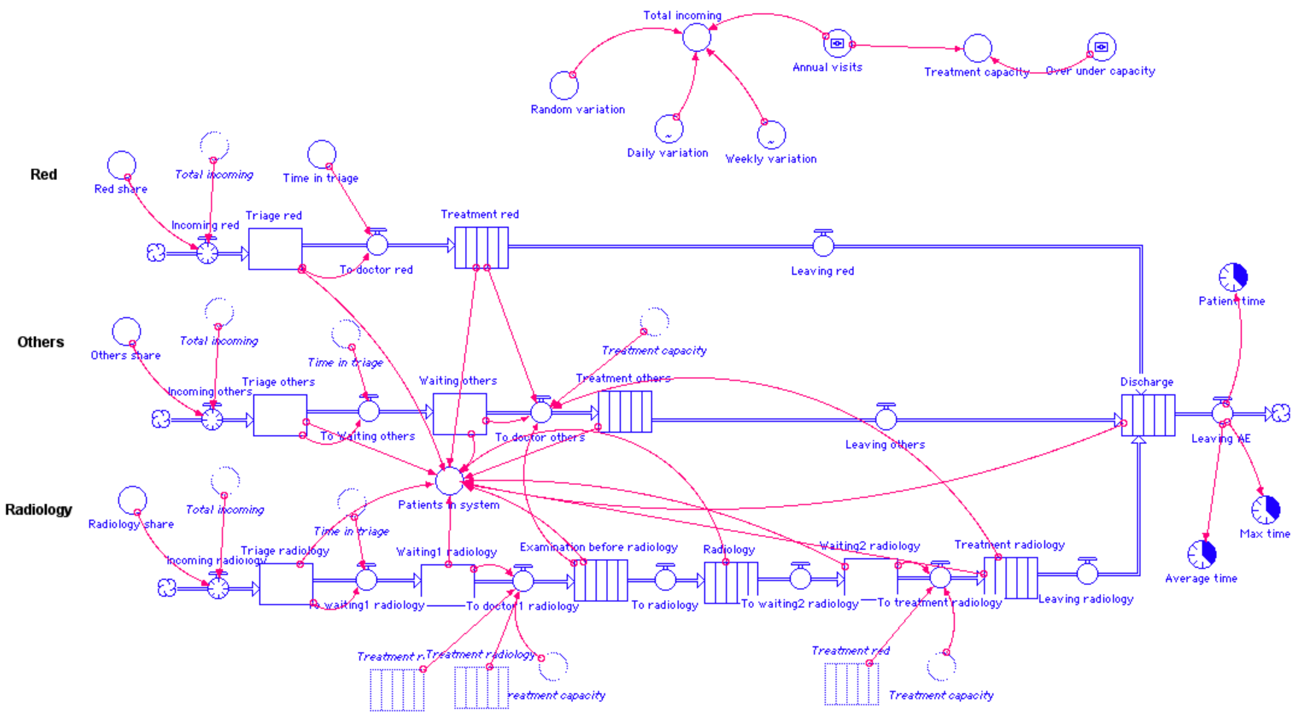



*Figure 30: Quantitative simulation model*

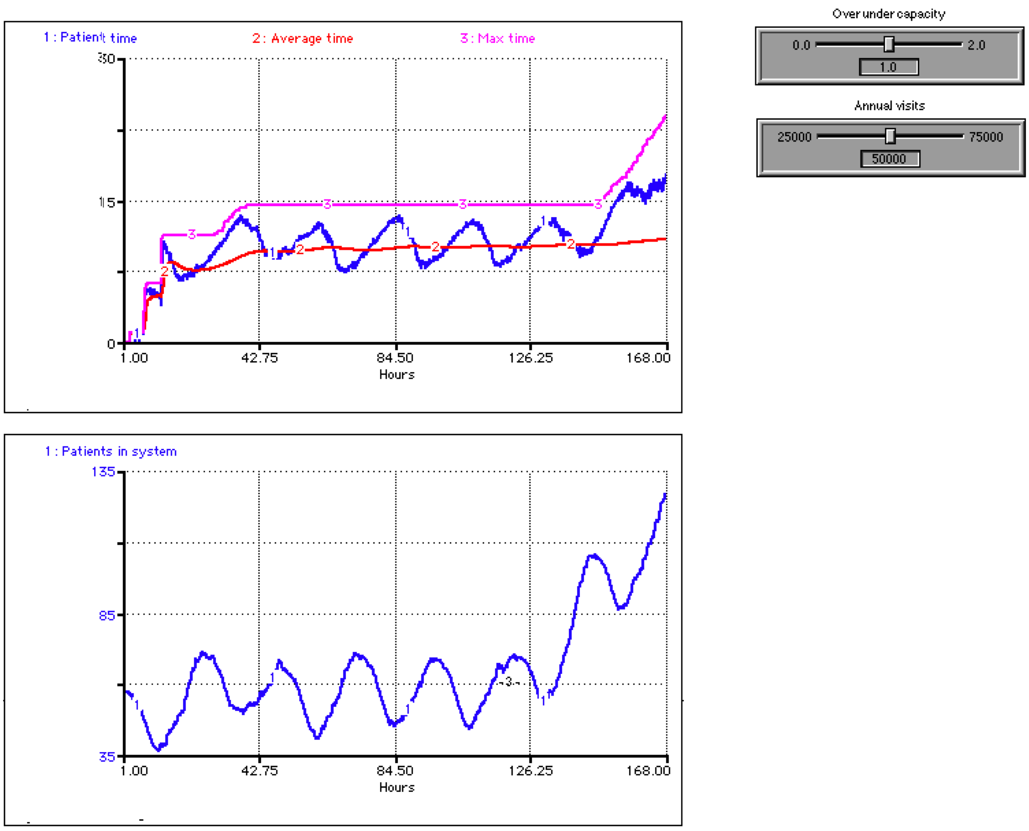



*Figure 31: Initial simulation interface*

## Meeting 3

We started the meeting by running through the extended stock and flow model. A variety of questions were raised:

- What if we can reduce waiting time for radiology and results to half?
- What if we can work with less than acute patients in different ways?
- If we can speed up throughput, the size of the waiting room could be halved.

We worked through minor changes step by step and noted that each one did not have a very significant effect, but together improvement could be significant. Varying patient inflows had the greatest effects

Their major "aha" moment came when they doubled the inflow, which led to long times in the waiting room and maximum crowding so that all areas were used for waiting. The reaction was “just like when everybody seemed to have HRSV”.

From my point of view that reaction is an important part of validating the principles of a model. Participants need to recognize the effect of the model. In healthcare, this usually means having very high variation in the inflow of patients. “Average” never happens in their world.

Several ideas were put forward for improving the model.

The participants were divided into four groups to discuss the causal loop diagram (Figure 32) and consider if anything was missing. The group reconvened and we walked through the causal loop diagram in its entirety and made some revisions.

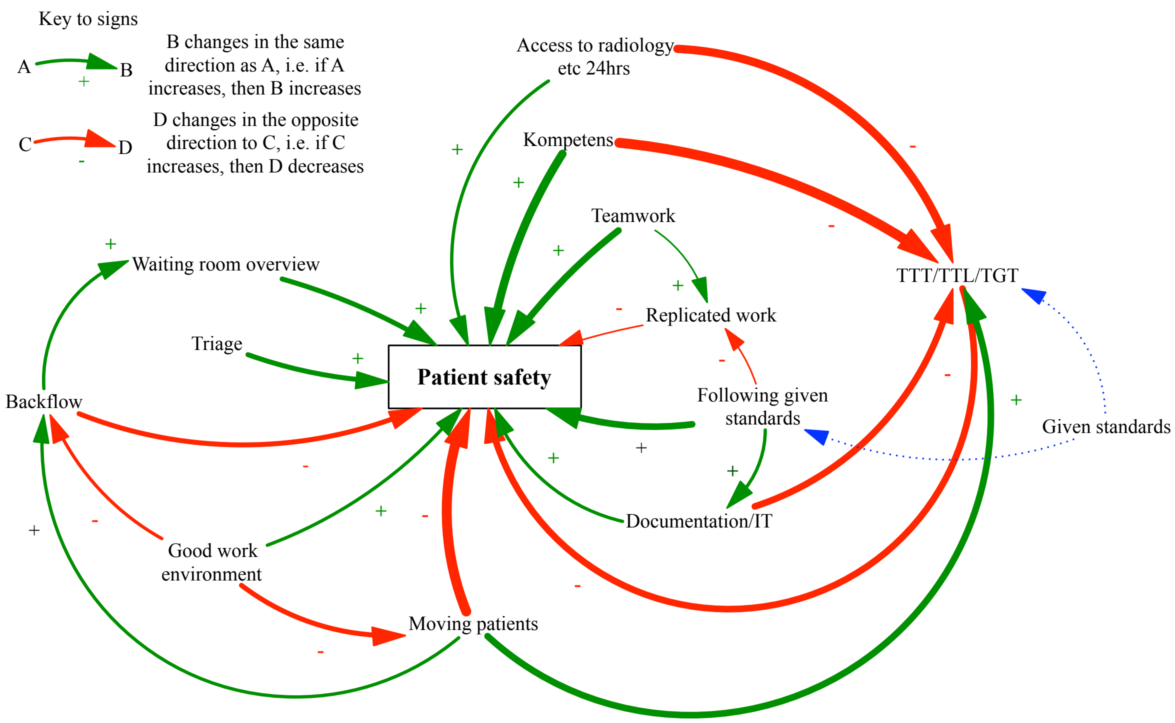



*Figure 32: Formal causal loop diagram*

We agreed that I should

- Combine both qualitative and quantitative aspects in the next iteration of the model
- Create a questionnaire to put numbers on the strengths of the relations and influences in the causal loop diagram.

## Causal Loop Diagram questionnaire

I built a questionnaire using Survey Monkey with two sets of questions.

I deconstructed the diagram into subsets showing all inputs to any variable, as in Figure 33.

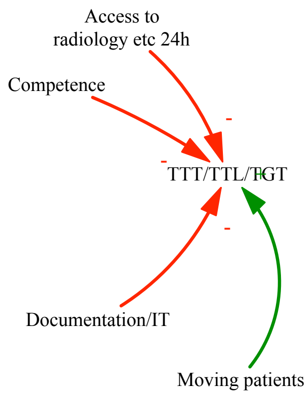



*Figure 33: Example of a node*

Questions were stated as in Figure 34

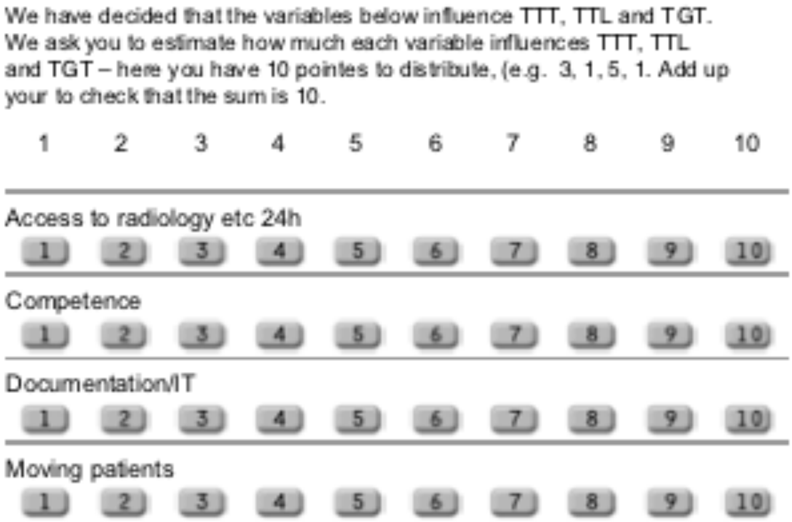



*Figure 34: Survey question example*

In the earlier cases, there had been some misunderstandings about how to distribute points. So, I included a pie chart as an example (Figure 35)

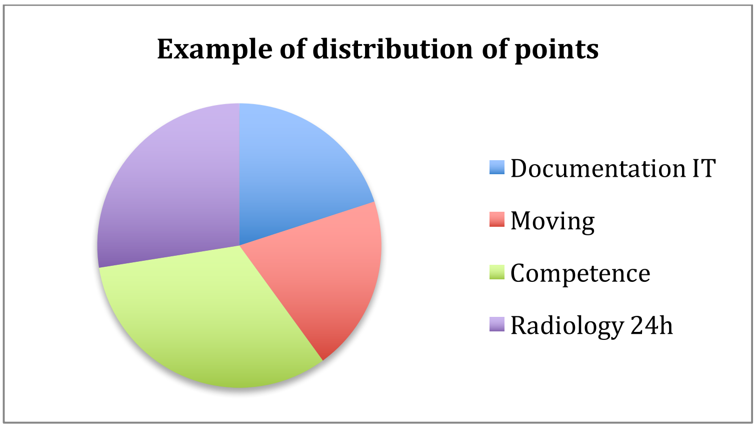



*Figure 35: Example of distributing points*

The purpose of second category of questions was to estimate an initial state for the causal loop diagram, an example is shown in Figure 36 Initial state example

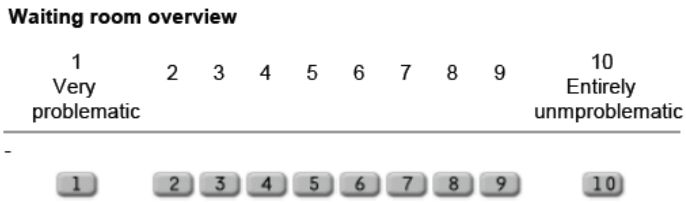
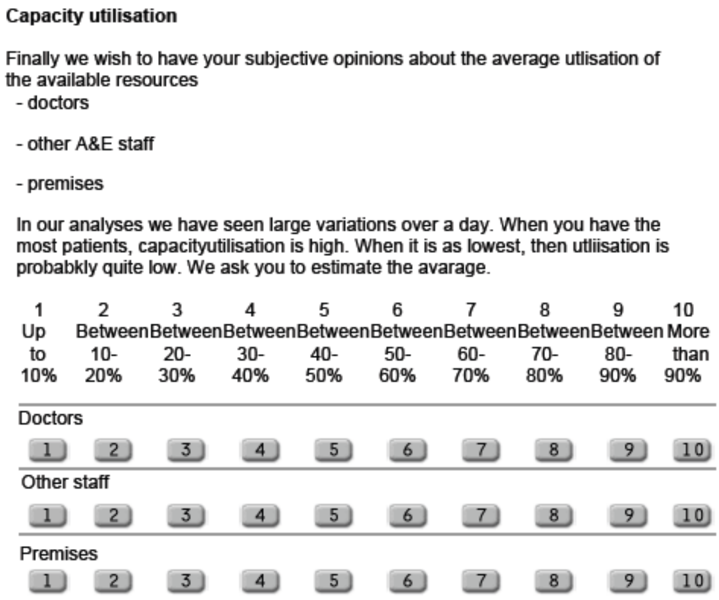



*Figure 36 Initial state example*

The initial model assumes a balance between patient flows and capacity. The purpose of the final questions was to assess capacity utilization (Figure 37).


**Capacity utilisation**

Finally we wish to have your subjective opinions about the average utlisation of the available resources
- doctors
- other A&E staff
- premises

In our analyses we have seen large variations over a day. When you have the most patients, capacityutilisation is high. When it is as lowest, then utliisation is probabkly quite low. We ask you to estimate the avarage.

| | 1 Up to 10% | 2 Between 10-20% | 3 Between 20-30% | 4 Between 30-40% | 5 Between 40-50% | 6 Between 50-60% | 7 Between 60-70% | 8 Between 70-80% | 9 Between 80-90% | 10 More than 90% |
|---|---|---|---|---|---|---|---|---|---|---|
| Doctors | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Other staff | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Premises | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

*Figure 37: Assessing balance between capacity and demand*

Based on the results, I modified the Causal Loop Diagram so that the thickness of the lines reflected their respective influence (Figure 38). When doing this, I began at the centre of the diagram, and recalculated when branching out so that the effects become weaker further out.

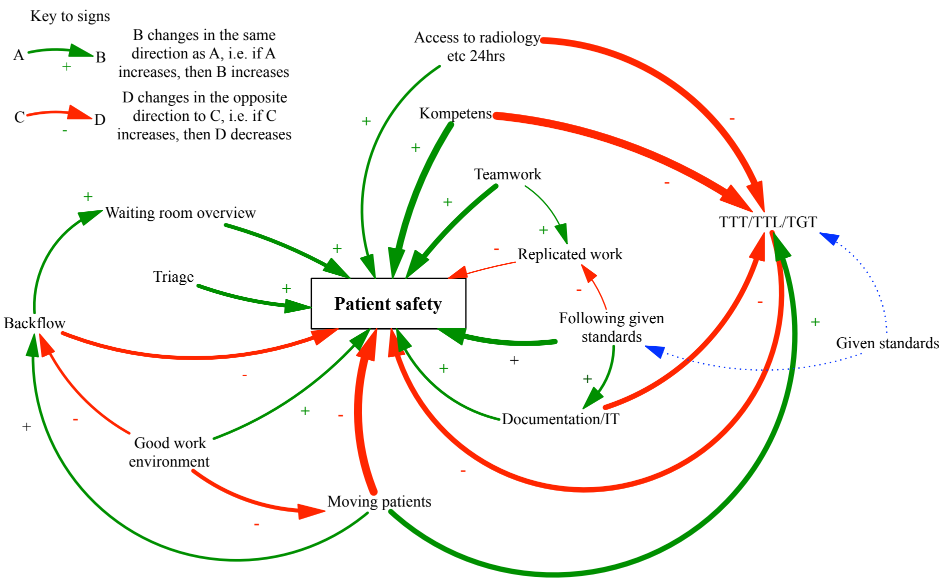



*Figure 38: Weighted causal loop diagram*

The average results of the present state of each of the variables based on the questionnaire are shown in Figure 39.

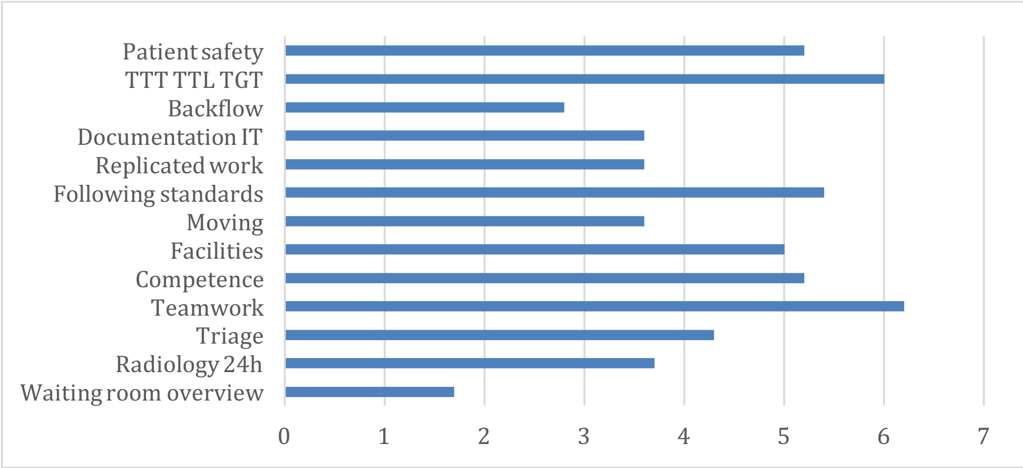



*Figure 39: Present state of key variables*

I was somewhat surprised by the results as many variables are scored relatively low. Patient safety only received an average score. The overview of waiting patients received the lowest score.

## Before meeting 5

Based on the causal loop diagram I built a stock and flow model reflecting the qualitative aspects (Figure 40).

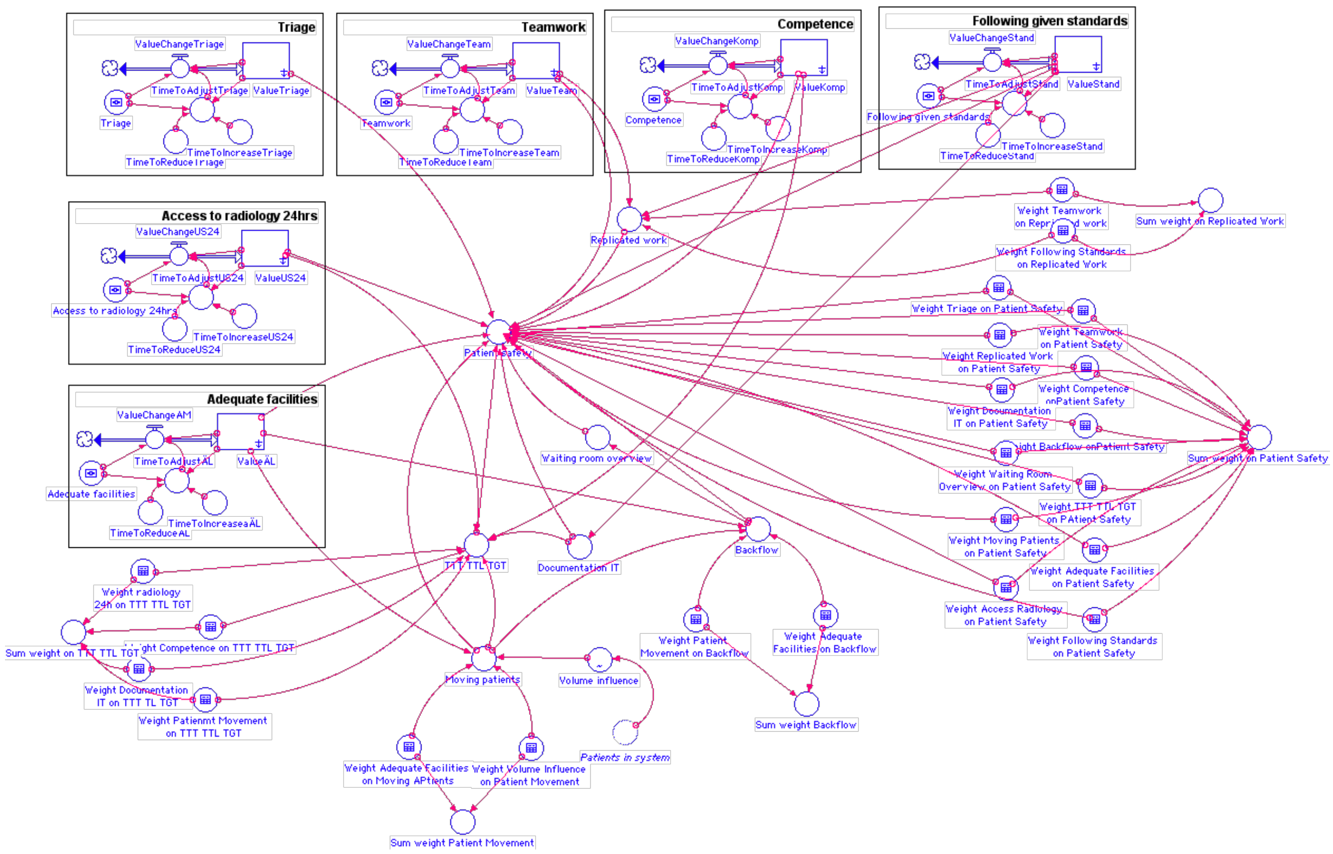



*Figure 40: Simulation model of qualitative aspects*

Each variable that can be changed is represented by a module above. Each model has a stock showing the present state of the variable and is influenced by a trend function with a specified time to improve respectively worsen, where I made initial assumptions like:

- How long does it take to build competence e.g. by training and recruitment?
- How fast can competence erode e.g. by key staff leaving.

I also built a flight simulator interface (Figure 41) for this part of the model to allow for changing key variable states. My plan was to use the pause function of the simulation, run it for a short while at initial states, then ask the group what or which variables they would like to change, consider how much effort can be utilized over a short period, continue the simulation etc. My purpose with this type of simulation is to help the group understand the effects of interactions and identify which interactions seem to have the best effects towards the stated goals.

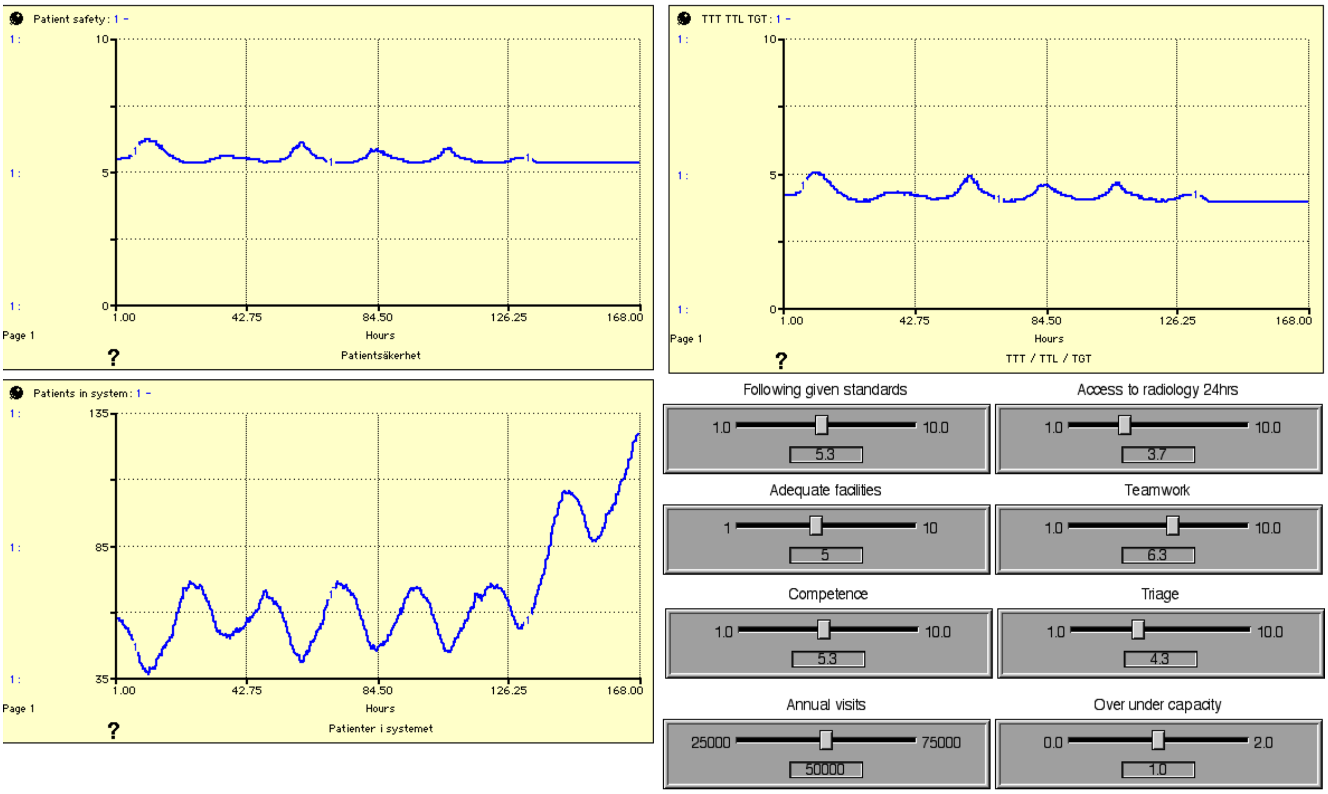



*Figure 41: User interface*

## Meeting 5

As I walked through the weighted causal model, their response was that I seemed realistic. We then ran several runs of the stock and flow model, first testing my initial ideas to get an understanding of the model mechanisms and then a series of runs based on suggestions by the group. Overall, they considered the model realistic and that it reflected reality.

- Increases in patient volumes led to increases in waiting and throughput times and a reduction in patient safety
- An increase in competence, with everything else constant, led to a slow increase in patient safety
- Allowing for medical testing and radiology around the clock led to a substantial increase in patient safety, maybe more than realistic
- Improving triage from 4 to 7.5 led to a small increase in patient safety
- A slight overcapacity allowed for coping with short peaks in patient inflow.

The group had a lengthy discussion about how they define triage, work environment and teamwork.

My impression was that they wanted a model that could answer all their questions. During our discussions, they understood that such a model required significantly more model building time and that the model as it was could allow them to answer almost all their questions.

We decided that I do some fine-tuning of the qualitative part of the model and turn it into a runtime version that they could continue working with themselves as there were no resources left for additional modelling or support from my side.

As I saw it, a main issue was that patient flows peak every afternoon/evening while they have fairly constant staffing and that they needed to address how to handle the known parts of inflow variability. They also needed to consider how to faster move patients into regular wards when they are under pressure.

My general impression was that the unit and the group were short of space considering the patient flows, had already done a lot of studies and had significant data, and were engaged in discussions and simulations. Some years later the department received entirely new and larger facilities.

## The runtime model

*The runtime model is prepared as seven pages using buttons to navigate (Figure 42). The first page was the introductory starting page. The actual simulations occur on the second page. The weights for the causal diagram could be changed on page 5. The causal loop diagram is shown on page 3, and the stock and flow parts are shown on the remaining pages.*

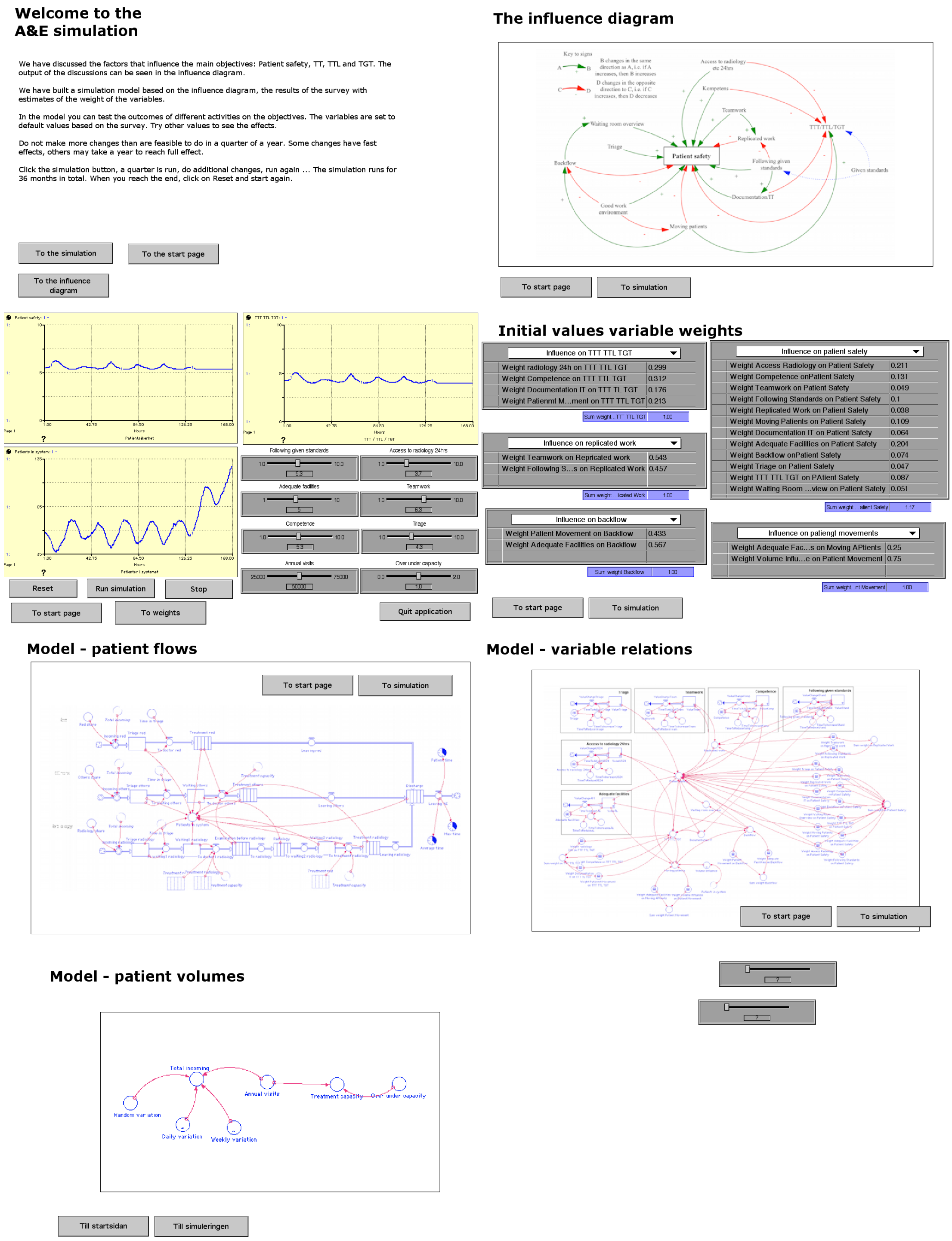



*Figure 42: The runtime model*

## Case 8 – Paediatrics (2)

### Project context

This work was done at what at the time of the study was a hospital to be built in a geographical area with low income and a majority of inhabitants with non-Swedish roots. Key out-patient services were provided in temporary facilities. The project leader was familiar with System Dynamics and had in previous roles introduced the concepts into Swedish healthcare.

As the hospital was in "start-up mode" potential patient volumes were unknown and efficient resource allocation important. Any new patient entering the system would have a longer initial meeting followed by a series of meetings. How to plan and dimension such interventions for efficiency?

My colleague and I were invited to a management team meeting to discuss areas of interest as well as a meeting with the head of the commissioning unit that financed the hospital. We were also asked to provide an initial sketch of possible pathways.

The project spanned five months from the early exploratory meting to final "delivery". The actual modelling took place over a period of 4 weeks. The actual modelling work took about 3 days.

### Initial sketch of possible pathways to introduce System Dynamics

In our initial draft, we wanted to open up several pathways so as to both introduce System Dynamics and create involvement and learning:

> **Operations-oriented simulation at the local hospital**
>
> At our meeting, we discussed the development of simple simulations close to actual operations, such as the dynamic effects of taking patients into a care program with 12 visits over as many weeks.
>
> Two possible major pathways
>
> **Process led by consultants**
>
> Work begins with a short initial meeting to frame the underlying issue and discuss how simulations could contribute. The consultant then drafts a simple model to be discussed at a meeting where models are developed interactively. Total time 1-2 days.
>
> Alternatively, model building can be done interactively in a small group.
>
> **Training in simulation**
>
> We suggest a hands-on training course with simple applications in the fields of the participants over three days, needing one day of planning and preparations. We often use the simulation application MyStrategy in early stages. The program is reasonably priced, ha a lower learning threshold than other applications and a more intuitive interface. We have an agreement with the provider and have access to their training materials.
>
> The training can be supplemented with brief support interventions.

### Early exploratory meeting

We held an early exploratory meeting with the hospital project leader and the person responsible for quality assurance, and three areas of interest were identified:

- Using System Dynamics to explore how to plan patient intake and flows in a rapidly expanding setting
- Use Lean methodology in the administrative section so as to avoid bottlenecks and allow for growth while maintaining efficiency
- Meeting the director of the commissioning unit about the possible use of System Dynamics in resource allocation, planning and growth for the rapidly expanding hospital.

### Second exploratory meeting

A second exploratory meeting was held with the paediatrics manager and the person responsible for quality assurance, during which many interesting issues/questions were raised:

- What is our flow of incoming referrals?
- Children on the road to obesity
  - Extensive investigation
  - Motivate those not motivated to do anything
  - Involve the whole family
  - Obesity leads to
    - Depression, self-harm etc.
    - Diabetes etc. at 35 years
    - Reduced quality of life over 20-25 years
- Can we design successful ways of working? What does that cost?
- We are still new and not well-known, so referrals will grow
- Too short visits may lead to a care trajectory that will be seen as wrong a few years later.
- Not just treat the children for the reason why they were referred
- A well-planned and prepared first meeting will make a second meeting unnecessary.
- Which staff categories do what at which stage of the care process?
- 30% of all visits generate follow-ups within one year

### Exploratory meeting with the commissioning unit

The project leader, quality manager and we met the director of the commissioning unit (DCU). One of the main concerns of the DCU is to optimise the system and they note that there is a lack of tools for this and that there are many special interests making it difficult to consider the whole view. He noted that access creates demand, that false positives drive cost and that there are significant differences in diagnostic capability between units. On the whole, the DCU showed an interest in the suggested approaches.

### Decision meeting with the hospital management team

The hospital introduced the session by focusing on the difficulties of production planning as the hospital is scaling up. The existing tools do not support the necessary planning. The challenge is to provide as much as possible with the given allotment of resources – how then do we measure the value created?

Each of the unit managers gave an exposé of their main areas of work and challenges. Common threads were the effects of scaling up and having resources to match demand growth as well as planning intake taking into consideration that any first visit may generate 4-10 follow-ups. The project leader noted that there is no resistance to change as staff have sought to work at the hospital knowing that it was a “start-up”. She noted that it is important not only to focus on treatment but also on epidemiology and prevention.

The decision was taken to go ahead with a swift project using Lean methodology in the administrative department. This was to be led by my colleague and not described here. It was also decided to scope System Dynamics in paediatrics, which became my task.

### Before meeting with the paediatrics manager

The scoping of System Dynamics in paediatrics was given a budget of 2-3 consulting days for meetings and modelling work, which in itself was a challenge. As nobody at the hospital apart from the director had any knowledge of System Dynamics at the time, I also had to somehow include creating an understanding of what System Dynamics can do.

As planning issues in an expanding ”business” seemed to be an issue I decided to build a very simple System Dynamics model highlighting the issues of planning when there is a constant increase in the number of referrals, there is a time-consuming initial visit followed by a series of follow-ups (Figure 43 Example of a System Dynamics model). I decided to build this model using MyStrategy as each stock and flow contains a mini-graph showing how that particular component changes over time. Many studies have shown that newcomers to System Dynamics have difficulties seeing the non-intuitive interaction between stocks and flows.

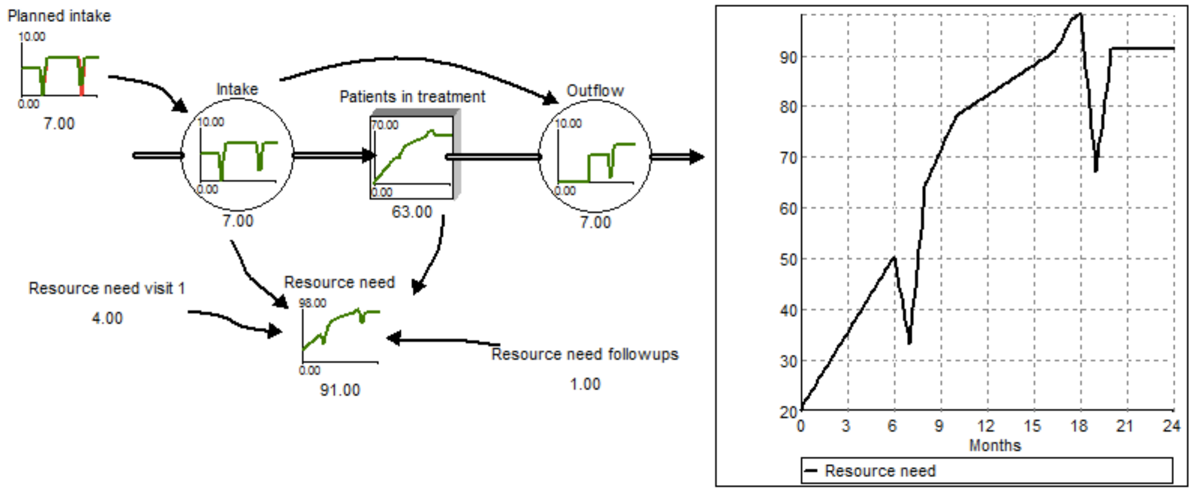



*Figure 43 Example of a System Dynamics model*

The model shows a planned intake with an annual increase and a dip in the vacation month. New patients "consume" 4 resource units at their first visit and remain in the system for 10 months consuming one resource unit per month.

## Meeting with the paediatrics manager

I briefly explained the model to the manager of the clinic and ran it. His immediate response was "so this is System Dynamics" and very rapidly suggested using the methodology to simulate another issue where he could see that it would be useful. The manager saw possibilities to use System Dynamics to study two other cases

## 1 Roundish children

According to the manager very young children with a body mass index slightly above the norm have a high probability to follow a trajectory to being obese when young adults. Figure 44 BMI-growth in children was provided by the manager.

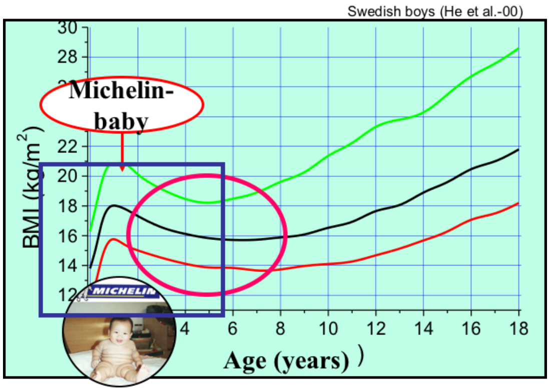



*Figure 44 BMI-growth in children*

Slight overweight in small children is rarely seen as problematic. Problems do not arise until late teens and in adult life.

The clinic had at that moment 33 children in treatment. The initial stage is series of sessions with doctor, nurse, dietician and psychologist, 4.5 hours in all. Regular follow-ups take 1 hour. The success rate is higher with younger children than young teens.

The national average of children with obesity is 4%, but the average is 13% in the uptake area of the hospital. There are 11 000 children in the area.

The manager asks questions such as how to balance resources with the inflow of referrals and how to prioritise.

## 2 Children multi-visits to emergency services

Children in the area make a total 17 000 visits per year to the emergency intake at the major hospital close by offering emergency services. 600 of the children make more than 5 visits per year, averaging 8 visits. Politicians and the commissioning unit suggest that the local hospital should take over as many visits as possible. The manager suggests that there may be a better way and has done tests on a small number of patients, where they and the parents have had a long review of health status, meeting doctor, nurse and psychologist. Initial results show that they switch to the lower visiting frequency.

The manager asks if System Dynamics can show if this method is efficient and what level of resources would be required to gain significant change.

The manager asked me to initially proceed with the multi-visitors and we set up a meeting to provide me with additional information on roundish children.

### Additional information about obesity in children

I had a meeting with the clinic manager and a senior nurse. Here is short version of the basic facts:

- Surgery involving gastric bypass or band can be done once the patient is more than 15 years old. Involves surgery for the gastric intervention as well as surgery for removing excess skin. The patients need lifelong annual follow-ups and medication as their ability to take up important nutrients is diminished
- 25% of the children suffer clinical depression and treatment, some of whom fail in school and cannot find work.
- 40% get diabetes before 50 years of age
- Significant numbers have heart issues after 50 years of age

I was given a paper by Ingvar Nilsson & Anders Wadeskog (2008) , as well as additional clinical data.

### The multi-visitor model

I rapidly built a simple model to illustrate the basic issues, see Figure 45 The multi-visitor model. The upper third of the model is an aging chain for the population of children. My basic intention was to have the basics to simulate changes in births. In the middle is an aging chain for the multi-visitors where a portion of the younger children are subjected to the proposed treatment. Treatment begins with the youngest cohort and any remaining resources are used for older cohorts. The lower third of the model contain cost calculations.

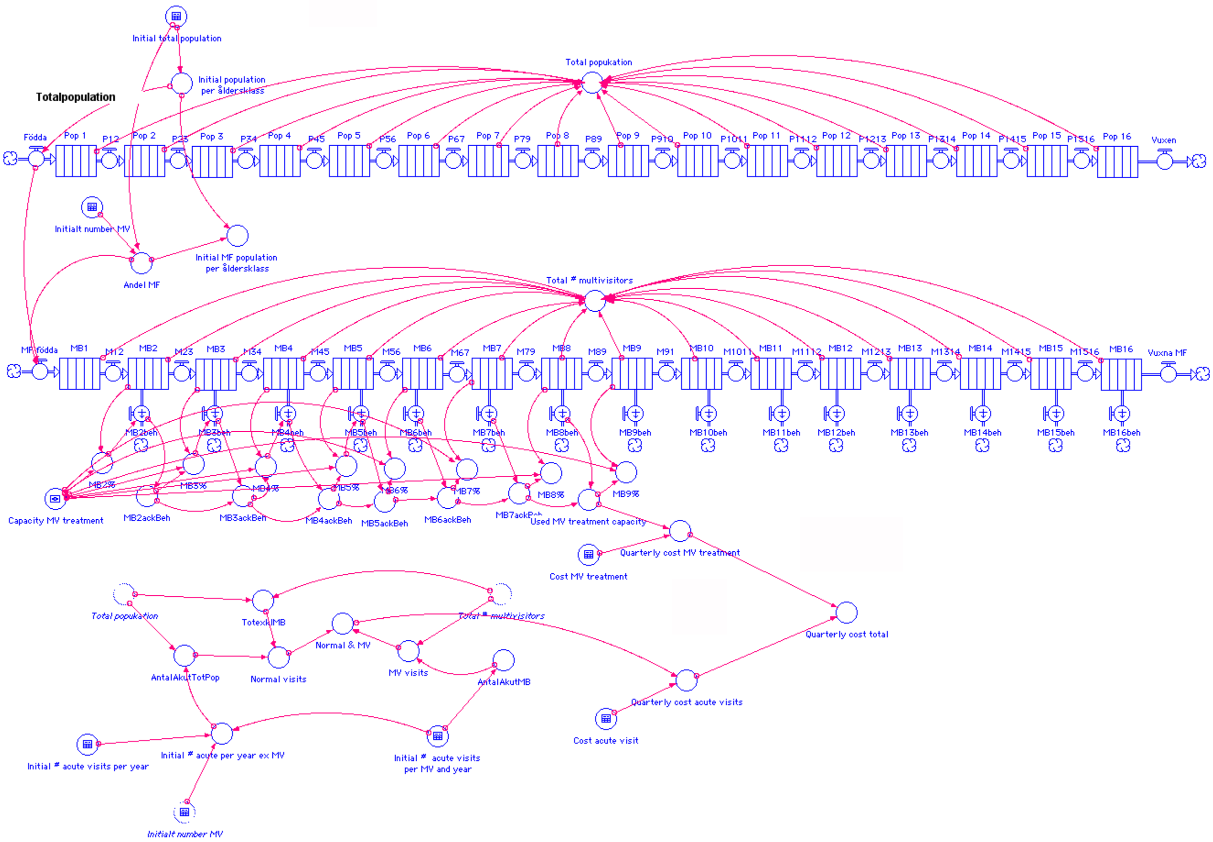


*Figure 45 The multi-visitor model*

The main presentation to the manager was the fight simulator interface (Figure 46) where any of the basic numbers such as population, number of multi-visitors, number of visits and costs could easily be changed. In the top middle, there is a slider determining the capacity for the preventative visits at the clinic. It is possible to do several runs with different capacities and see the different results in the same graph.

There are four graphs

**Top left**

Shows the total population number and number of multi-visitors

**Bottom left**

Number of visits by those with normal visiting patterns, all visits and the number of preventative visits

**Top right**

Same as top left but retains the results of each run

**Bottom right**

Shows the total number of visits as retained by each run

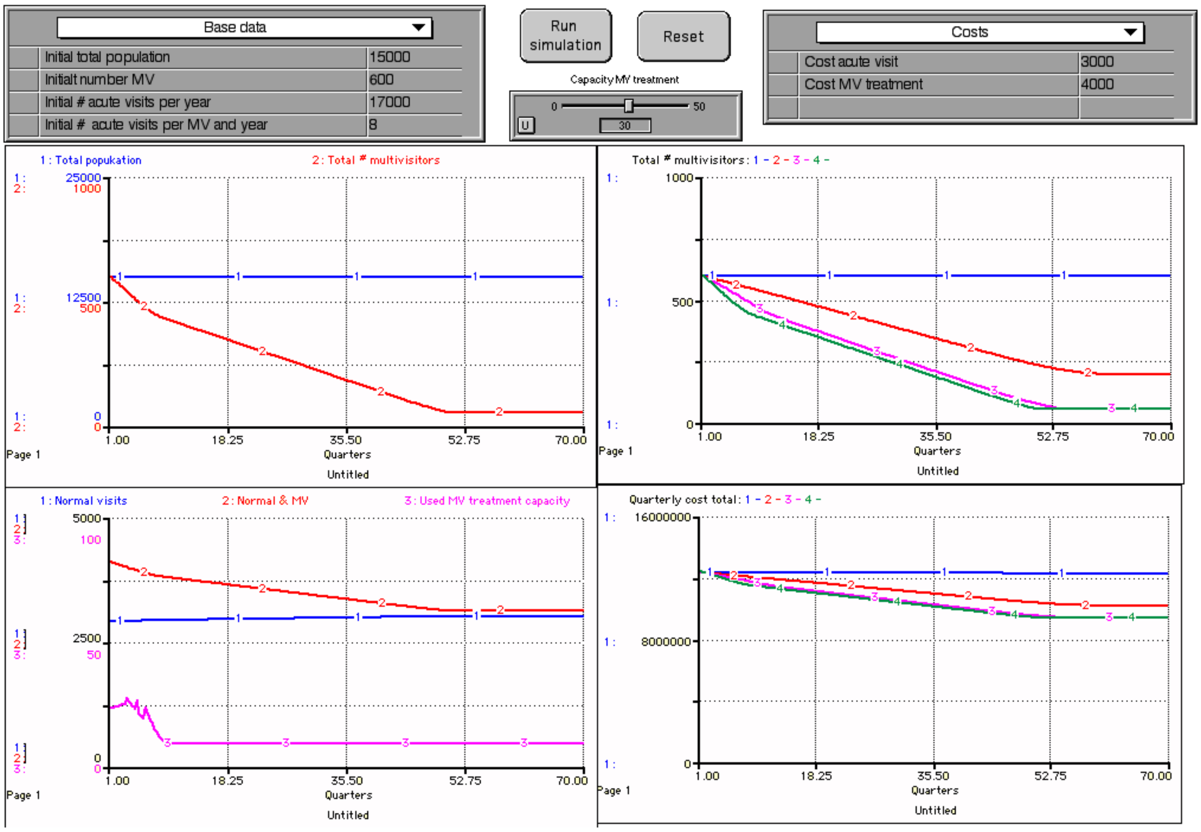



*Figure 46 Interface - multivisitors model*

The graph above shows the results of three runs: a base run without any intervention as well as with 10, 20 and 30 preventive visits per quarter. 10 visits per quarter yield a significant reduction in the number of visits and costs. Increasing to 20 visits yields a marginally increased effect. Increasing to 30 has virtually no effect. The reason for the marginal effects is that interventions can only be given gradually and begin with the youngest and the young coming into the system. As more capacity is available for the older, they have moved up and out of the aging chain.

### Meeting with the paediatrics manager

I began by showing the basic principles of the model with the aging change and how interventions were applied. We then moved to the interface graph and we ran a series of simulations with an increasing number of preventative interventions. The manager declared himself very satisfied with the model and saw no use in elaborating on it further as it would satisfy his needs as they were.

I was asked to build a model for the roundish children using similar principles.

### The "roundish children" model

Again, a rapid build to test the principles with several aging chains. The persons are tracked by age cohort until 17 years old, then in an adult cohort until 70 years old. It was a conscious decision to oversimplify adults. The purpose of the model was to test broad principles and later revise phenomena for adults if required. See Figure 47 The roundish children model.

The top aging chain is the base population and the second is the affected part of the population. I built it as an aging chain to be able to revise and later add actual distribution by age group.

Then follows an aging chain that is subjected to treatment. Those that are successful go down to the lowest aging chain where they keep their heathy behaviour. Those that fail go into aging chains and subjected to future ill health.

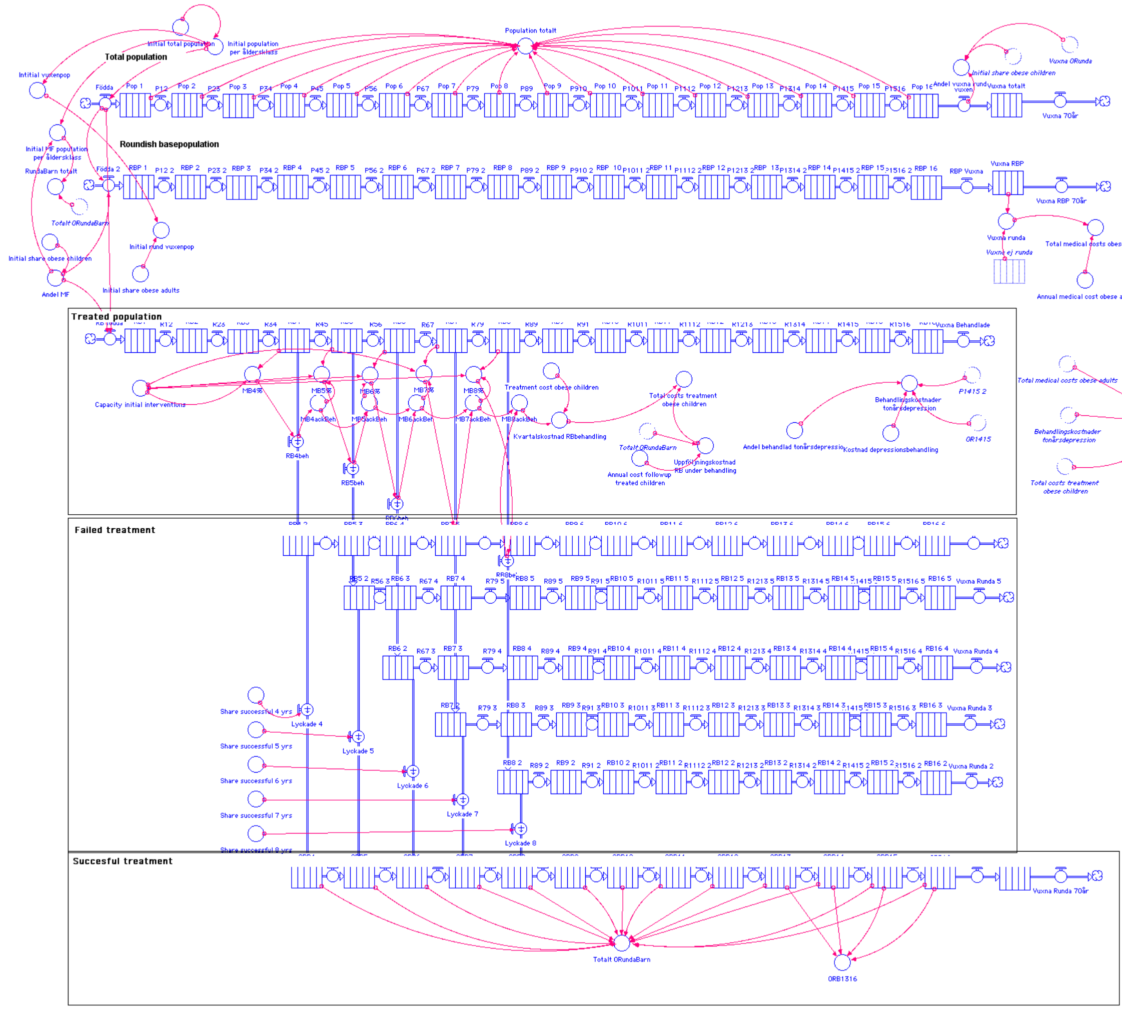



*Figure 47 The roundish children model*

I built a “flight simulator” interface where basic data could easily be revised, see Figure 48. The idea was to prepare for developing the model for use in e.g. discussions with the commissioning unit, where data could be changed if challenged. The simulation is run for 300 quarters, i.e. so long that adult effects are seen fully.

There is a slider where the number of initial visits are allocated in increments of 10 per quarter. The graphs are retained until cleared so that multiple runs can be done and compared. The top left shows the costs for initial and follow-up interventions. Bottom left shows the medical costs for adults. Bottom right total costs for interventions and adult costs.

The marginal effects of adding more interventions decrease as interventions can only be given gradually and begin with the youngest and the young coming into the system. As more capacity is available for the older they have moved up and out of the aging chain.

As can be seen in the lower graphs a change in baseline incidence of obesity from 3% to 6.5% leads to more than a doubling of adult medical costs. Doing 10 or 20 interventions per quarter leads to a significant cost decrease, and in the latter case to a level below baseline.

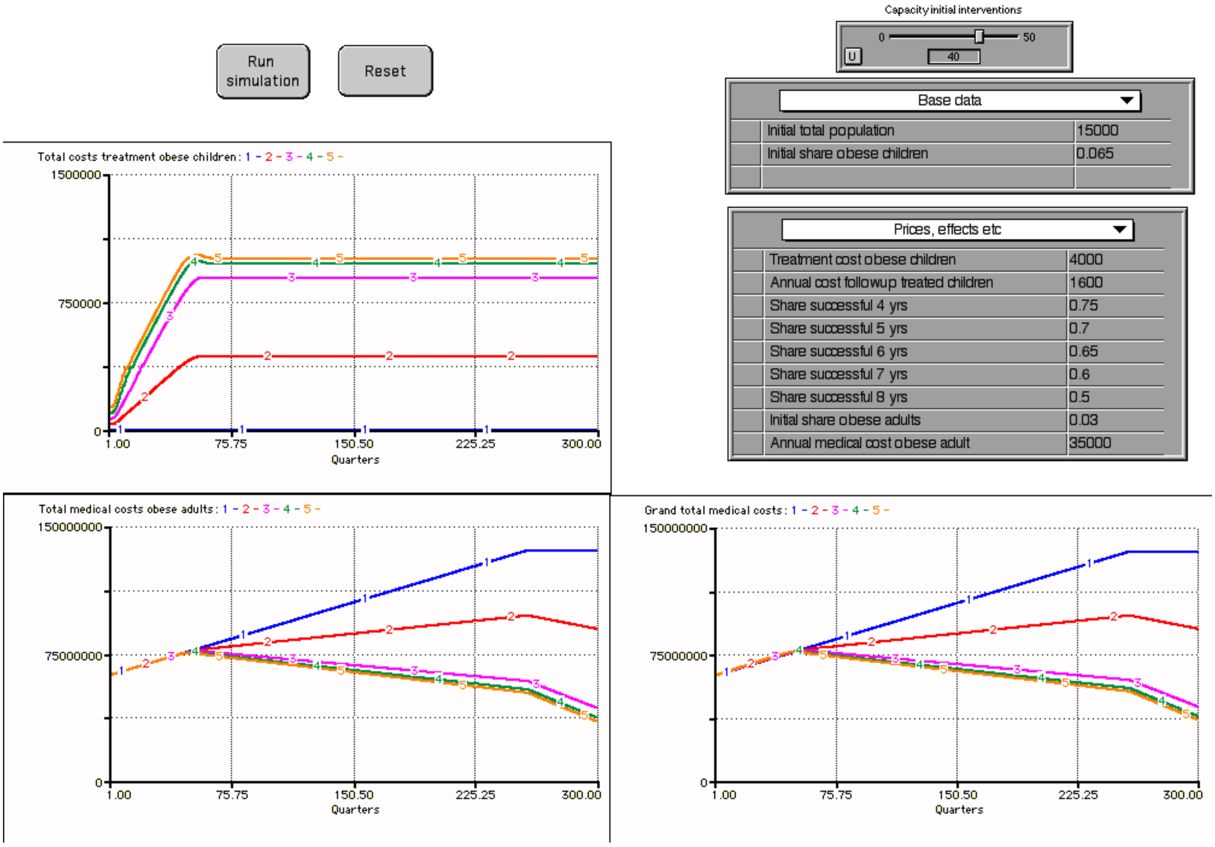



*Figure 48 Interface - roundish children model*

### Meeting with the paediatrics manager

I began by showing the basic principles of the model with the aging change and how interventions were applied. And as with the multivisitors moved to the interface graph and we ran a series of simulations with an increasing number of preventative interventions. Again, the manager declared himself being very satisfied by the model as it was. It showed the basic principles sufficiently.

### Presenting the model

The project leader and the paediatrics manager were to present the model at the annual conference of the European Health Management Association. To facilitate their presentation, I prepared a runtime version for them. They reported the presentation as successful.

Olsson, M. and O. Panfilova (2009). *Lessons learned from designing innovative* care. EHMA Annual Conference. Innsbruck.

## Case 9 – Obstetrics (2)

### Project context

The project was part of the EU-financed project “KASK Innovation” a cooperation between hospitals in Denmark and Sweden. The Swedish part was about how to develop and test tools and work methods to investigate and break down barriers or reduce resistance to organisational innovation in a large and complex organisation. They wanted to test the use of System Dynamics in that setting.

### Manager’s description of the follow-up meeting, prior to starting the project

3-5 days after a birth, mother and child are followed up. One important purpose is to identify any problems or complications and perform a phenylketonuria test for genetic disorders on the baby. The test is time-critical as it needs to be carried out 3-5 days after the birth.

As stays in the post-natal wards have been shortened, the mother and child comes back to the department for the follow-up. The meeting is scheduled when they leave post-natal.

The meeting is planned to take 30 minutes. Weight is checked, if reduced then breastfeeding is discussed and advice given. The midwife looks for any indications of complications, ill health etc. If so tests are taken. However there is significant variability in used time. The follow-up for first-birthers can take longer. For those coming with their second or later child, little follow-up may be needed.

At times the patient record from the birthing is discussed to sort out any misunderstandings.

There are a number of problems such as having sufficient time slots to schedule within the given time frame and people not arriving at the scheduled time, disrupting planning and causing stress among the staff.

### Project proposal

**Background**

The main purpose of the follow-up meeting is to serve as closure and follow-up after a child is delivered. The child, mother and family have then been home a few days. A midwife holds a 30 minute meeting with the child/mother/family. If necessary, relevant initiatives are taken for further treatment. The child is always weighed, which can lead to breast-feeding observation as well as a PKU-test (phenylketonuria), which can be done 2-3 days, but not later than 5 days, after the birth.

As management perceives a queuing problem a different procedure has been discussed, based on drop-in principles. The queue issue mainly depends on variation in birthing numbers, but also problems in adhering to reserved times.

As part of the evaluation of new procedures, systems simulation has been proposed to give quantitative data for work methods and dimensioning

**Purpose**

We intend to support the pilot study work of changed follow-up procedures by systems simulation. This means that an executable model is developed in a suitable systems simulation tool allow quantitative investigation of alternative solutions.

The main objective is quantified capacity data, and using it to obtain patient service parameters. Differing birthing rates from one day to the other will be considered as well as extrapolation of total numbers for future higher capacity.

We will also support and drive a process where alternative solutions will be evaluated by the simulation.

**Work process**

We will build a work process around a series of four meetings with modellers and those responsible for operations. During the first meeting a simple model will be introduced based on birth rates and capacity at the unit. Opinions put forward during the meeting will lead to changes in the model directly at the meeting or in the time before the next meeting. Time between meetings will also be used for additional data collection, to be specified.

**Resources**

Two consultants will be present at each meeting (2-3 hours). In the time between meetings, models will be developed and data analysed. Our assessment is that there should be no more than two weeks between meetings and 2-3 days of consultancy work between meetings.

## Project group

A project group was formed consisting of
Project leader from the hospital's Operational Development
Obstetrics manager
Deputy obstetrics manager
3 midwives
1 assistant nurse.

## Project plan

Prior to meeting 1

- Develop simple model to introduce methodology and open up for discussion
- Initial planning and introduction of method for Operational Development

Meeting 1

- Present initial simple model
- Discussion of the model and what the ”problem” is
- Decide on focus for the next iteration of the model
- Discussion about required data

Prior to meeting 2

- Data collection
- Modeller meeting: model sketching and method
- Develop model
- Liaison and knowledge transfer between modellers and Operational Development

Meeting 2

- Presentation of enhanced model
- Discussion of the model and how it illuminates the ”problem”
- Decide on focus for the next iteration of the model

Prior to meeting 3

- Additional data collection
- Modeller meeting: model sketching and method
- Further model development
- Liaison and knowledge transfer between modellers and Operational Development

Meeting 3

- Presentation of enhanced model
- Discussion of the model and how it illuminates the ”problem”
- Discussion about operational consequences
- Developing policies that the model should illuminate
- Decide on focus for the final iteration of the model

Prior to meeting 4

- Additional data collection, if necessary
- Modeller meeting: model sketching and method
- Developing final model
- Liaison and knowledge transfer between modellers and Operational Development

Meeting 4

- Presentation of final model
- Simulation of different policies

- Discussion about operational consequences
- Discussion of the work, method and result from a stakeholder perspective

After meeting 4, evaluation of work, method, results and learning for Operational Development.

### Notes from meeting 1

The participants from obstetrics described the following problems/issues:

- Increase in births is creating problems with managing capacity for the follow-up
    - During 2009, 3350 of 3900 births came to the follow-up. The majority of the others stayed long enough in connection with the birth that PKU-test could be taken then.
    - 28% came later than within 5 days
    - The maximum capacity of the entire department is 4200 births per year
- Patient numbers differ from plan
- How to use time for care instead of booking?
    - Secretaries would not need to rebook
    - The booking system creates problems in itself, such as double booking
- Taking care of visitors that need more time than 30 minutes
- Utilizing excess time
- Visitors miss appointed times, 13 of 68 were late
- More might be included in the PKU test
- The PKU test might done earlier, after a minimum of 48 hours instead of 72
- Paediatric doctors have a daily appointment time slot using the same rooms
    - Sometimes the time slot is extended
    - Doctors are sometimes late
    - Leading to delays the rest of the day

Additional notes

- 13 available time slots available Monday, Wednesday and Thursday. Additional 13 on Tuesdays, 6 on Fridays. Weekly total 84
- Coordinator works Monday-Friday so that midwives need not be interrupted
- Consider doing more PKU while still in department after the birth. Average stay is 2.5 days, i.e. many exceed 48 hours
- Premises
    - The waiting room is a problem
    - Paediatric doctor uses the room used for follow-up
    - Hearing is tested
    - An additional room is used when two midwives are on duty
    - Other activities
    - Aurora (support for mothers anxious before birth)
    - Breastfeeding

I had prepared a very basic simulation model to illustrate what System Dynamics (Figure 49) is and what a model is. Based on my earlier experience from working with obstetrics and modelling healthcare in general, I am aware that it is important to include substantial random variation in patient flows at an early stage, as coping with the variation is a significant issue for staff.

This model includes a known number of births per year, a monthly seasonal variation, and randomization. A stock was created to represent the target group, 3-5 days after birth.

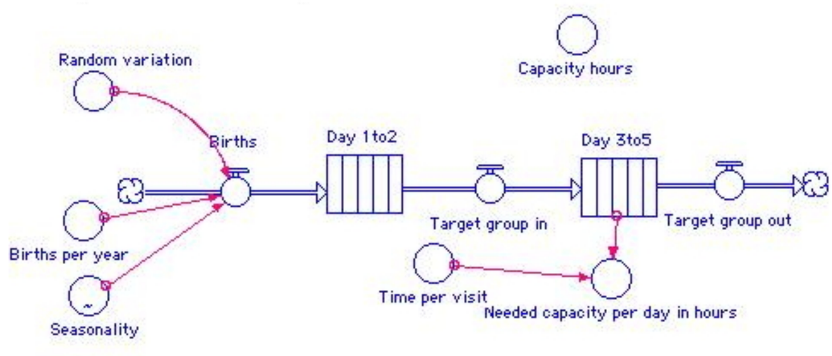



*Figure 49 Model meeting one*

A first graph (Figure 50) was created to illustrate the variation in births (red line) and that most of the variation was not absorbed when looking at the target group, 3-5 days after birth (blue line)

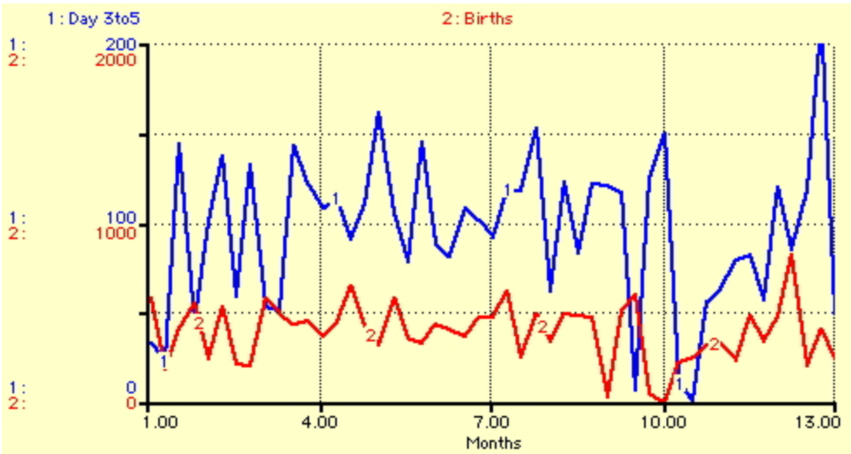



*Figure 50 Patient flows*

A second graph (Figure 51) was shown to illustrate the possibility of comparing patient flows with capacity. When the graph was shown, it was pointed out that both visitor and capacity data were initial estimates.

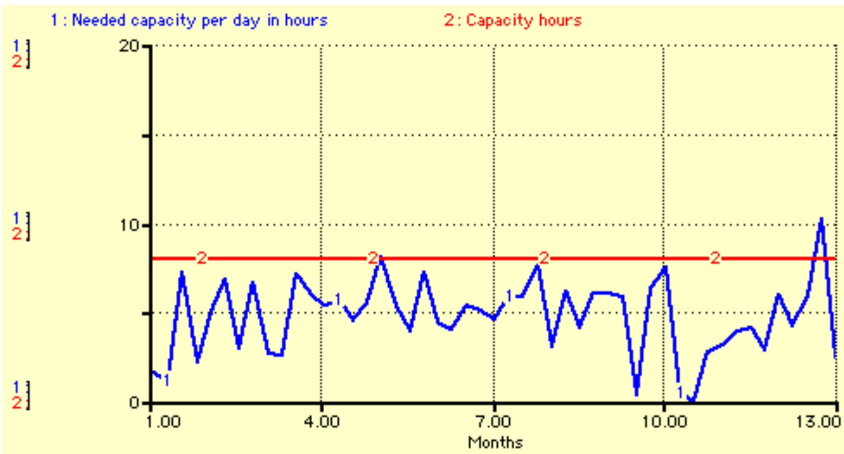



*Figure 51 Patient flows - capacity*

Participants' reflections

- Exciting
- Might put an end to myths by showing facts

Statistics that were deemed necessary

- Results of a questionnaire about when visitors wish to come
- Average care time at obstetrics, including birthing
- First-birthers

### Between meeting 1 and 2

As we modellers were receiving data two major discrepancies emerged. In the pre-planning phase of the project the department had conducted a simple survey to find out when visitors preferred to arrive. In Figure 52, the results are shown together with the distribution of available time slots. We concluded that this indicated that a pure drop-in system might not be possible, and visitors somehow needed to be directed to less attractive arrival times. It would not be possible to schedule midwives to match desired arrival times.

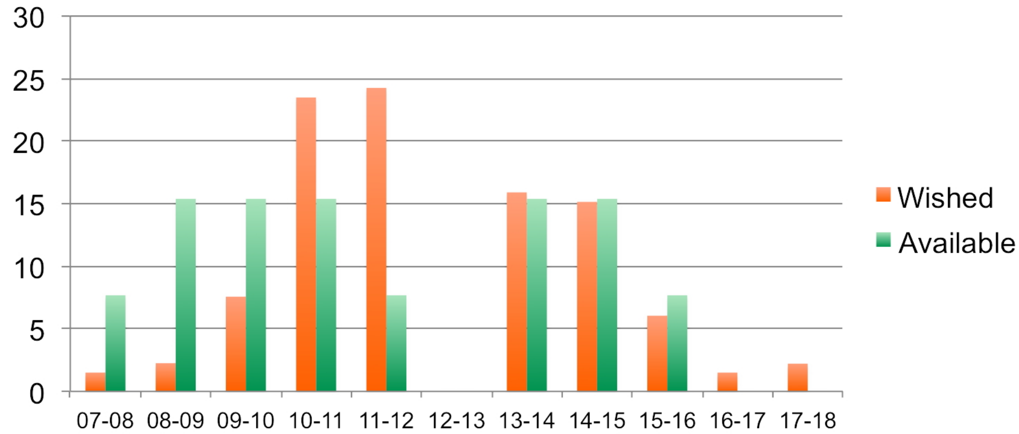



*Figure 52 Preferred and available time slots*

The second discrepancy had to do with distribution between weekdays. Given that the PKU test has to be administered within 3-5 days after the birth this would allow for three possible arrival days, but the unit was not open over weekends. The implication is that a child born on a Wednesday could be tested Saturday-Monday, but has to come on the Monday. This is illustrated in Figure 53. This effect calls for higher capacity on Mondays and Fridays.

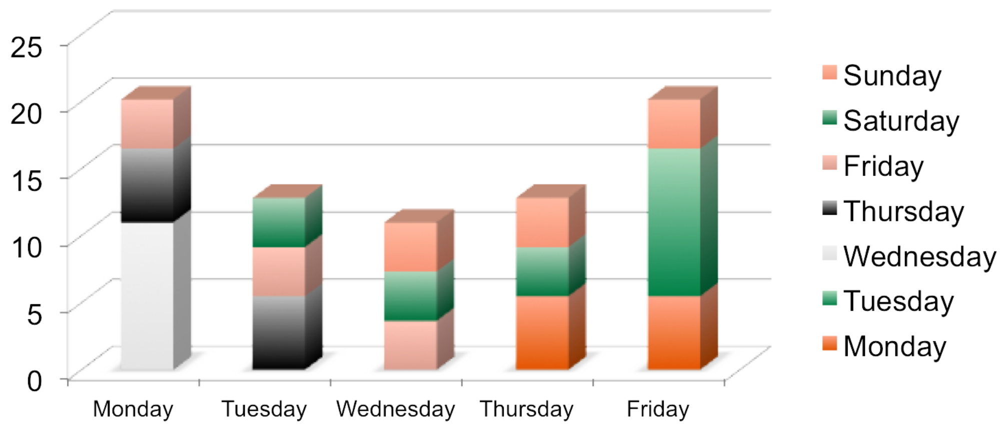



*Figure 53 Necessary capacity by weekday*

This was not reflected in how time slots actually were scheduled. Capacity was lower on Mondays as the premises then were used for meetings for planned Caesareans, as can be seen in Figure 54. The group realised that this mismatch most likely was the most significant hurdle in scheduling people within 3-5 days of birth. Staff was less of a bottle-neck for rescheduling than facilities, which were used for multiple purposes.

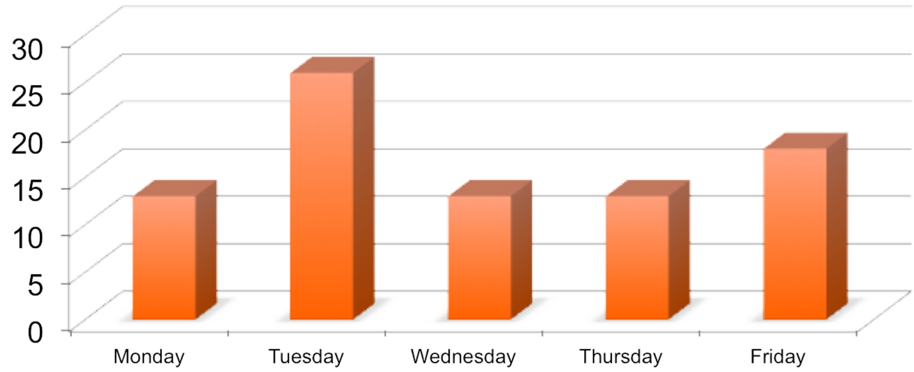



*Figure 54 Actual capacity by weekday*

We modellers decided to present this material at the second meeting and invite discussion about how these discrepancies might be addressed. We realised that the final models would have to use a time-stamp function, allowing us to measure the actual throughput time for individual visitors. We decided to develop tentative models illustrating the issues at hand step by step. First a model showing effects of preferred arrival times and capacity, then adding the time-stamping.

### Meeting 2

The graphs showing the scheduling discrepancies were shown and discussed. The group realised that a pure drop-in system would be difficult to achieve as it would require real-time rescheduling of staff to cope with the peaks. Discussions began along two major lines of thought, how visitors could be nudged to arrive at "unattractive" times and how to increase capacity during preferred times.

Moving capacity from Mondays to Tuesdays was initially seen as an insurmountable issue as it involved scheduling of doctors over whom the midwives have no control. The department manager decided to raise the issue with the doctors.

A revised System Dynamics model was introduced (Figure 55). Compared to the initial, very basic model shown at the first meeting, this model included randomized arrivals according to preference (Figure 52 Preferred and available time slots) and matching it with the necessary capacity (Figure 53), illustrated in Figure 56 Capacity by weekday. The simulation runs over a three-week period, in order to show the difference between weeks created by the randomization.

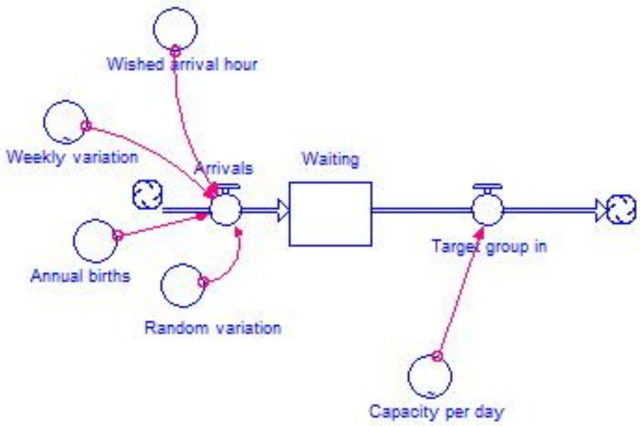



*Figure 55 Basic model meeting 2*

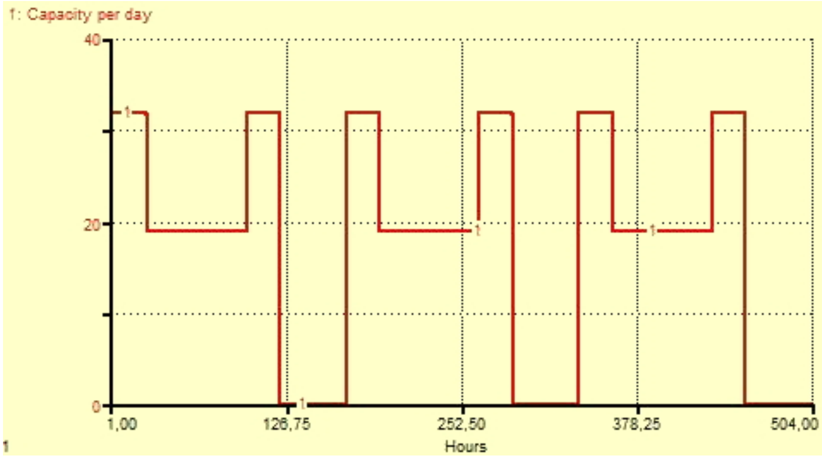



*Figure 56 Capacity by weekday*

Figure 57 Arrivals shows the randomised arrivals. The basic arrival pattern is that from the patient surveys.

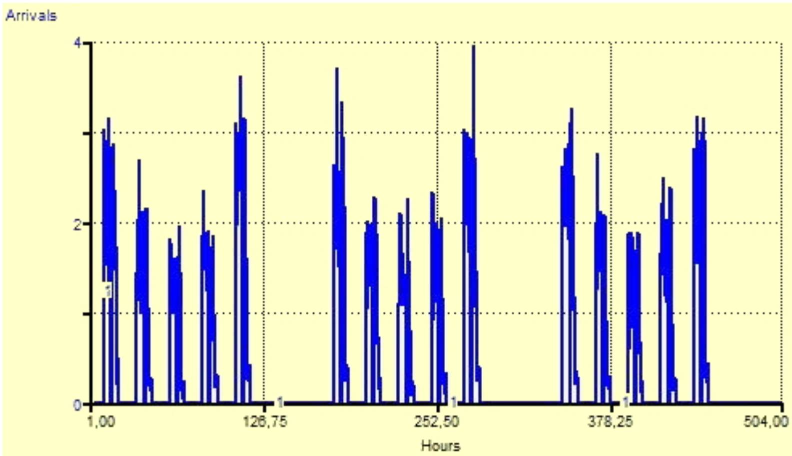



*Figure 57 Arrivals*

Figure 58 Waiting shows the number of visitors waiting based on arrivals and capacity. The number of persons in the waiting room peaks at 5-6, implying waiting times up to 2.5-3 hours.

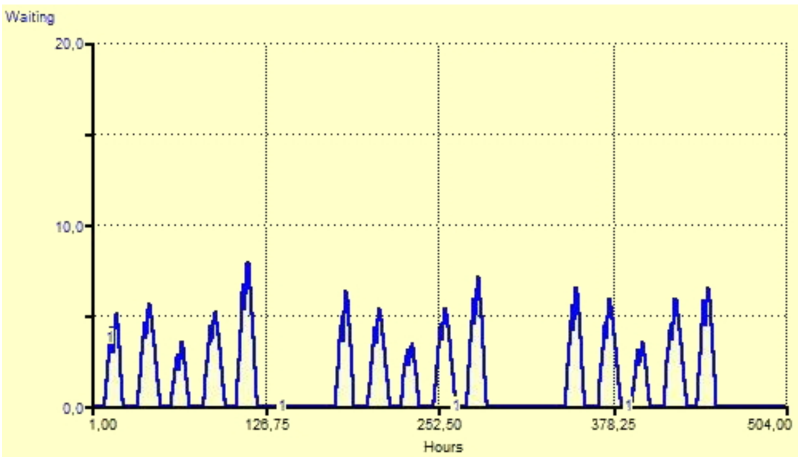



*Figure 58 Waiting*

This model intensified the discussion about influencing arrival times so as not to have a completely free drop-in system.

A further developed version of the model was introduced, which allowed for time stamping, i.e. measuring the waiting time for individuals in the simulation. The purpose was to allow for analysis of what was behind the data in Figure 58 Waiting.

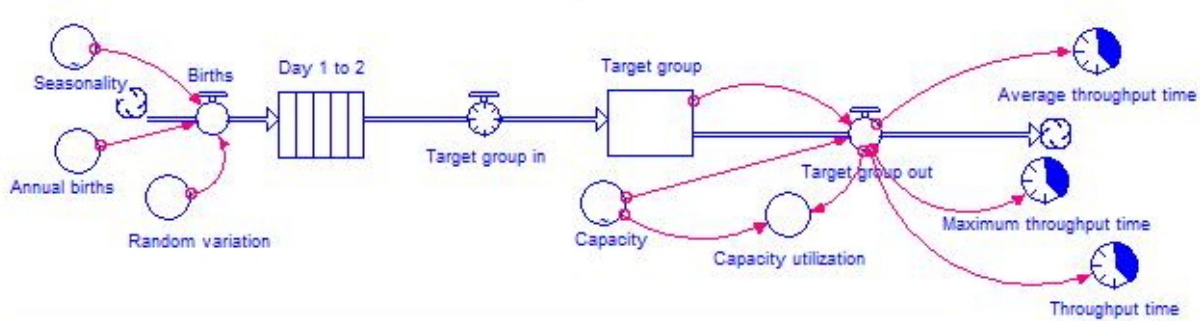



*Figure 59 Basic model meeting 2, including time stamping*

The time stamping allowed for interesting analysis, see Figure 60 Real-time, average and maximum throughput times. For technical reasons, pure waiting time could not be measured, the throughput time includes the meeting, i.e. waiting times are 30 minutes shorter than throughput time. The graph shows an average waiting time of just over one hour. The maximum waiting time is close to 3.5 hours.

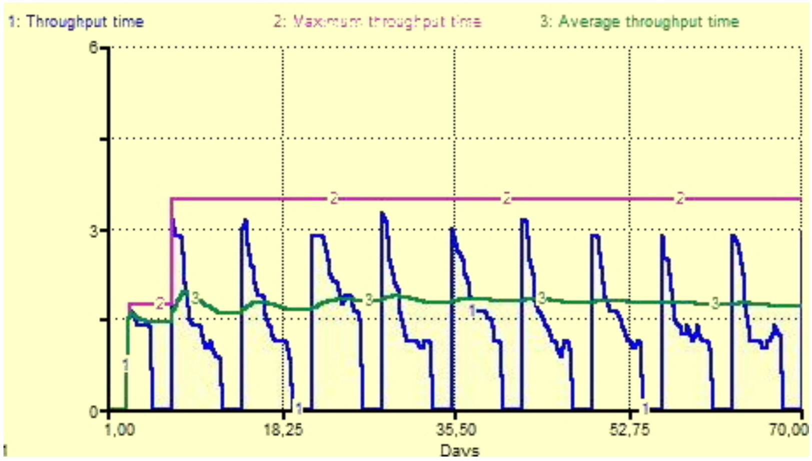



*Figure 60 Real-time, average and maximum throughput times*

In the preparatory building of the model the modellers questioned themselves if the given capacity data was correct. This was seen as an opportunity to create a version of the model allowing for real-time adjustment of capacity. The program has the capability to build what is often called a flight simulator, with key variables and key output in a graphical interface. This concept is showed in Figure 61 The first "flight simulator". This intervention allowed us to introduce concepts on how a final model would be built using a similar type of interface.

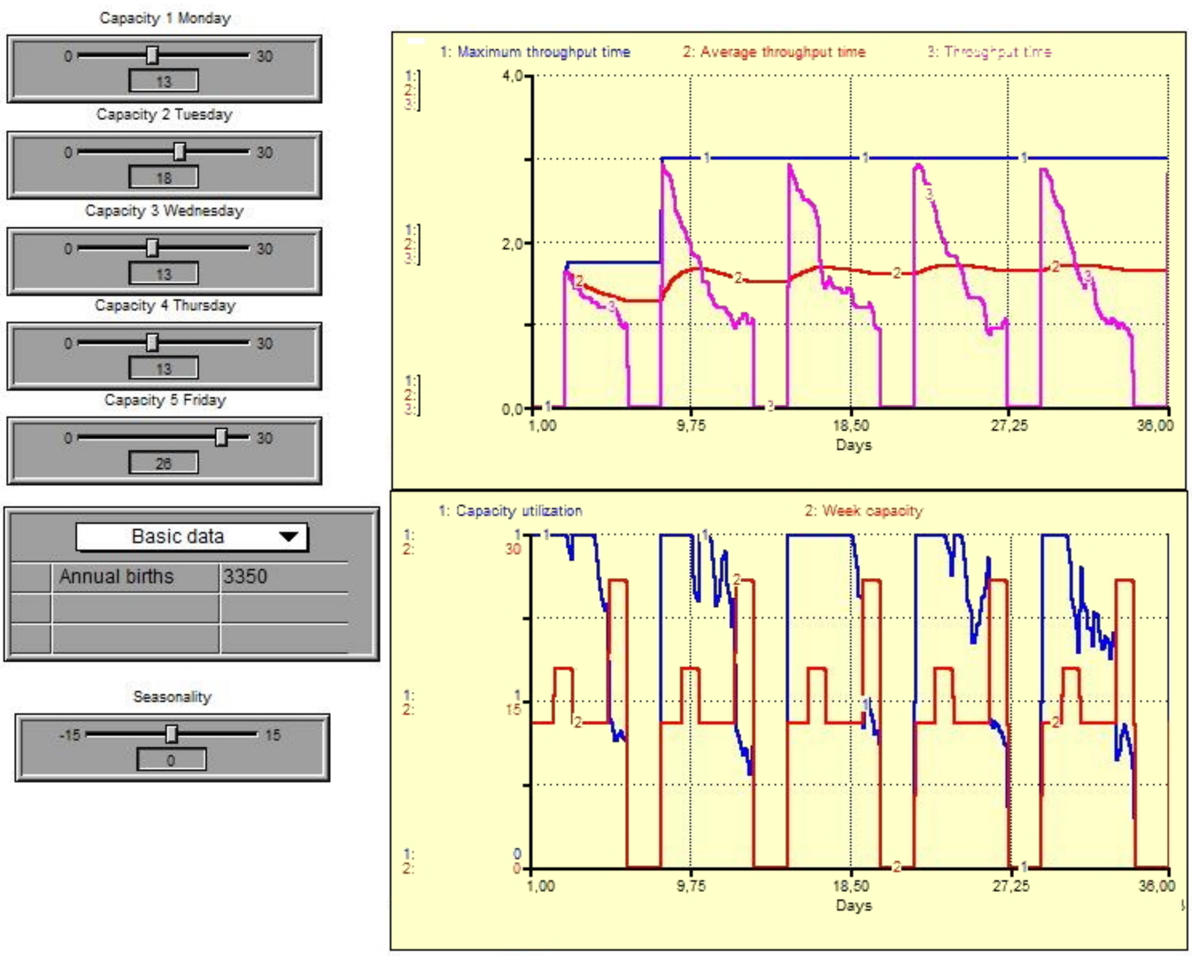



*Figure 61 The first "flight simulator"*

It was decided to review both planned and actual scheduling. Staff mentioned that sometimes when the waiting room is full additional capacity could be drawn in during parts of the day.

Summary of meeting discussions

- Suggest that visitors not bring siblings or other relatives as waiting room gets crowded
- Queue system informing about waiting times
- Queue numbering
- Coffee, magazines to alleviate waiting
- Review usage of premises
- Staffing
    - More staff at peaks
    - 2 midwives 10-14
    - Call in extra staff when needed
    - Stretch into lunch and late afternoon
- Scheduling
    - Take away time slot at 0730
    - Inform about high number of visitors between 10-14, to nudge away from those time
    - Directed “drop-in”
    - Give time-slots for dropping in
        - 10-12 7 visits
        - 13-16 7 visits
    - No drop in on Mondays, only scheduled visits
    - If a visitor needs more time, schedule a second meeting
    - Variable time 20-30 minutes
- Do a pilot test of open drop-in

- Separate PKU test from follow-up, to be taken at maternity ward by dropping in round the clock, any day. This would focus the visit on actual follow-up.

It was decided to use the next meeting to discuss different possibilities to influence arrivals and work with capacity to use as input for the development of a model for the fourth and final meeting.

### Between meeting 2 and 3

Discussions between the modellers mainly focused on alternative problem definitions and solutions, which could be brought into the discussions during meeting 3. We also began considering the principles of a final model. Given the resource limits it would not be possible to build an "ultimate" model, which could replicate everything in detail. It would be large, unwieldy and probably not fit for purpose. We decided that the aim should be to bring the important parameters into the flight simulator interface and find a way of interpreting operational suggestions as model variables.

### Meeting 3

The meeting was mainly spent reviewing purpose, problems, data, suggestions etc. Here follows a summary of the notes

Initial position and preconditions

- Task of the unit
  - PKU within 2 to 5 days (could be earlier)
  - Hearing test after 2 days
  - Follow-up of the condition of mother and child, support
- Work methods
  - Consulting Monday-Friday
    - Weekends when urgent
    - Extra capacity on Tuesday afternoon and Friday
    - Friday time slots never fully used
  - Resources
    - Midwives alternating (40 of 90)
    - One assistant nurse for hearing test and reception, 4-5 alternating
    - One consulting room, one extra when needed
  - Time reserved for half hour visits
    - Longer time often needed
    - Late arrival common
  - Capacity handling
    - Planned gap in reservations during morning and afternoon
    - Extra midwife can be called
    - Different working hours (some leave at 1530, others at 1600)
- Perceived problems
  - System for reservations is time consuming, uncertain and error-prone
  - Visits taking longer time
  - Visitors often late
  - Stressful working environment due to delays and visitors with scheduled times
  - Varying popularity of this job among midwives
  - Visitors find it difficult to adhere to time with new child
  - Friday capacity
  - Varying work pressure due to variations in births
  - How will the present procedures function with future higher birth levels?
  - Slow change process at the hospital
- Switching to drop-in
  - Which degree of choice is desirable/possible? Free choice of day? Time of day? Time per half day?
  - Which additional changes should be considered
    - PKU at maternity ward (x%)

        - Separate basic follow-up and additional support
        - Train midwives for situational course of conversation, directed to time needed to cope with queue (visual aids needed)
        - When can planned additional resources be added?
        - Simple reservation system, card based, for semi-regulated drop-in
    - Temporary staff addition
        - From obstetrics staff based on expected volumes
        - Other staff, which?
- Consequences
    - Premises
    - Coping with waiting visitors
        - Coffee and beverages
        - Forecast waiting time
    - Work methods for reservations
    - Work methods for situational steering

### Between meeting 3 and 4

We, the modellers, focused on detailing the final model to incorporate most possible decisions that could be made and incorporate them into the flight simulator interface. During the process, all possible variants of input data became difficult to take in. We decided to prepare a detailed introduction running a small number of scenarios to show how different sets of assumptions and decisions played out.

### Meeting 4

I built a final model with an interface showing all variables, Figure 62 Variables and numerical output. To the left is a section determining the basic distribution of arrival times during the day. The default data was based on the visitor survey. The distribution was adjusted by moving the sliders. At the bottom was a function summing up the total to ensure that no more or less than 100% was allocated. The distribution of arrivals was handled in a similar way, middle bottom. Staff levels were assigned in a numerical table, top middle, where one could switch between days. Top far left was the number of visits; this was determined by expected births and the share of those visiting. Below that target is waiting time and a seasonality function to allow for periodical variations in birth rates without having changed the number of visits. The switch at lower right bottom was to test scenarios when visiting time was cut to 25 minutes when there was a queue. The purple data box contained calculated data, average number of visits per hour and capacity utilization.

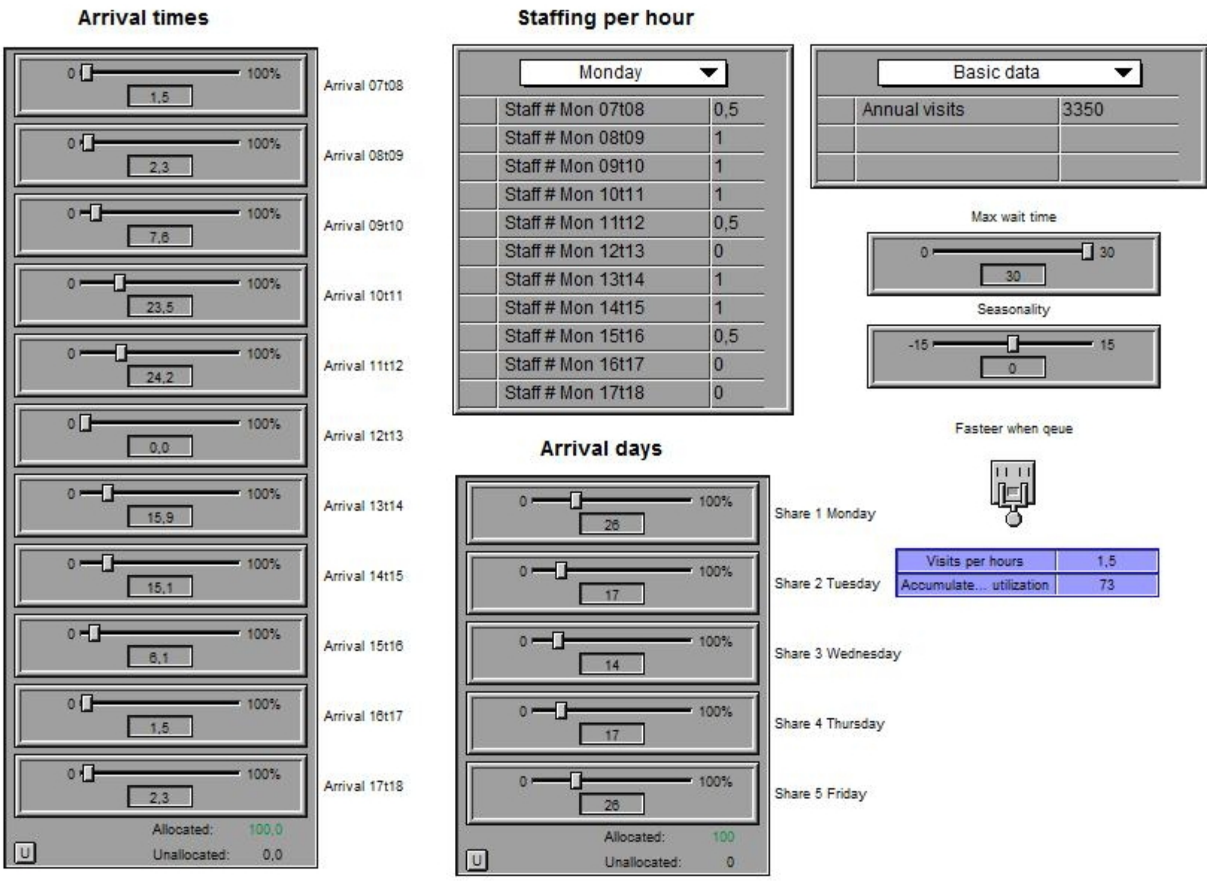



*Figure 62 Variables and numerical output*

In the flight simulator, there were two key graphs. One showed in and outgoing visitor flows and the other showed the number of people waiting, instantaneous waiting time and average waiting time.

I had prepared a set of scenarios both to show the functionality of the model and the consequences of operational alternatives already discussed. When building the model one vital decision was what to do when visitors had long waiting times. Should I let them go home and come back another day? How should the model handle visitors that were still waiting when the unit closed down for the day? I decided that allowing for people to go home and come back was unsuitable as the visit had to be within a narrow slot of days. From a model point of view, I let visitors stay, even overnight, in the waiting room until they were attended to. This in order to focus on finding work methods that coped with the actual arrivals.

The first scenario was based on arrivals according to the visitor survey and current staffing levels. As had been shown in earlier simulations this did not work as there were long waiting times and visitors remaining overnight due to the obvious mismatch between preferred arrival times and actual capacity. The blue line in Figure 63 Initial run shows that there are people waiting overnight and the backlog does not clear up until early next morning when staff are scheduled before new visitors arrive the same day. The initial run also clearly shows the under-capacity on Mondays. Many are waiting until the next day and the backlog is cleared thanks to the double capacity on Tuesdays.


*Figure 63 Initial run*

Next I switched capacity between Monday and Tuesday. I ran every scenario three times in order to show the effects of randomization in arrivals. There were still long waits and people not served the same day.

Cutting visit time when there was a queue had little effect. The randomization showed that slight overcapacity was required, 77% also required some ability to stretch or add additional time slots in real time. Increasing seasonal volume by 15% had negative effects, so some sort of coping mechanism was necessary like forecasting expected births some weeks ahead.

Some method for directing visitors to specified half day, nudging to less popular times within that time most effective. One of the best outcomes is shown in Figure 64 Ideal run.

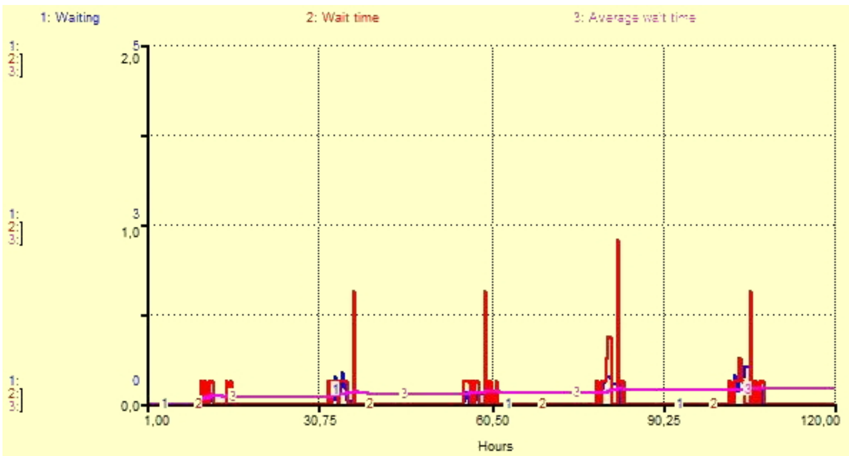



*Figure 64 Ideal run*

At the end of the fourth meeting the group had a clear framework for a pilot implementation.

- There would be a schedule of available time slots for visits, grouped by half days
- For each half day invitations would be printed according to the number of time slots
- Invitations would inform about the half day time span available for visits, that waiting times could be longer around mid-day, with shorter waiting times early in the morning.
- When leaving the maternity ward after the birth the parent would be given an invitation
- During periods where the number of births exceeds the available time slots, additional capacity would be created and more invitations printed.

### Pilot and implementation

The modelling was carried out late spring 2010. A presentation was held for all midwives and other staff in June. The meeting began with revisiting the background and the problems that the work group had been asked to address. We ran through a series of scenarios using the final model, highlighting issues like the described mismatches between demand and resources over a day and week, respectively. Using the model, we described methods to optimise arrivals. A key realisation among participants was that we underlined that when a midwife goes to the waiting room to get the next visitor, the waiting room will never be empty. There should be no reason to be stressed about that. The pilot implementation was planned in August and finally implemented in October. Some adjustments were made and the drop-in was made permanent.

### Evaluation

The two most critical numbers to evaluate were actual waiting times and visitor satisfaction.

From a modeller's point of view, actual waiting times were critical. As a model, never entirely can replicate actual behaviour there could be concern that the modellers and the group were overoptimistic when running scenarios and adjusting parameters. That concern turned out to be unjustified when measuring real waiting times during 8 weeks late 2010. As shown in Figure 65, the results were probably better than expected. 58% of all visitors had a wait shorter than 15 minutes, another 27% waited between 15-30 minutes. A very small number had very long waits, which also was indicated in the simulations.

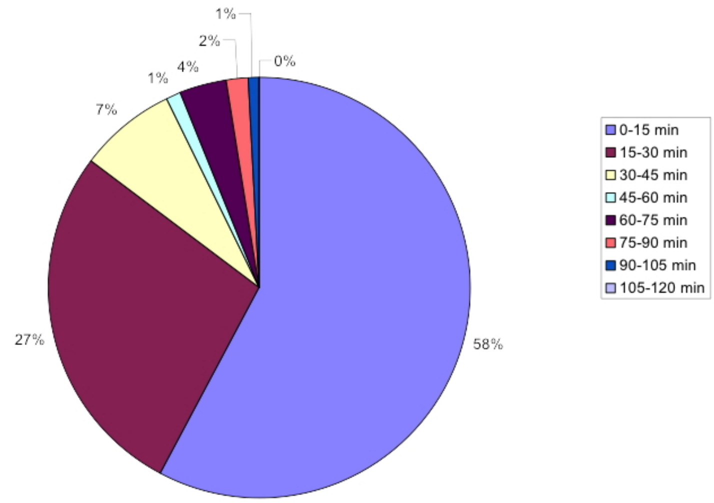



*Figure 65 Waiting times*

Visitor satisfaction was surveyed during two weeks in February 2011. Satisfaction levels are grouped by waiting times in Figure 66 Visitor satisfaction. A very high proportion was very satisfied. Nobody was dissatisfied. Even the very few with longer waiting times were somewhat satisfied, which can be seen as indication that the waiting time did not differ from expectations, i.e. the information material was good.

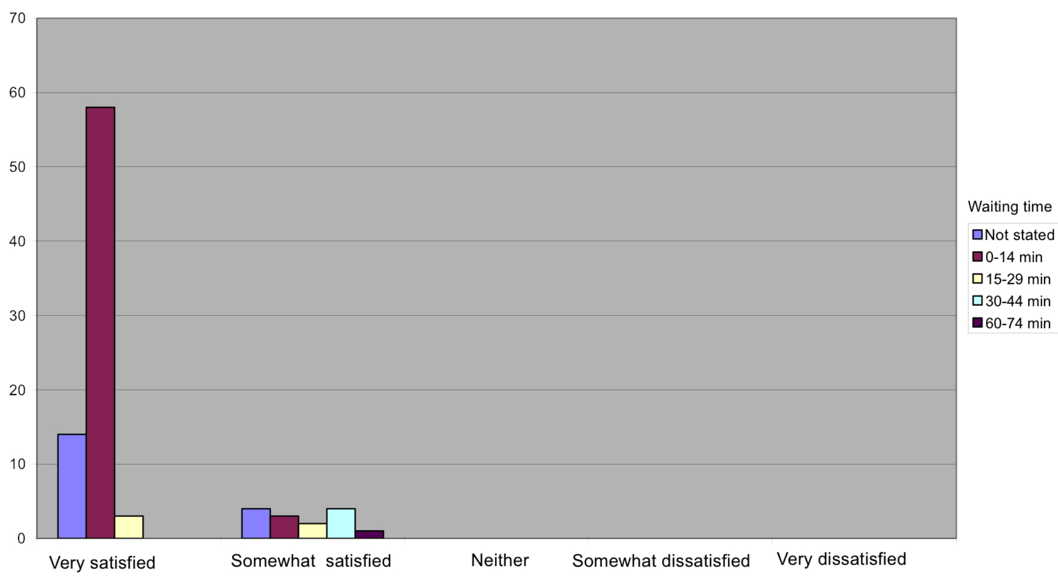



*Figure 66 Visitor satisfaction*

At a follow-up meeting after the evaluation the group was satisfied that the project had turned out well. Some minor issues were to be handled:

- Improving the information material
- Signage to the unit
- Signage within the unit
- Queue numbers

When discussing the value of the simulations, the deputy obstetrics manager in charge of daily operations said, “The simulations made it exceptionally clear where the problems were”.

## Case 10 – Malignant melanoma of the skin

This is a major project spanning several years financed by Vinnvård. The process began with a presentation about System Dynamics to the manager of the dermatology clinic at a major university hospital. The clinic formulated the following issues:

- Analysis of patient flows.
- Effects of changes in care programs?
- Effects of continued increase of incidence?
- Prepare different scenarios for different incidence rates.
- How can prevention and early diagnostics affect disease trajectories?

This case description summarizes the main investigative paths that were followed.

### Excerpts from the research proposal

The main focus of this project is how a revised care program for malignant melanomas can affect patient flows through the four clinics that are primarily involved and anticipate and respond to possible future changes in the supply of and demand for these clinical services.

Above all, the sub-project will contribute to the development of work methods and management systems that increase the capability of work groups to develop and improve their work methods in the long term. This is done by democratizing and developing efficient methods for organizational development and building on quality register data and evidence.

The sub-project will be based on an action-oriented research methodology. A System Dynamics model will be developed by representatives from participating units. It will be built used group modelling techniques giving the researchers the basis for model building. Models will build on actual data and evidence. Completed models will be evaluated and developed to a computerized simulation model judged to realistically replicate the functions of the studied activities. The more detailed steps in our work are described below.

We intend to develop a generic project model, which can be used for different purposes. When developing it we will be studying other attempts, such as Wolstenholme's generic project model (Figure 67), which has been applied in several studies in the National Health Service.

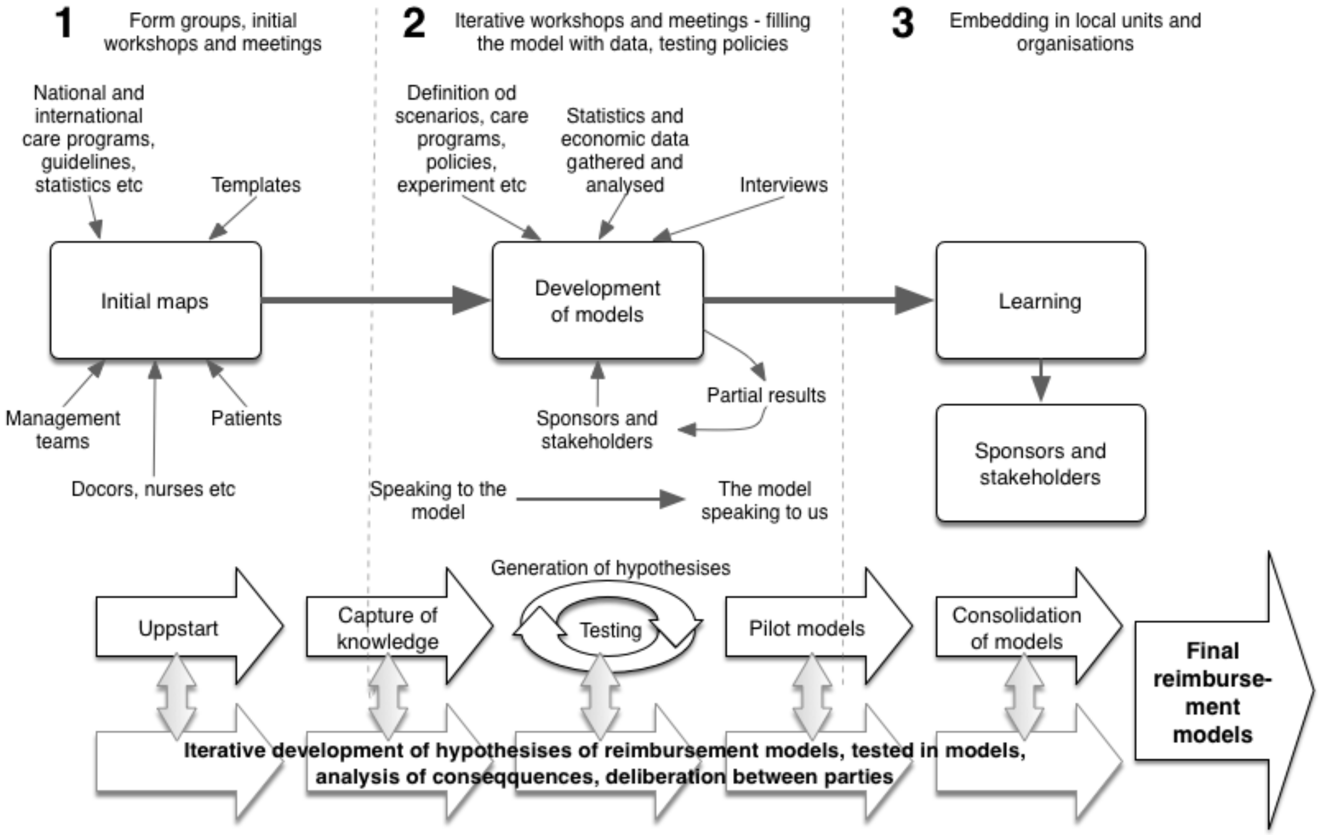



*Figure 67 Project plan based on Wolstenholme et al., (2004)*

The project starts by defining objectives and tasks based on input from stakeholders and the clinical project owner. To this we add available information such as national or international care programs, guidelines, evidence, statistics etc. We also plan to interview and meet key persons. Based on this we create initial maps and create early models based on our own experience and applicable models from other countries.

Thereafter we begin an iterative process in collaboration with a work group and the stakeholders. The model is developed in steps. First, we ensure that it correctly replicates the present situation, as described by each stakeholder, to ensure that the model reflects each relevant perspective of the actual situation. Then we together test different scenarios and policies. As the model is refined, additional relevant data is input.

### The project and steering groups

The core project group consisted of a senior dermatology specialist / associate professor, a dermatologist in specialist training and Ph.D. student, me and another system dynamist. The steering group included the professor of Dermatology, the clinic manager and the clinic research coordinator.

The project was initially planned to run over 3 years, but took 6. This was due to balancing the research effort and the clinical workload of the participants from the clinic. The project was in hibernation for almost a year waiting for ethics approval before we could access data from the Swedish Cancer Registry. In all, both groups met about 60 times.

Project outcomes have been presented in academic journals and conferences and are listed at the end of this case description. This case description aims to describe the research process and the investigative work.

### Patient flows

The system dynamists received a thorough introduction to the different forms of skin cancer, types and classification of malignant melanoma. We also studied national and regional cancer statistics and guidelines and care programs for malignant melanoma.

The increase in incidence was a major concern.

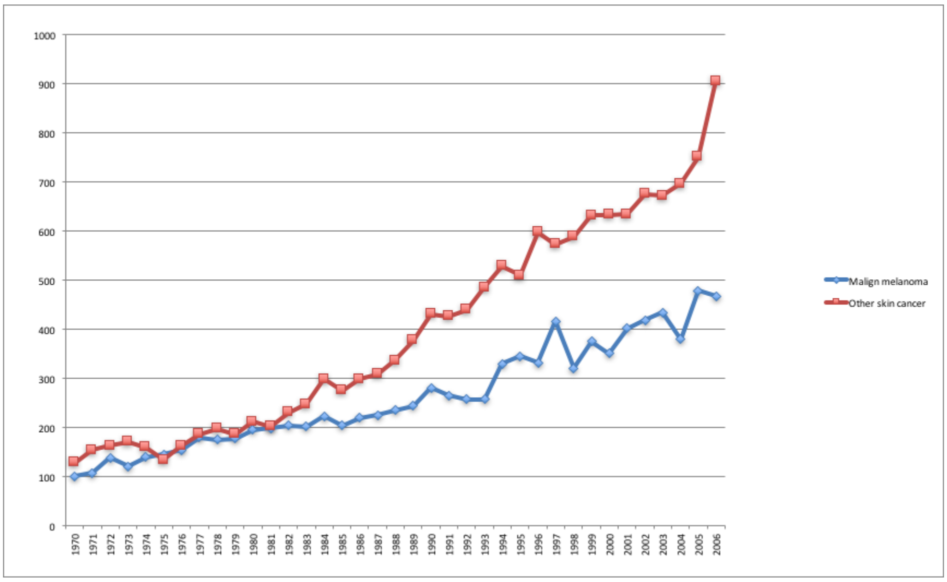



*Figure 68 Incidence of malignant melanoma (blue) and other skin cancers in the Western Region of Sweden*

The studied clinic had approximately 4000 tumour related visits per year, I mapped the pathways as shown in Figure 69. 60% of these are referrals indicating suspected cancerous tumour. The remaining 40% are scheduled check-ups of patients diagnosed with severe cancer to check for relapse or patients belonging to genetic risk groups. Most are examined at tumour rounds at the department of dermatology, a small group are examined acutely, and an even smaller group have such large suspected cancers that they may require plastic surgery and are examined jointly by dermatologists and plastic surgeons. 30 % (1200) have surgery to excise the suspected cancer tumour and the tumour is sent to pathology for diagnosis. Of these, 150 patients are diagnosed with malignant melanoma and a subset of them are moved to regular check-ups.

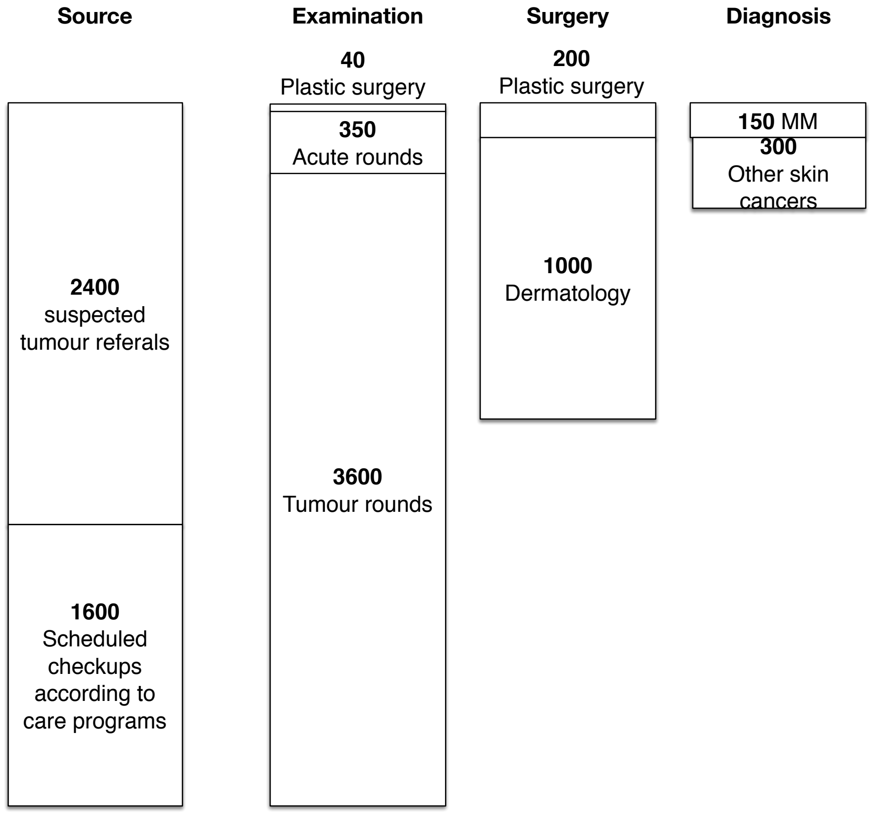



*Figure 69 From referral to diagnosis*

I also created a diagram of patient flows (Figure 70) to use as a basis for a tentative System Dynamics model (Figure 71).

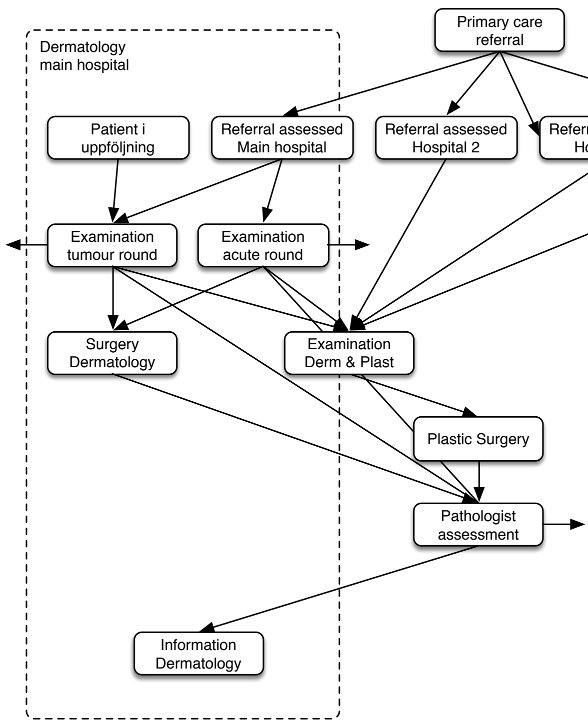



*Figure 70 Initial patient flow diagram*

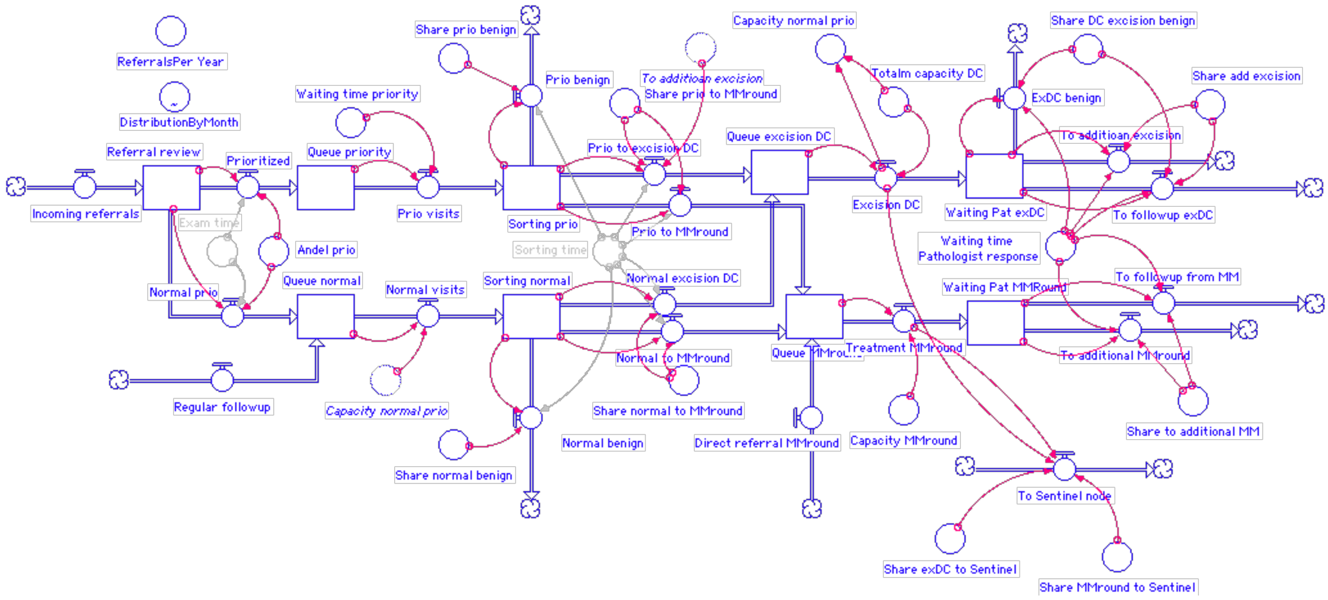



*Figure 71 Tentative System Dynamics model*

To get data to populate the model I interviewed the reception staff and the department statistician and concluded that there was such a lack of data that it was not possible to continue with tentative model. We discussed this in the work group and with the reference group and decided to build a generalised model with estimated data and instead focus on studying the effects of different follow-up programs.

I also sent a questionnaire to several primary care units to find out what proportion of patients concerned about pigment changes resulted in a referral to the dermatology department and got so few responses that the particular study was cancelled. I also attempted to find data about leisure travel to sunny destinations in the winter and the number of sunbeds, but travel data was expensive to buy and sunbed data was not accessible.

## Incidence and cancer growth rates

We rapidly decided to build a model replicating incidence and cancer growth to use as a base for experimenting with different interventions. We realised that the concept of incidence is not well suited for simulation purposes. Incidence is at the point of diagnosis. In the case of cancers, it may be more or less advanced when diagnosed and there are stage definitions. In other words, the cancer has occurred before it is diagnosed. When building a simulation model, we want to capture that at some point after cells mutate, a cancer occurs and eventually is observable. From that point in time there is a patient's delay until the patient observes, grows concerned and seeks medical help after which there is a doctor's delay until diagnosis and initial treatment.

Inspired by a paper by Homer, Hirsch et al (2004) and Wolstenholme et al (2007) my System Dynamics colleague conceptualised and built a "patient generator" (Figure 72), where a cancer would occur and be unknown and grow along the stages on the vertical axis. At some point the patient seeks medical assistance and the cancer becomes suspect along the horizontal staging (patient's delay) and is finally diagnosed and treated (doctor's delay). The concept allows for changed cancer staging e.g. while waiting for examination etc. The principles were realised in a model as shown in Figure 73.

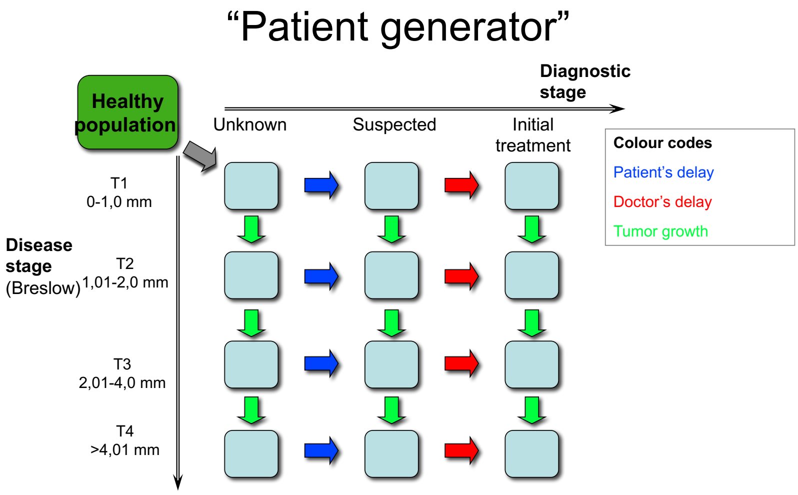



*Figure 72 Patient generator principles*

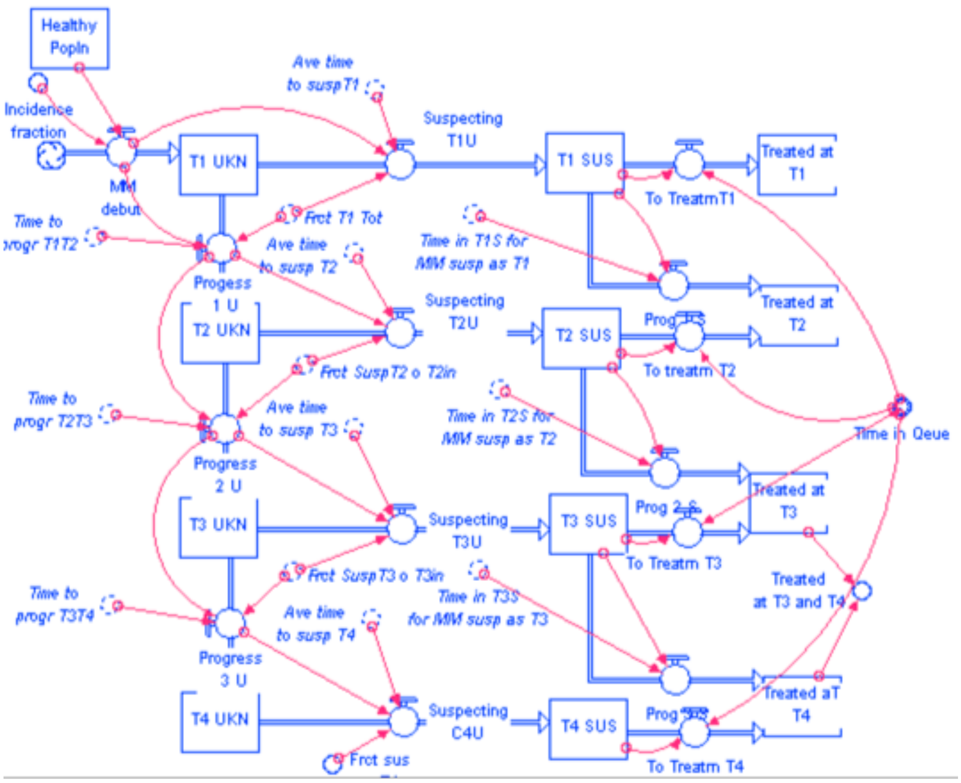



*Figure 73 Patient generator System Dynamics model*

The dermatology specialists in the work group and reference group did extensive literature research to find papers where cancer growth rates had been studied. As blind studies with cancer patients are not done in order to study growth rates, other methods have been used such as examining older photos of patients to narrow down the time slot when the cancer was observable. There are several classifications of different types and staging of malignant melanoma, but we decided to simulate two general categories: slow and fast growing. My colleague built models replicating tumour growth for the two categories.

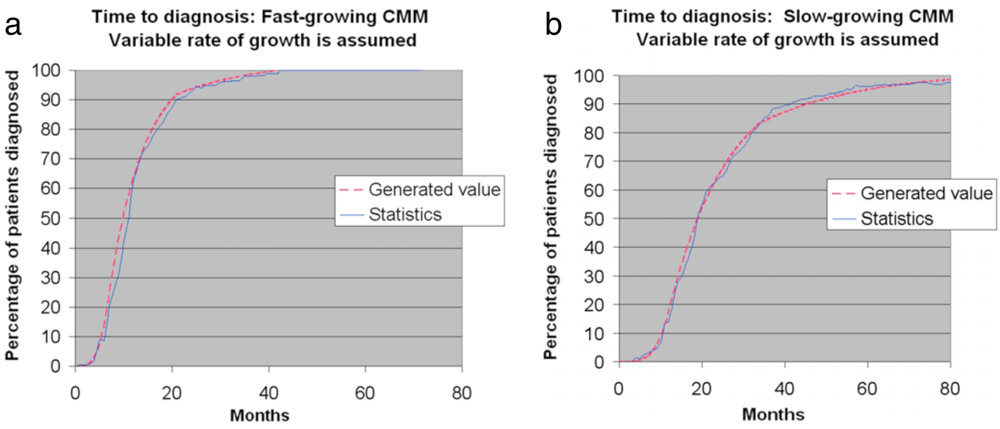



*Figure 74 Matching actual tumour growth with simulated*

To finalise the model, we needed assumptions about patients' and doctor's delay, respectively, for the two categories. After extensive research the dermatologist uncovered a paper by Blum et al (2007), which provided sufficient data. My colleague built a flight simulator to test the effects of different patients' and doctors' delays on health outcomes.

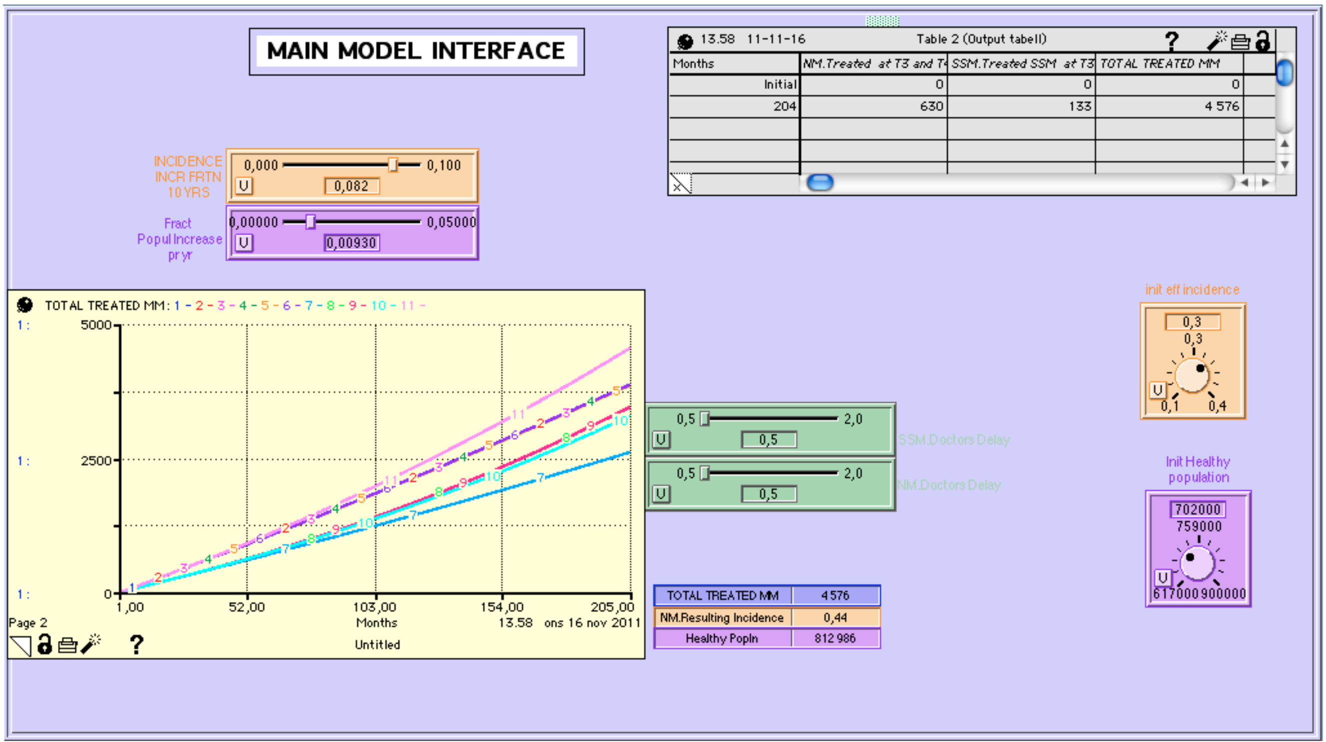



*Figure 75 Main model interface*

What we did was a form of reverse logic. Medical studies are usually about procedure seeking statistical confirmation. Our approach was the reverse - analytical results seeking medical procedure – what is worth doing.

It is often believed that it is most important to shorten the delay between patients seeking care and receiving treatment. The model showed the doctors' delay is so low at the clinic that making it shorter does not have any significant effects. However, Blum's paper shows that patients' delay can be 1-2 years. If the tumour is aggressive the time is shorter, but becomes more severe before treated. In the model, we assumed that 80% of the patients can be influenced and adapted the s-curve for accumulative time (Figure 76). Health outcomes are shown in Figure 77. The more patients that seek help earlier the fewer patients are diagnosed in the most serious stages, meaning higher survival rates, better health outcomes and lower healthcare costs.

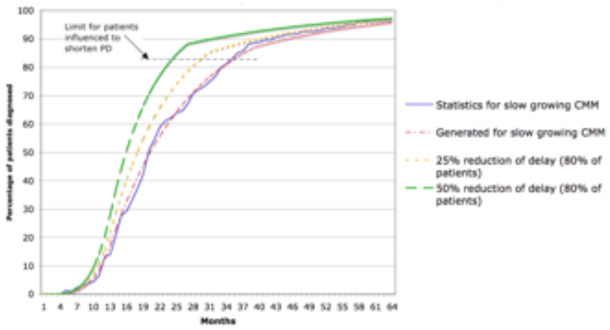



*Figure 76 Accumulated patient's delay, actual and shortened 25 and 50% respectively*

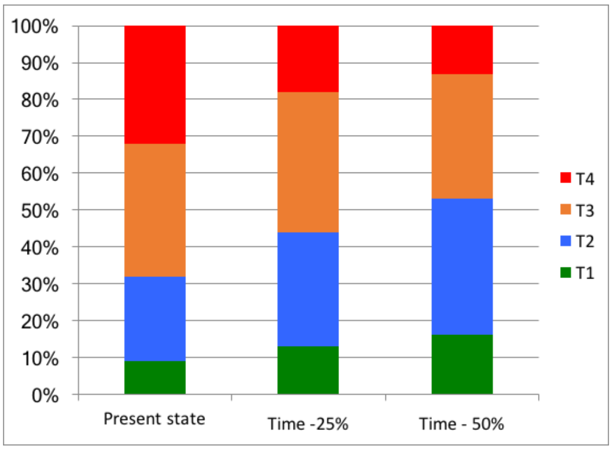



*Figure 77 Patients' health outcomes by stage*

The National Board of Health and Welfare publishes national guidelines for malignant melanoma, but it is up to each health region to establish care programs. Two members of the work and reference group have studied differences between the three largest healthcare regions as to how patients with malignant melanoma are followed up, Paoli and Claeson (2011). The differences by stage are shown in Table 6.

| **Western region** | **Stockholm region** | **Southern region** |
|---|---|---|
| • Stage 0-IA (MM in situ / LM / MM < 1mm no ulc.)<br>Individual decision about follow-up<br>• Stage IB (MM > 1mm with ulc or MM 1-2 mm)<br>Every 6 months for 5 years<br>• Stage II A, B and C<br>Every 3 months year 0-2, then every 6 months year 3-5<br>• S Stage III (N1a-N3)<br>Every 3 months year 1, every 4 months year 2, every 6 months year 3-5, annual until year 10 | • Tis-T1 (MM in situ / LM / MM < 1mm)<br>No follow-up<br>• T2 (MM > 1mm)<br>– Every 3 months for 3 years, photo doc every 6 months<br>– Every 3 months year 3-5 by primary care<br>• Stage III (N1a-N3)<br>Every month year 1, every 2 months year 2, every 3 months year 3-5 | • MM < 1.5 mm<br>One follow up postop<br>• MM > 1.5 mm<br>Every year for 3 years |

*Table 6 Regional differences in the follow-up of malignant melanoma*

I built a System Dynamics model to be able to compare the effects of the different care programs on resources. The interface is shown in Figure 78. We searched for information on regional health outcomes but were not able to find data that supported the analysis of the health consequences of the differences. The intention of the model was to study the effects of the number of initial visits, follow-up visits and the effects of more precise referrals allowing the number of referrals that do not lead to diagnosis to be cut. The graph in the lower right hand corner shows the number of visits depending on regional follow-up regime, based on the patient numbers of the region. Even if West and Stockholm have different care programs, the number of visits are almost the same, but substantially lower for South.

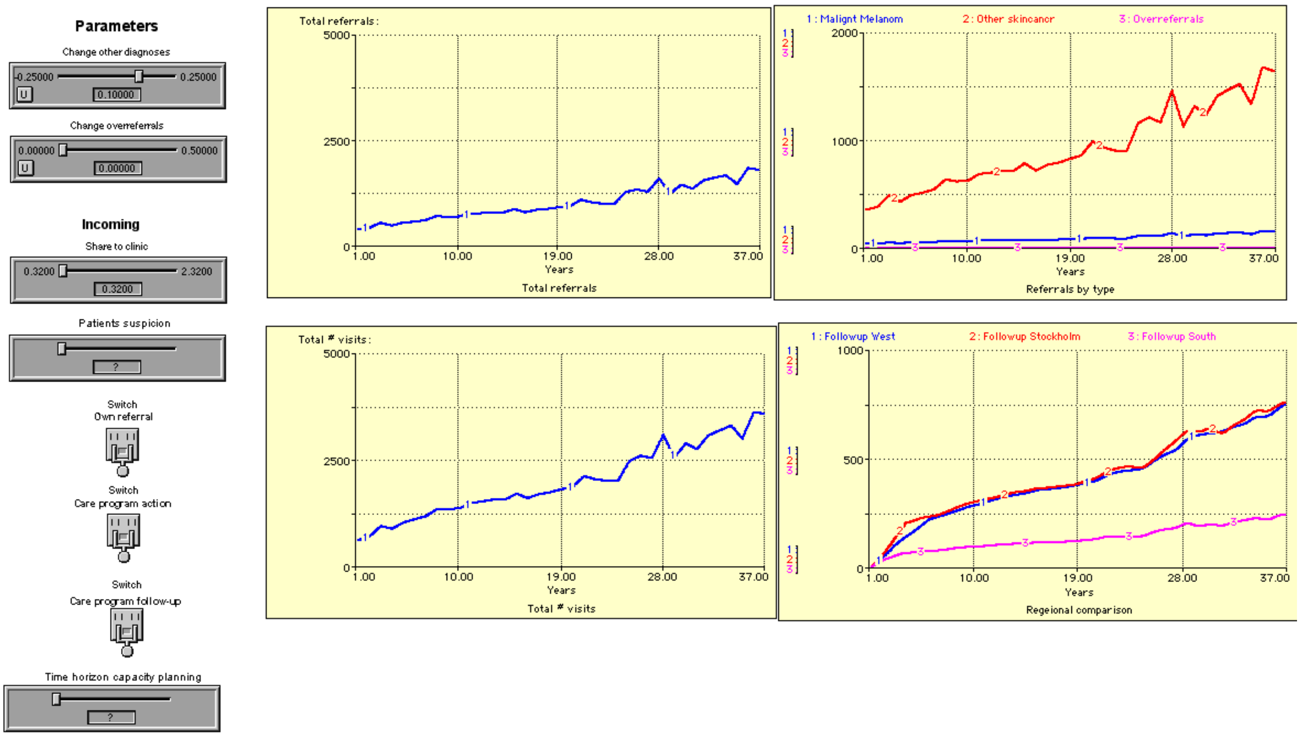



*Figure 78 Initial System Dynamics policy model*

We decided to study the different care programs of the Western region, with the intention of building a policy model allowing us to experiment with different care programs. As an example, the analysis of one of the melanoma stages is shown below. Figure 79 shows the accumulation over time share of patients who have a relapse or metastasis. Figure 80 shows the same accumulation, but with the check-up points in red. Assuming that all relapses or metastases are found, the accumulation is reset as shown in Figure 81. As can be seen the risks peak at between 5 and 4%. This lead to a lot of discussion in both the work group and reference group. No matter how regular the screening, it is important that patients self-examine their skin. If there is a relapse, metastasis or new melanoma directly after a check-up it can become very malign if not spotted until the next planned examination. We decided to incorporate the effects on number of visits based on different acceptable risk levels in the model being built. Figure 82 show that if a risk level of between 5-7% is accepted then only 4 follow-up visits may be required instead of the planned 14.

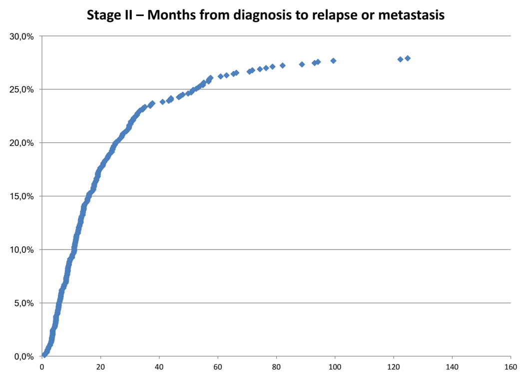



*Figure 79 Accumulated time from diagnosis to relapse or metastasis*

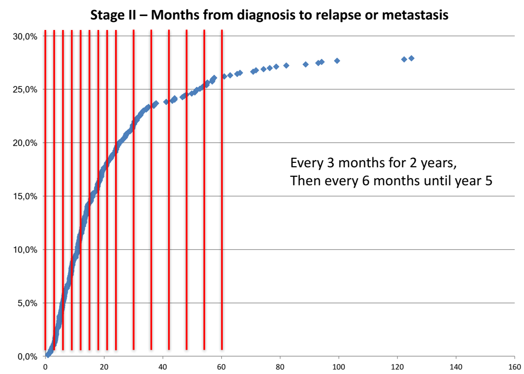
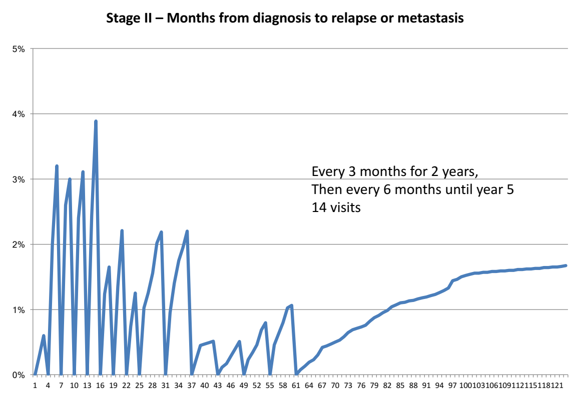



*Figure 80 Accumulated time with check-up points in red*



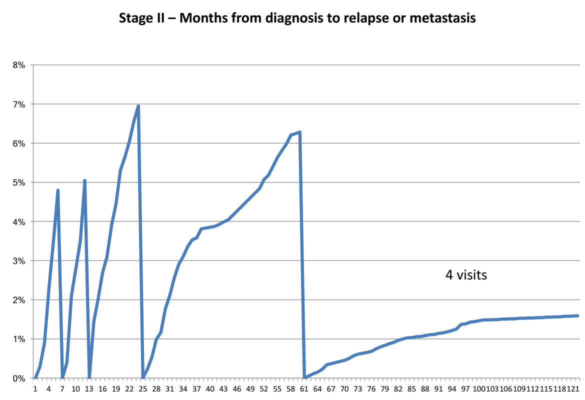




*Figure 81 Accumulation assuming all melanomas are found at check-up*

*Figure 82 Alternative check-up points allowing 5-7% risk*

I finally built what we called the logistics model, the basic structure as shown in Figure 83, with red arrows indicating parameters that can be adjusted in the user interface. The model uses data on the healthcare costs and societal costs of morbidity and mortality based on a study carried out at Linköping's University by Tinghög, Carlsson, Synnerstad, and Rosdahl (2007).

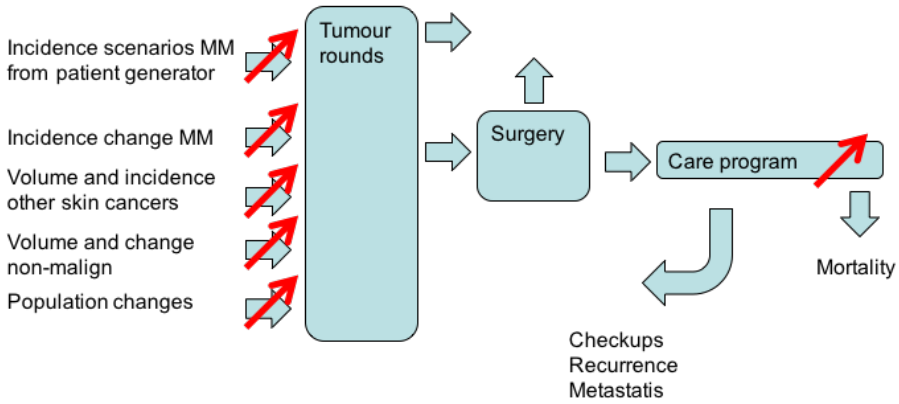



*Figure 83 Structure of the logistics model*

Figure 84 shows the interface and the base run of the model. The model allowed to experiment with the following parameters:

- Patients delay 100% (i.e. unchanged) or reduced to 75% or 50%
- Selection of risk level in follow-up programs, unchanged, up to 2%, 4% and 6% respectively
- Annual population growth
- Incidence rate malignant melanoma
- Incidence rate other skin cancers (included here as they use the same resources)
- Ratio benign referrals, i.e. visits that could have been avoided to some extent

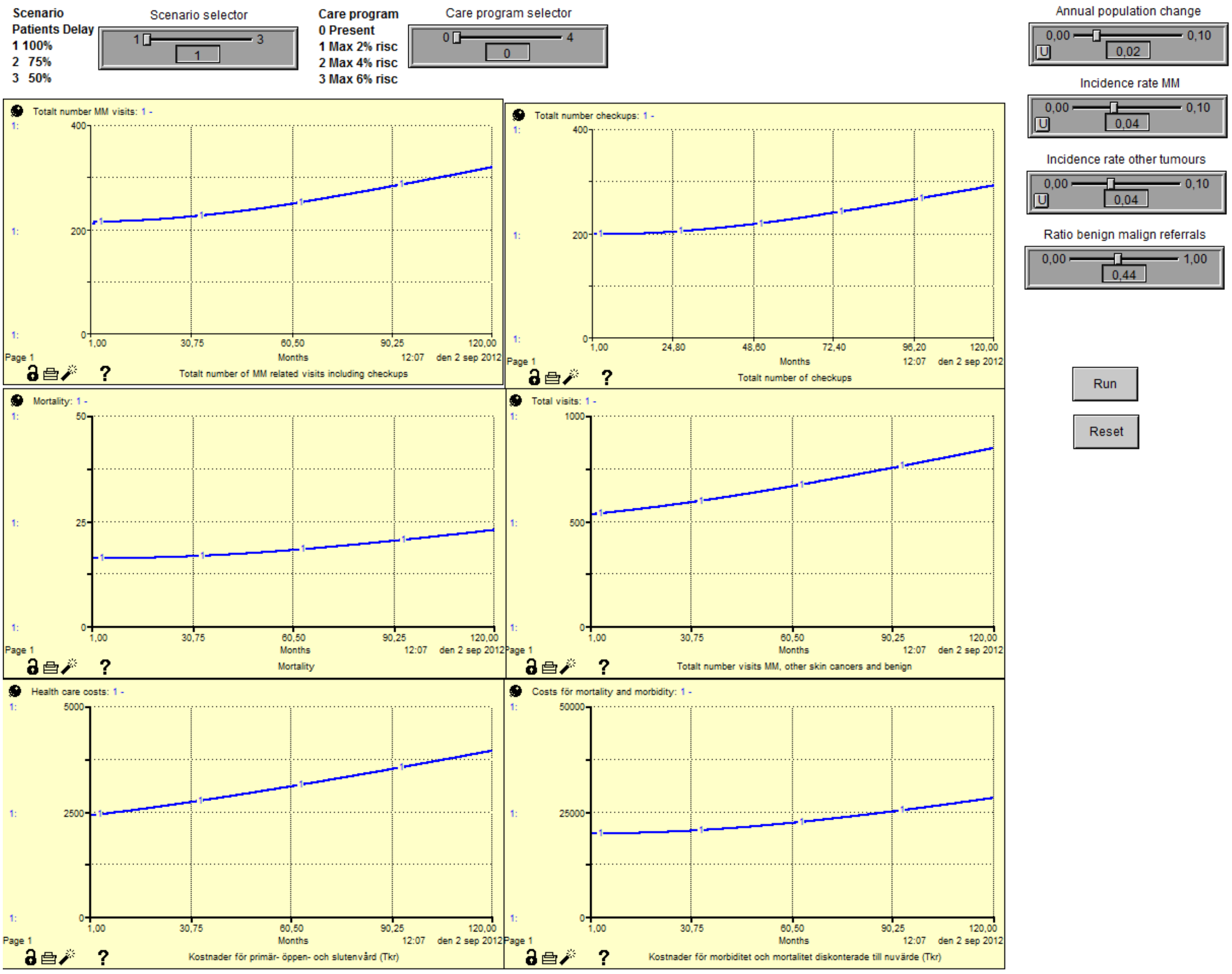


*Figure 84 Interface and base run of the logistics model*

At the end of the project we had a workshop with the work group, reference group and key staff in smaller groups each with a computer running the model and exploring any scenarios that they wanted. One key finding was that the best health outcomes were a result of cutting the patient's delay by 50%. Figure 85 shows the base run and the effect of patient's delay. The participants in the workshop noted that even after such an intervention, and if there is no change in incidence, then health outcomes are back to the starting point. So not only is early discovery important, but also prevention. Changes in care programs and referral quality had negligible effects on outcomes.

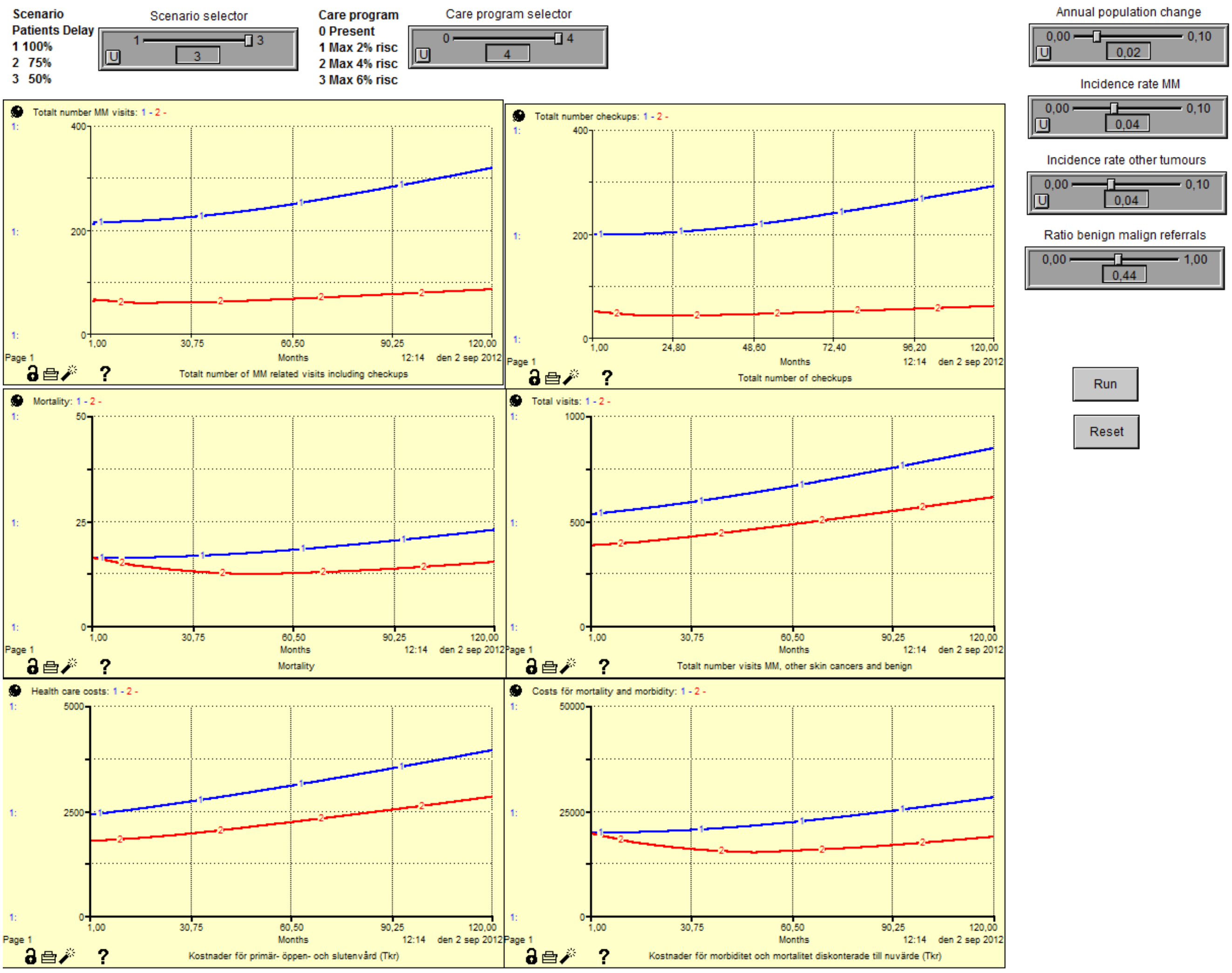



*Figure 85 Cutting patient's delay by 50%*

## Academic presentations and papers

The main results have been published in two academic journals. One paper from a medical perspective and the other from a System Dynamics perspective:

Claeson, M., S. Hallberg, P. Holmström, A.-M. Wennberg Larkö, H. Gonzalez and J. Paoli (2015). "**Modelling the Future: System Dynamics in the Cutaneous Malignant Melanoma Care Pathway**." Acta Dermato-Venereologica 96(2): 5. *

Hallberg, S., M. Claeson, P. Holmström, J. Paoli, A.-M. Wennberg Larkö and H. Gonzalez (2015). "**Developing a simulation model for the patient pathway of cutaneous malignant melanoma**." Operations Research for Health Care, 6: 23-30.

Claeson M, Holmström P, Hallberg S, Gillstedt M, Wennberg A-M, Paoli J. ”**Multiple primary melanomas: A common occurrence in Western Sweden**”. Accepted for publication in Acta Derm Venereol 2016*

Results have been presented at conferences:

M Claeson, P Holmström, S Hallberg, H Gonzalez, A-M Wennberg, J Paoli, **Multiple primary melanomas in Western Sweden; 1990-2013**, Poster at the 3rd International Conference on UV and Skin Cancer Prevention, Melbourne 2016 *

Claeson, M., S. Hallberg, P. Holmström, A.-M. Wennberg Larkö, H. Gonzalez and J. Paoli. “**Modeling the future - System Dynamics in the health care pathway of cutaneous malignant melanoma**”. Poster at the 2nd International Conference on UV and Skin Cancer Prevention, Berlin 2013

Holmström, P., M. Claeson and S. Hallberg (2012). A System Dynamics '**Flight Simulator' for the Evaluation of Policy Interventions in Patient Pathways for Cutaneous Malignant Melanoma**. The Operations Research Society Conference 54, Edinburgh, OR Society.

M. Claeson, "**Modeling the future - System dynamics in the health care pathway of cutaneous malignant melanoma**". Invited speaker at the conference "Facts and consensus about skin cancer prevention", Vadstena, Sweden, 2016.

Partial results were also presented at meetings arranged by the Swedish Association of Local Authorities and Regions:

2010, On the theme of the value of simulation for researchers working with simulation in healthcare
2009, An inspirational day about simulation-based management for regional directors and managers

*) Two of the papers form the core of M Claeson's doctoral thesis:

Claeson, M. (2016). **Epidemiology of cutaneous malignant melanoma in Western Sweden**. Doctor of Medicine, University of Gothenburg.

## Case 11 – Lung cancer

### Project context

The project was initiated by the West Regional Cancer Centre that was running a development program for regional cancer process leaders in cooperation with the Centre for Health Care Improvement at Chalmers. The project was funded by Swedish Association of Local Authorities and Regions. Below excerpts are from the research application.

**Purpose**

The purpose of the project is to model and simulate how reimbursement constructs can ease and stimulate more coherent and efficient cancer care from a patient perspective. In addition, it will create improved conditions for learning and decision-making in the steering of health care. The learning will take place through

- Modelling as a method to improve learning around the context of care processes
- Simulation to test possible effects of changes in reimbursement and other steering systems
- Testing to develop a model based description of internal dependencies in the healthcare system.

**Expected results**

A process model that

- Integrates quantitative and qualitative data, including costs, where
- Leverage points can be identified, and
- Optimal effects be achieved in order to process quality and good cancer care, through
- Changed reimbursement models

It will be possible to apply the process model on the other 20+ cancer processes included in the investment on regional process owners, where the possibilities of diffusion throughout the region should be high. As other regions are developing similar process orientation then the model can be expected to be useful also outside the region.

**Project plan**

The project will begin by defining objectives and tasks from stakeholder groups and commissioning authorities in the entire care chain, see the project model below. We will then map available information in the field such as care programs, guidelines, evidence, current care processes, data from quality registers, hospital production planning and the regional care database, cost per patient, DRG-based reimbursement etc. We will be interviewing and meeting key persons.

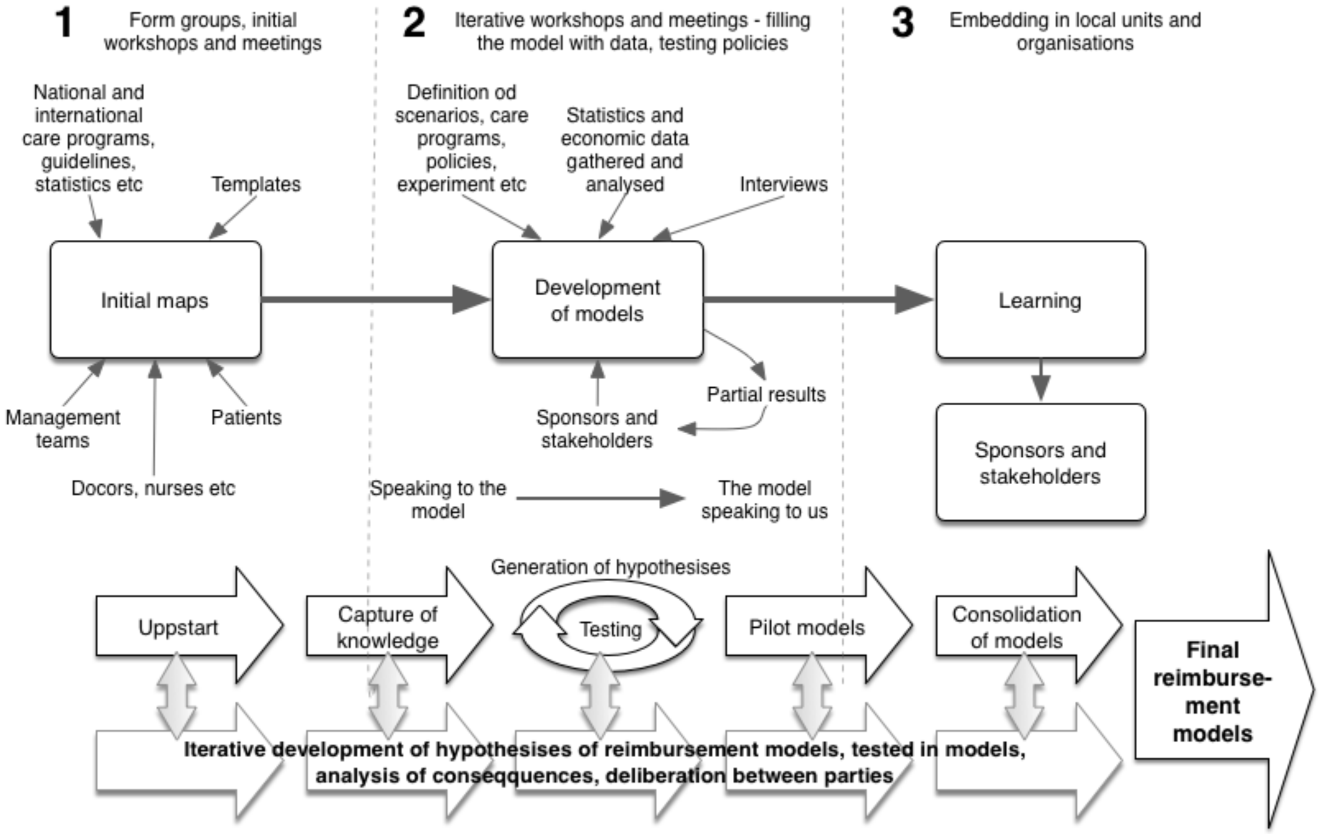



*Figure 86 Project plan based on Wolstenholme et al., (2004)*

Based on this we will build initial models based on our own experiences and appropriate models from other countries. The model will be developed in steps. We begin by ensuring that it replicates the present state as described by the respective stakeholders. The purpose is to ensure that the model shows relevant perspectives on reality. Then we together test different scenarios and policies. As the model is refined, more data is added. The method can be seen as a plan-do-study-act cycle where model, hypothesises etc. grow iteratively and through mutual learning within and between groups along the entire care chain.

By continuously switching between action and reflection in and between groups along the care chain, deeper understanding of cause-effect is achieved. We believe that modelling and simulation can accelerate learning and affirm the motivation of co-workers in the care chain. The ambition is to jointly identify the factors, including reimbursement models, which can affect the outcomes of patients in the complex system.

Before each cycle, hypothesises are developed by developing the model further and adding data. During the work leverage points are identified, i.e. that which creates a lot of value in relation to efforts. In addition, one can study the risks of sub optimisation and undesired side effects. Every cycle sharpens the analysis and learning as process and effects are made explicit. Hypotheses can be developed as to the effects of reimbursement systems when simulated in the model.

Finally, there will be a complete model with relevant scenarios and policies. As different stakeholders and actors have been involved in the process, it can be expected that they will rally around the model as such. Through simulation desired outcomes can be identified, in turn leading to stances on policy, routines and reimbursement models to achieve the desired results. As simulations allow different scenarios to be tested, it is possible to focus on high impact and relevant scenarios, and avoid scenarios with undesired effects.

## Project groups and work

The research group consisted of a senior lung cancer specialist acting as regional and local process owner, a local process mapping specialist, and me and another System Dynamics modeller. The research group has met around 25 times over a two-year period for mapping, discussion and analysis. As the project was so extensive, mainly highlights relevant to my thesis are included in this case description.

A reference group was formed with representatives from patient groups, hospitals, commissioning units, the regional health care office and the regional cancer centre. The reference group has met three times during the project and a fourth time for taking part of the results.

Members of the work group have presented intermediary results at two workshops and the final report at a national conference arranged by the Swedish Association of Local Authorities and Regions. The work group has held two presentations for a group of regional cancer process leaders as well as two workshops with staff at the involved hospital.

### Phase 1

The project group began by identifying the key issue, which was the time from a referral for suspected lung cancer until a diagnosis was established. Figure 87 shows cumulative numbers over time for the hospitals in the region. For the hospital studied, the median time was 33 days and it took 79 days to diagnose 80% of all referrals. The longest recorded time was 203 days. It took longer to reach a diagnosis for those that did not have lung cancer as more tests needed to be taken to discount the lung cancer hypothesis. The arrows in the graph shows the directions that the curve needs to be pushed towards.

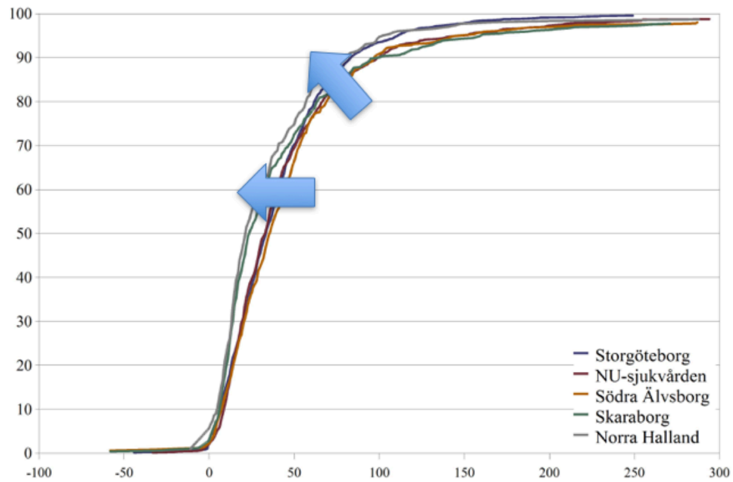



*Figure 87 Cumulative days from registered referral to treatment decision for 5 hospitals*

The purpose of the project is to reach a qualified diagnosis faster in order to reduce the risk of tumour growth during the diagnosis period, reduce patient uncertainty and use resources efficiently.

There is significant variation in referral inflows, +/- 33% on a monthly basis and + 150% / - 75% on a weekly basis. When a diagnosis was reached, 50% do not have lung cancer, 13% are treatable, 25% have metastasised and 12 % are too far advanced. Interestingly, patients referred for suspected lung cancer but diagnosed as such cannot be easily identified through the patient record systems, and the records had to be studied manually.

The process owner began a manual study of patient records and recorded steps and time in a Gantt chart spreadsheet. An example is shown in Table 7.

| | | | | | 1 | | | | | | | | | | 10 | | | | | | | | | | 20 | | | | | | | | | | 30 | | | | | | | | | | 40 | | | | | | | | | | 50 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2010-09-20 | Lung x-ray primary care | Suspected malign | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2010-09-27 | CT thorax primary care | Suspected maiign | | | | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2010-09-29 | Phone consult lung clinic | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2010-09-29 | Referral to lung clinic | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2010-09-30 | Referral to clinic registered | | 0 | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2010-10-06 | Parallell referral from oncology | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2010-10-13 | First visit lung clinic | | 13 | | | | | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2010-10-13 | Lung x-ray primary care | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2010-10-13 | Spirometry + CD-diff | no remark | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2010-10-13 | Referral broncoscopy | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2010-10-21 | Broncoscopy | Failed | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | |
| 2010-10-21 | Referral broncoscopy sedation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| 2010-11-01 | Broncoscopy sedation | Sample taken | 11 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | | | | |
| 2010-11-10 | Response 1 PAD | Adenocarcinom | 9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | X | X | | | | | |
| 2010-11-10 | Visit clinic for info | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | |
| 2010-11-15 | Response 2 PAD | Adenocarcinom | 14 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 2010-11-15 | Referred to breastcancer team | | | 46 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X |

*Table 7 Example of data from patient records*

The time charts were discussed extensively in the project group. We found the approach most useful as the process owner with hindsight could review decisions taken about tests etc. and we could see that much time was spent waiting for tests, waiting for results or waiting to arrange follow-up meetings. Over time, more and more patients were studied until one year's cadre had been included.

Interwoven with the study of records the process owner also defined an ideal process (Table 8), which could be carried out in seven work days.

| 0 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Referral received | First visit | PET-CT | Bronchoscopy EBUS | CT-led TTNA | Msk | Summing up |
| Referral reviewed | Spirometry | Work test | Pleuraus | | | Decision |
| | CO-diff | | Other biopsies | Subtyping | CA-leg | Inform patient |
| | Lung x-ray | | CA-leg | CA-leg | Subtyping | |
| | Lab | Card-bed | | | | |
| | Radiospiro | PET-round | | | | |

*Table 8 Ideal diagnostic process*

The patient record study identified factors that contributed to longer time to diagnosis

- Sub-optimisation due to allocation of external examination costs
- Early patient-doctor meetings with junior doctors led to more tests and longer time
- Delays due to other units
- Tests performed in wrong order, according to availability instead of relevance
- Unnecessary patient-doctor meetings generate reimbursement without providing value and take time
- Follow-up by phone can be quicker but gives no reimbursement
- Delays between ordering test and implementation, delays in reporting results, delays in reading results.

As the project group produced data, analysis and conclusions were shared and discussed extensively with the reference group, providing direction for next steps. The manual review of patient records provided very rich quantitative and qualitative data.

The lung clinic was reimbursed on principles of an annual fixed budget, whereas the hospital had a mix of fixed allocation, activity-based reimbursement and up to 4% target related reimbursement. When the clinic used local radiology services they were "free" for the clinic as radiology also was reimbursed by budget. However, national guidelines recommend the use of Positron Emission Tomography (PET), which in most cases clearly indicates if cancer is present. The only PET resource is located at the regional university hospital and the local lung cancer clinic is invoiced per usage. As PET, then was relatively new and had insufficient capacity, this was under-budgeted at the clinic.

The insights provided by the patient record analysis led the process owner to develop a hypothesis that there were three almost equal contributors to the long time to diagnosis:

- Time wasted due to lack of orderliness
- Suboptimal patient flows – production systems
- Balancing capacity and the significant variation in patient flows.

The process owner rapidly addressed issues around wasted time. During the first year of the project time to diagnose 80% of all patients was cut from 79 to 53 days, without any need of change in the reimbursement system.

### Phase 2

In discussion with my System Dynamics colleague, I built causal loop diagrams to highlight the mechanisms of reimbursement systems. We wanted to discuss this with the reference group, and as it had representatives from several parts of the region we built slightly different diagrams to incorporate the different reimbursement schemes in use in the region, i.e. fixed budget, activity-based or a mix. We printed the diagrams as large work-sheets to facilitate discussion in the group (Figure 88 Worksheets with causal loop diagrams).

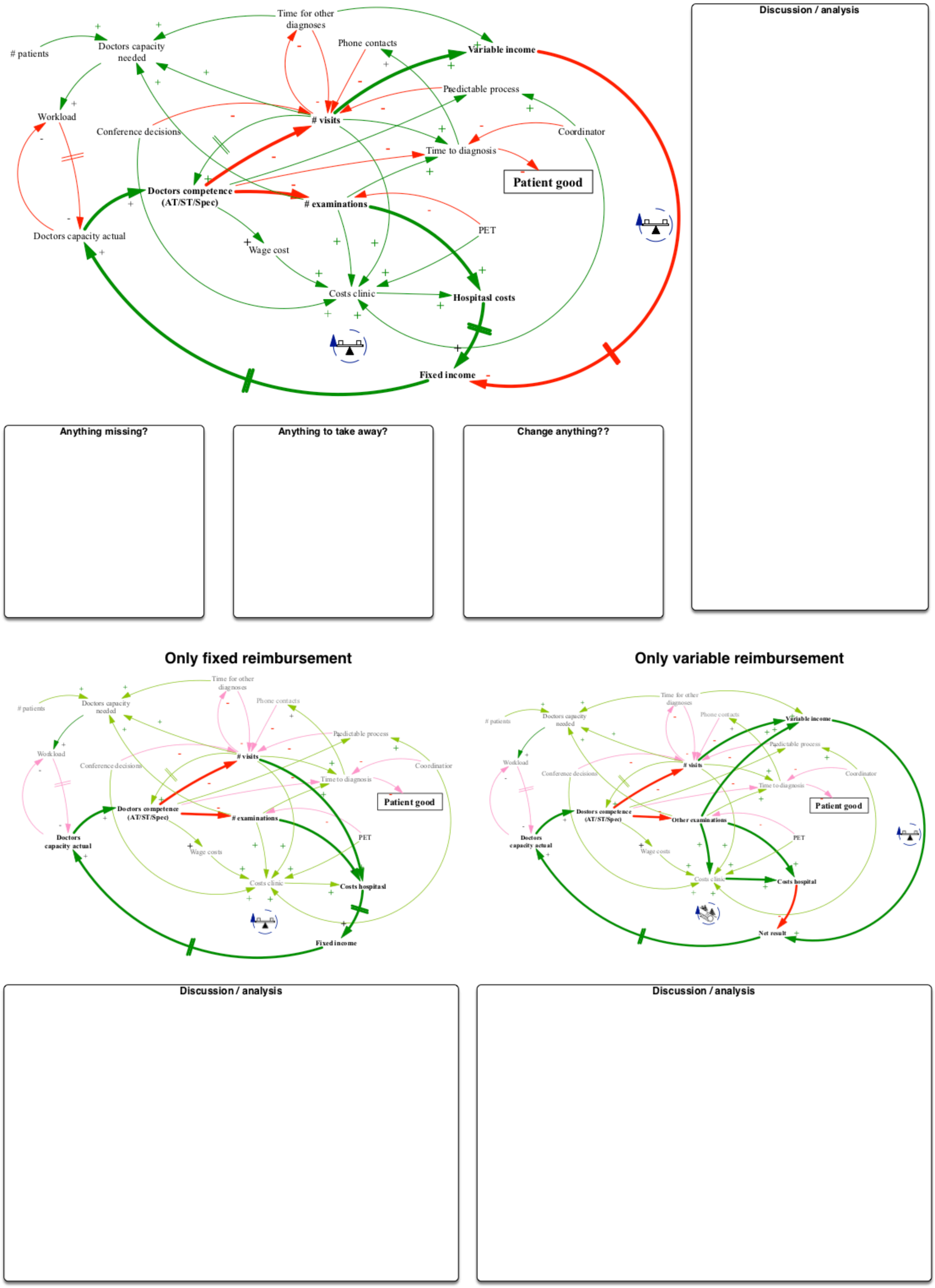



*Figure 88 Worksheets with causal loop diagrams*

Summary of the discussion in the reference group

- What to do with the positive results of efficiency?
  - Utility for citizens
    - Difficult to motivate in the organisation
    - Difficult to isolate specific effects
  - New needs emerge from specialities
  - Increased volumes eat up effectiveness
- Effects at the clinic
  - Shorter time to diagnosis (patient utility) is not an engaging objective
  - Standards are in place, but are they followed?
  - Other tasks than diagnosis of lung cancer also have priority
  - Resource allocation for lung cancer diagnosis and other activities (planned vs actual)
  - Dependency on other services such as radiology
- Required skills
  - At present funds are sparse for the training of specialists, how many years until a shortage is experienced?
  - Retaining competent staff is the problem, many factors influence
  - Which other competencies are critical apart from doctors?
- Effective process
  - Coordinators – from which profession?
  - Are coordinators the right way?
  - Early PET is right, but how to reimburse to achieve that?
  - Do standardised care processes lead to reduced need of doctors?
  - Planning and follow-up of capacity

The analysis in the project group focused on unintended consequences shown in the causal loop diagram.

- Often the patient initially meets an intern doctor, leading to more meetings and tests, which prolongs the time to diagnosis, but in an activity-based reimbursement system gives higher income.
- If a specialist physician does the initial meetings, a long-term effect of lower income can mean tighter finances for the clinic leading to senior physicians seeking work elsewhere.

The project group reached a point where we felt that we had a significant amount of data, but were unsure of how to proceed. As two members of the group did not have any experience of System Dynamics I built a small model (Figure 89) to illustrate the issues that we were facing. The model shows the effects of a randomized inflow of patients with fixed resources and time to diagnose. I built a "flight simulator" interface (Figure 90) to show how one can vary key factors like resources to cope with the variability of the inflow.

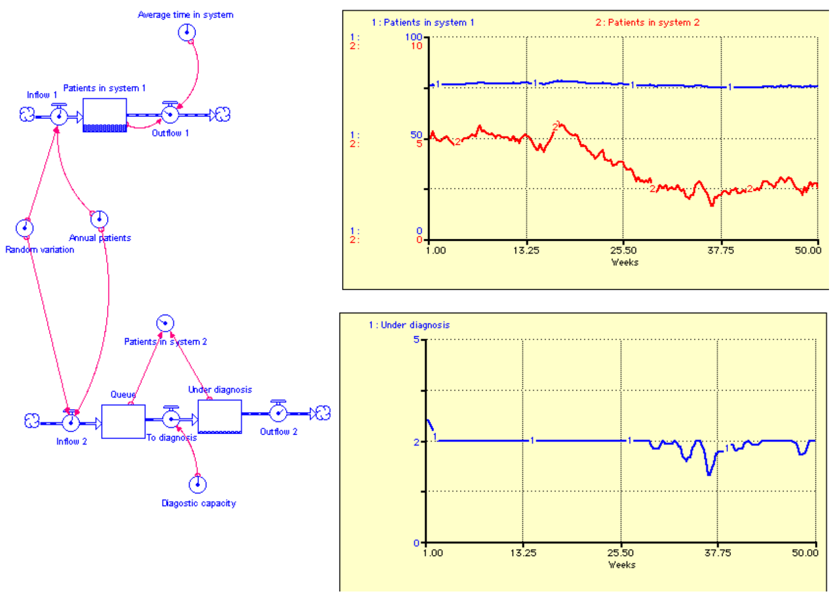



*Figure 89 Initial model to illustrate System Dynamics*

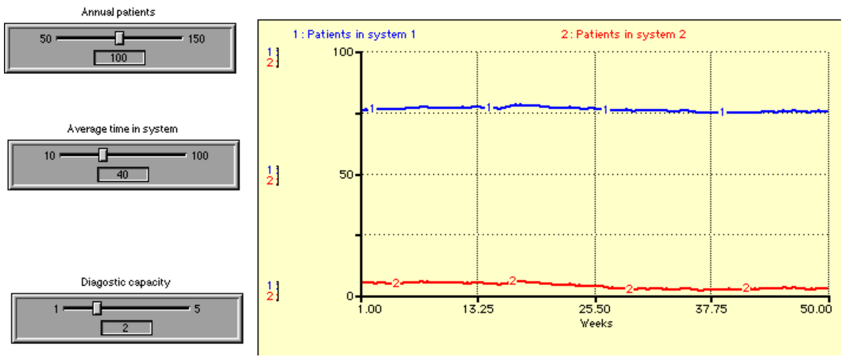



*Figure 90 "Flight simulator" interface of initial model*

The experimentation and discussion around this simple model created a lot of interest in System Dynamics as such to explore bottlenecks in the diagnostic process. Very often a knee-jerk reaction in healthcare is to request more resources. The group was asking itself if better planning can lead to positive results. We decided to identify a small number of basic pathways and focus on them and accept the fact that there will always be several outliers. The process owner went back to the mapping of patient records and identified two basic patient flows accounting for 86% of all patients (Figure 91). The combination of identifying the two basic flows and adapting the ideal process accordingly would allow the process owner to address the issue of suboptimal patient flows – production systems.

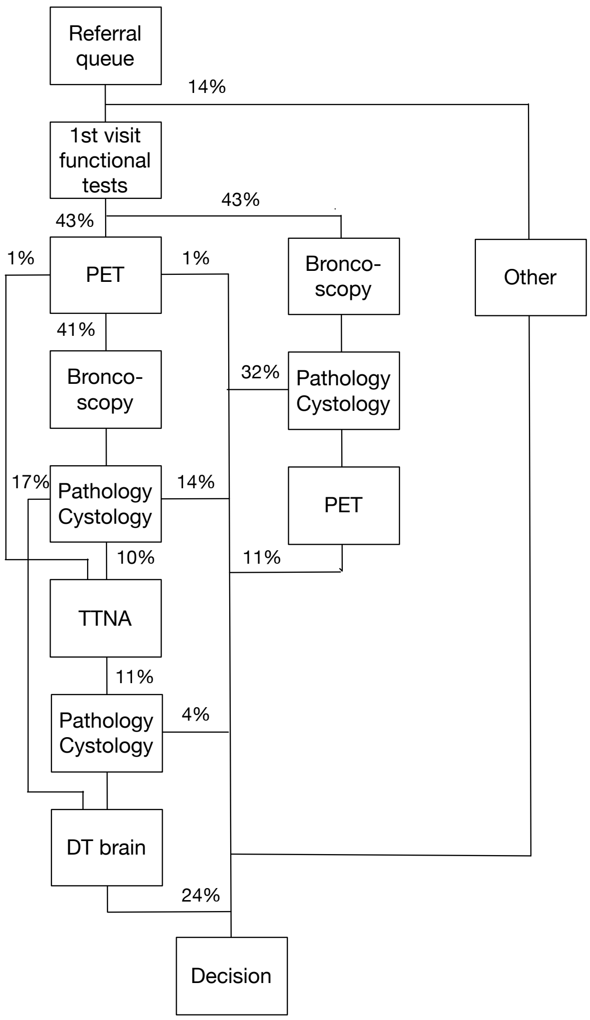



*Figure 91 Patient flows*

To address the process owner's third issue, balancing capacity and the significant variation in patient flows, my colleague built the System Dynamics interface shown in Figure 92. Actual patient inflow data by week was used as input in the model, and patients were randomly assigned to one of the three patient pathways. As each pathway competed for the same resources we could see surprising variation in demand for each resource over time, which reflected reality. Using the interface one could vary capacity, pre-planning etc. and run each set of parameters a large number of times to study the effects of variation.

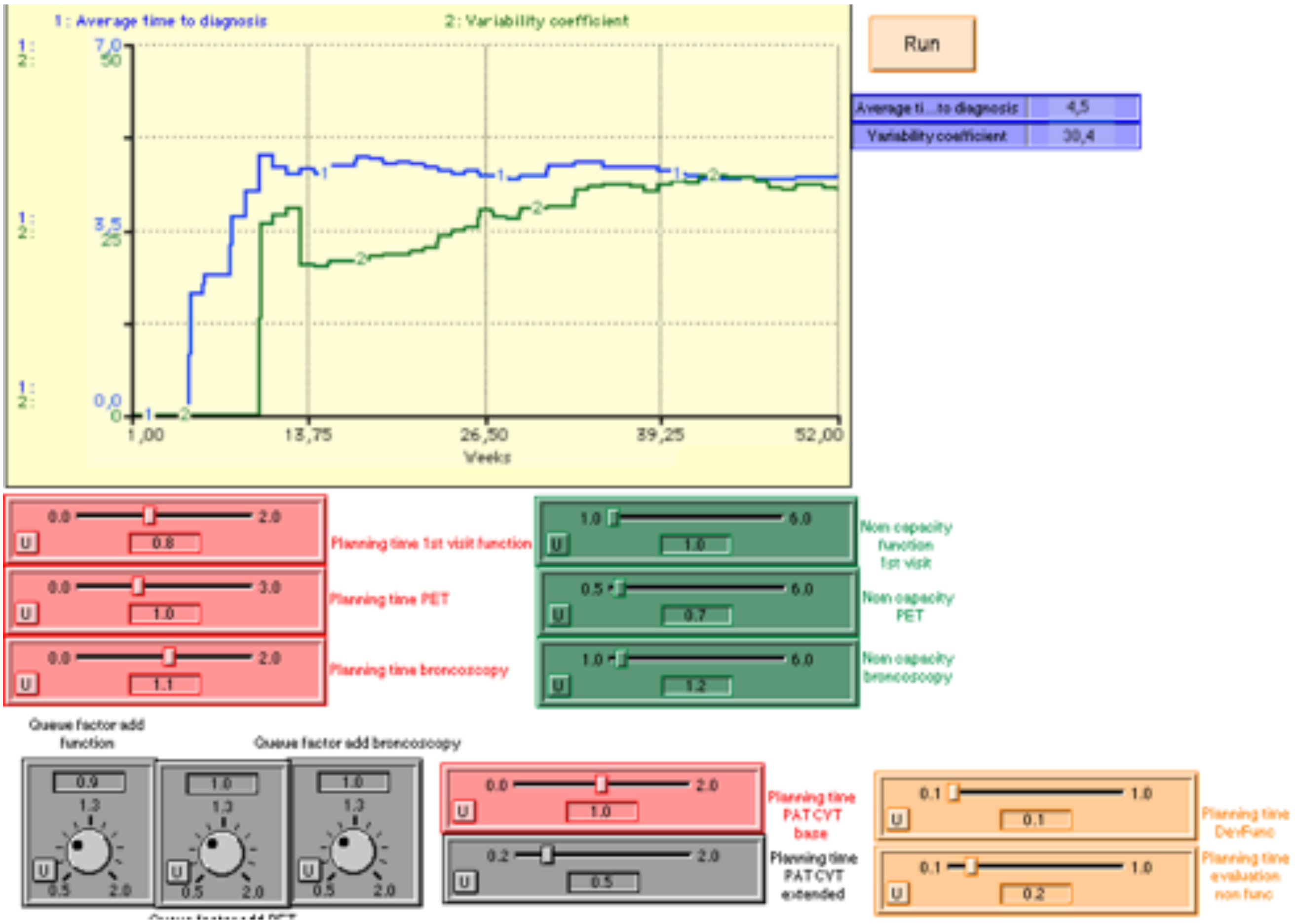



*Figure 92 Main part of System Dynamics model interface*

One of the most important results was that pre-planning and shorter planning cycles had more significant effects on time to diagnosis than adding more diagnostic resources such as radiology equipment.

When the model was ready it was used in two workshops with doctors and other key staff at the hospital clinic. The workshop was led by the process leader supported by the System Dynamics modellers. We ran the simulation model on several computers so the participants could experiment with the model. The key outcome was accepting that additional resources would not help and that different ways of working was needed and the discussions on how to do that began at the workshops.

Notes from the workshops:

Department

- We need a system for correct reservations
- Free time slots next week, we can have empty slots
- What happens to other patient groups?

Process

- Standard flow (early plan) medically possible, but we do not trust (do not know) time needs of others
- Why 1.5-week queue when we have 9 time slots per week?
- The hospital has a unique possibility with well-established structures to determine processes and the process owners can influence the line organisation.

Finance

- The line organisation must be allowed to prioritise quality and long-term view in process development.
- The financial system rewards multiple examinations, which is a risk.

Other

- No dramatic changes are needed to achieve significant results.

Reflections of the project group

- When unlimited capacity for diagnostic resources is tested, the effect is lower than expected
- Present measurement and follow up of total volumes, lead time (wait) and cost has to be done manually
- A planning system requires investment and is not the same as a case officer
- Cooperation and dependencies between other units both at the hospital and in the region, are needed if planning of first visit is to be realised.
    - Finance
    - Resources
    - Dependability
- There is a limit to how short times can be realised without additional resources.
- Other work at the clinic is influenced – how?
    - Must not be worsened.
    - Must also be developed
- Administrative time to plan has a complex relation to capacity.

### The reimbursement study

Our research objective had two dimensions. The first step was to optimise the diagnostic process and the second step to see how reimbursement systems could steer towards the optimal process. We had uncovered some basic patterns in the causal loop diagrams that we had discussed with the reference group. To further explore the issues the project group interviewed a hospital controller, the hospital finance director and a manager at the commissioning unit.

The hospital is reimbursed as follows:

- 48% is fixed and budgeted for the purpose of ensuring basic delivery of care
- 48% is variable based on DRG and activities. But there is a production ceiling above which no reimbursement is paid out. The hospital produces up to the ceiling.
- 4% is related to objectives. We understand this reimbursement is a way to encourage the hospital to take on higher costs in a specific area to attain regional objectives.

Internally the hospital works with annual budgets, i.e. the lung clinic has a fixed annual reimbursement irrespective of patient volumes and its participation in reaching hospital objectives. Radiology also has a fixed budget and is a free service to clinics. PET and other external examinations are invoiced to the clinic. New national guidelines recommend a significantly higher usage of PET, which for the clinic would mean additional costs of one million SEK. I.e. if a CT scan is done locally the cost is borne by Radiology, if done externally in connection with PET, the cost is borne by the lung clinic. The consequence is that there is a weak connection between the reimbursement system and patient wellbeing.

The hospital itself must cover any losses, i.e. losses one year means that the losses should be recuperated the next year. In addition, hospitals in the region are expected to rationalise one percent per year.

I built a model that would allow the exploration of different reimbursement models. The model is shown in Figure 93 and its interface in Figure 94.

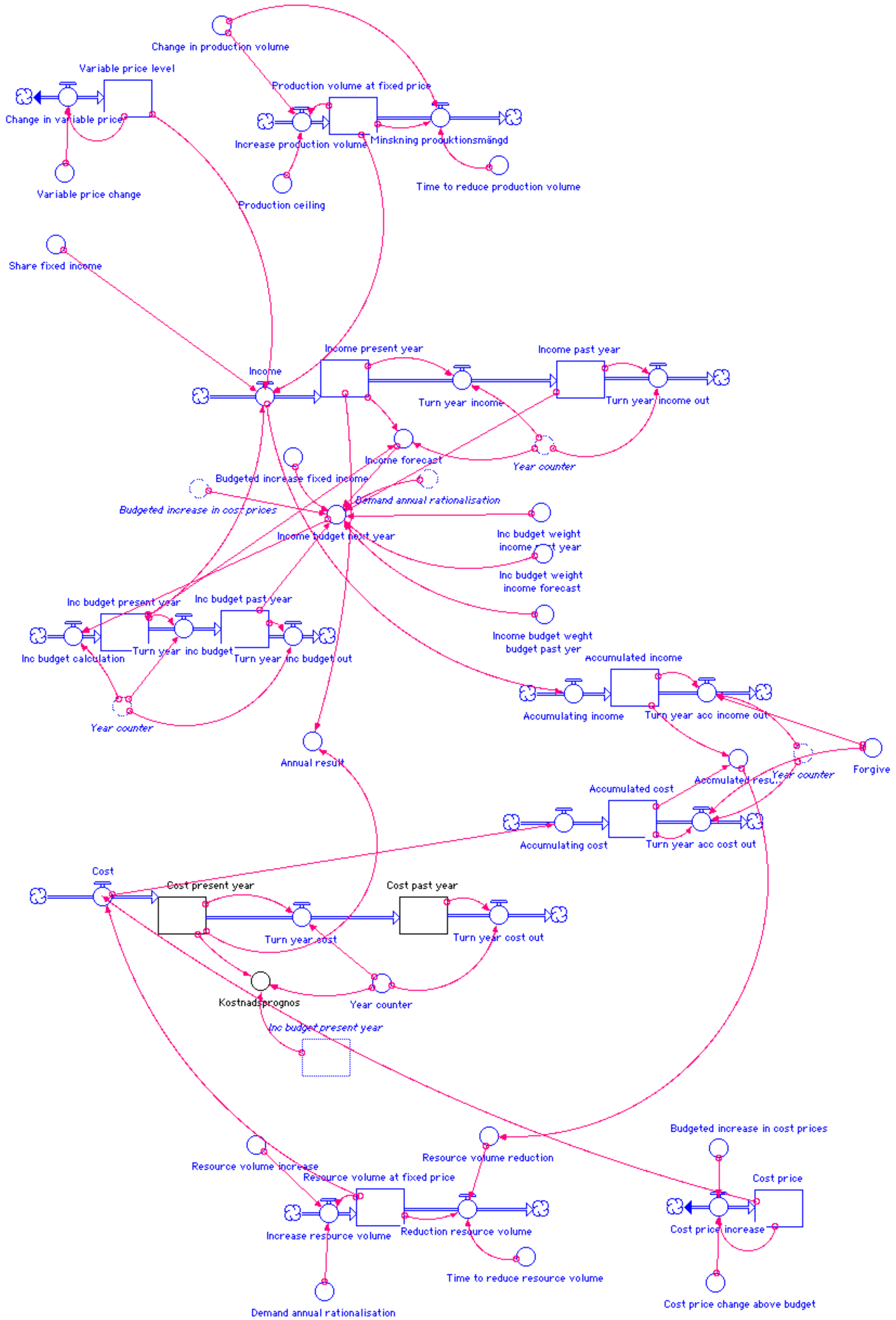



*Figure 93 The reimbursement model*

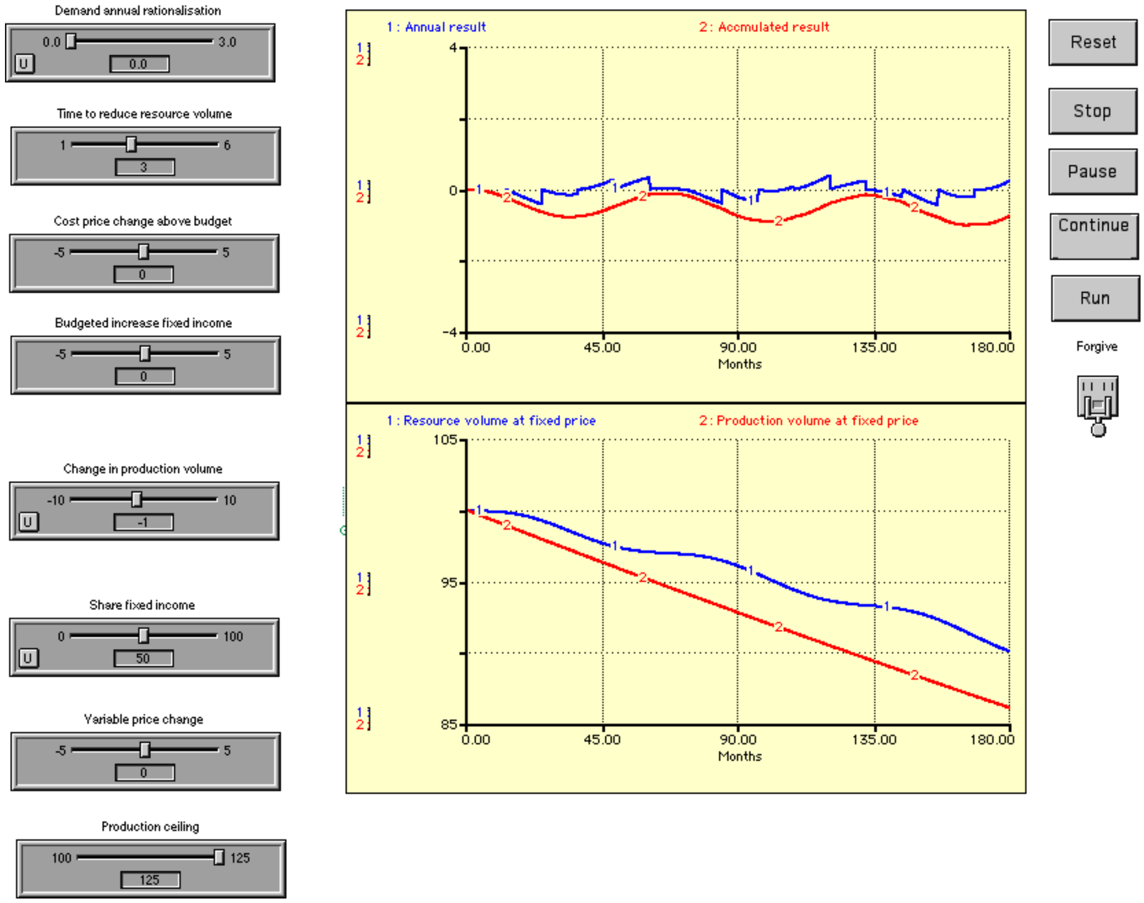



*Figure 94 Reimbursement model interface*

Over the years, the budget process has been characterised by demands on rationalisation and savings. The budget processes have been lengthy and decisions taken very late in the preceding year. Savings are expected to take immediate effect, but take a long time in reality, as staff may have to be redundant and facilities vacated. The effect of any delay is a loss, which according to the policies of the region must be compensated by the unit, i.e. further savings, which in turn take time to realise. The result is a cyclical effect shown in Figure 95. The conclusion of the project group was that there were no elements in the present reimbursement systems that would provide incentives for improvement.

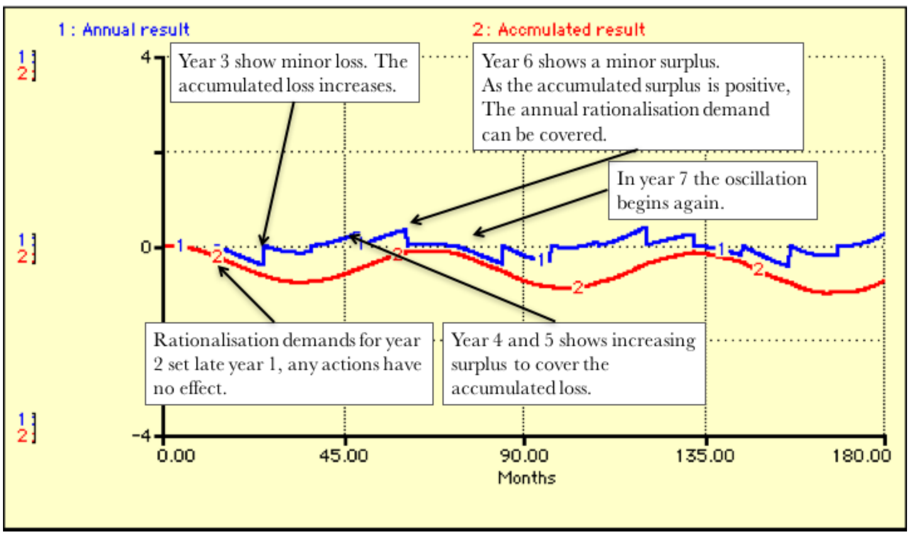



*Figure 95 Cyclical effects of rationalisation demands*

The project group developed hypotheses about how the reimbursement system could be developed:

- Plan for long-term achievements, at least 2 years, preferably 10-15 years. A known long-term reimbursement system would create the local prerequisites to create long term effects.
- Find measurements for quality and time that can be used.
- Staff effects need to be included
- Follow-up systems need not only focus on production and economy but also on process efficiency and patient results.

We presented our results at a national conference arranged by Swedish Association of Local Authorities and Regions. We particularly noted the lack of surprise over the dysfunctionality of the reimbursement systems that we showed. It was as though everyone already "knew". Our conclusion was that studies of alternative reimbursement systems could gain significantly by showing the systemic effects over time.

## Project report

The project as such was reported to the Swedish Association of Local Authorities and Regions in 2012 and presented at a national cancer conference in 2013.

Holmström, P., B. Bergman, S. Hallberg and C. Ridderbjelke (2013). **Ersättningsformer och processeffektivitet – modellering för styrning i ett komplext system**. Nationell konferens SKL. Stockholm.

## Case 13 – Accident & Emergencies (2)

Waiting and throughput times in emergency services had increased over the years and a national statistical study was commissioned to identify causes and possible remedies. Statistics were being collected at a number of A&E departments in Sweden. I was asked to participate as a minor sub-project to see if and how System Dynamics and Systems Thinking could illustrate root problems. Data collection was delayed and would not be accessible for my work, so I was asked to build on my experience and data from earlier A&E projects. Resources were highly limited. The intention was to take part in and present at a one-day workshop with the project team and people from the participating A&E units. I saw my main challenge as having a one-hour presentation and discussion to introduce System Dynamics to a group of people who never had worked with such methods. I presented results of triage in a second meeting.

I had worked with A&E departments as an organisational consultant and done one group modelling effort, described in a separate case. I considered myself familiar with core issues. As the participants were unfamiliar with System Dynamics I decided against building one large model and having to spend much time describing the model. Instead I opted for building a series of minimalistic models each describing phenomena that I had experienced as significant. I was also aware that the main study was to build on data-gathering and statistics and saw my intervention as focusing on causality rather than correlation. Initially I built on data from a previous case, beginning with an illustration of the main patient flows (Figure 96).

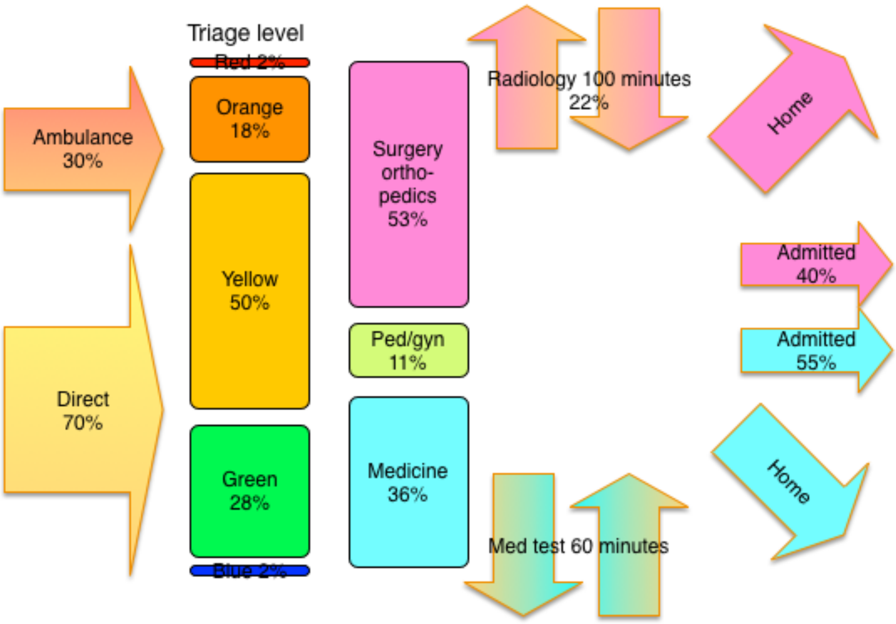



*Figure 96 Patient flows*

I also knew from previous work with A&E departments that staffing levels are relatively constant during the day and the week, whereas patient flows vary significantly over the day and peaks at the end of the week. Figure 97 shows the average variation in patient flows and staffing levels and patient inflows over a day and Figure 98 shows the variation in patient flows over a week.

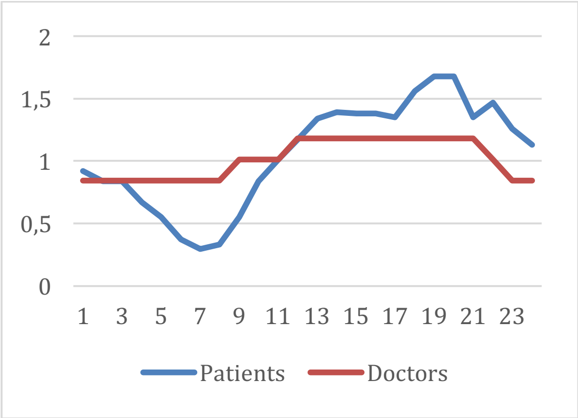



*Figure 97 Daily variation, patients and staff*

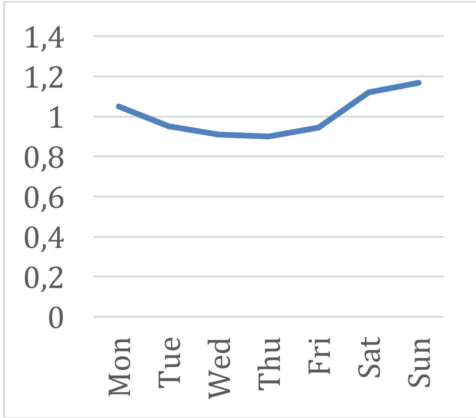



*Figure 98 Weekly variation, patients*

In my experience, most people understand that the mismatch between patient flows and resources will lead to queues as they see the discrepancy in the graphs, but they seldom intuitively understand that the queues accumulate. To illustrate this I built a minimal stock and flow model, assuming that patient inflows and resources are matched over a week. Patient are clocked when they enter and leave the system. I explained and ran the model during my presentation. As it was so simple it probably matched the participants' experiences of process mapping and they felt familiar with it

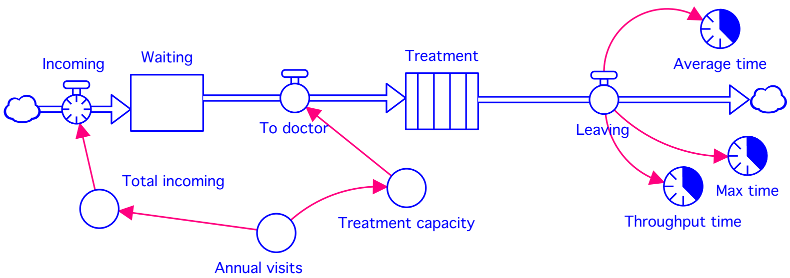



*Figure 99 Basic System Dynamics model*

I explained that I had added functions allowing variations in patient flows to be switched on or off and random variability added, as shown in Figure 100. It was also possible to add a variation in staff scheduling that matched the average patient flows as well as have overcapacity or under-capacity. I did not show the model with the added functions but went directly to the flight simulator interface as show in Figure 101.

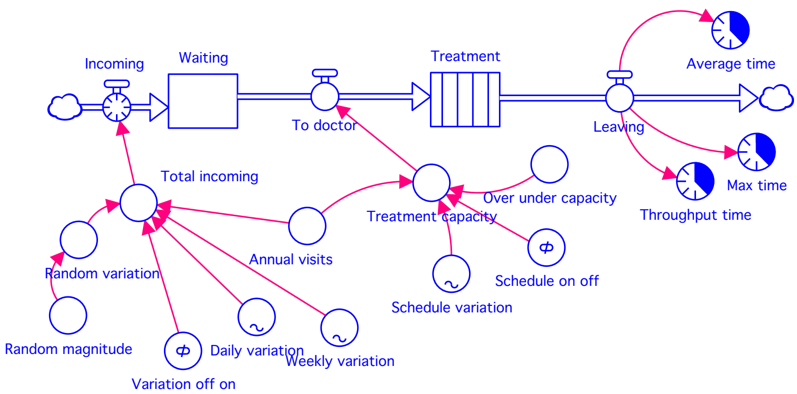



*Figure 100 Basic model with variables to create variation*

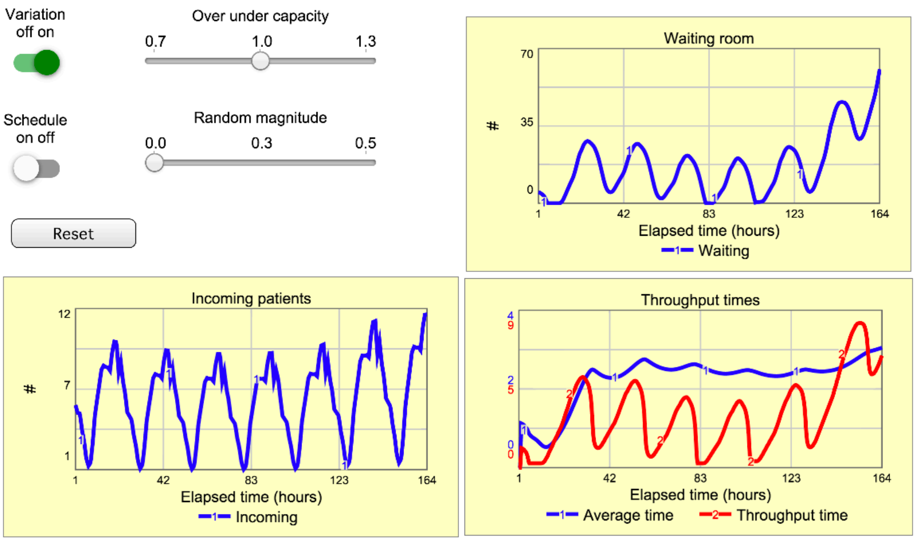



*Figure 101 Basic model interface*

I ran four different scenarios in the model

**Scenario 1 – Even patient inflow based on weekly average, unchanged staffing levels**

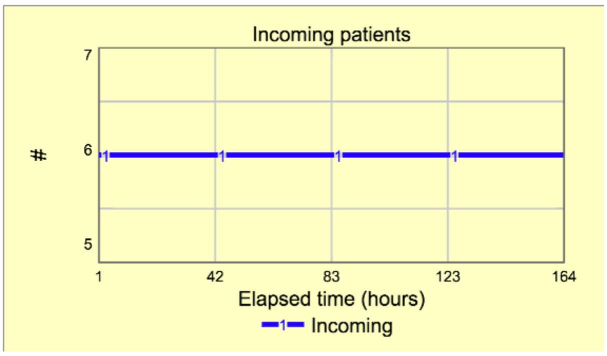



*Figure 102 Scenario 1 - Incoming patients*

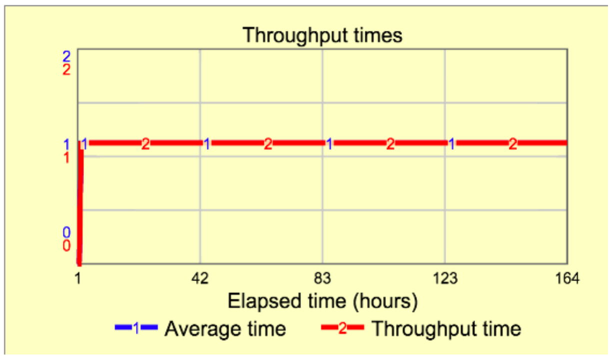



*Figure 103 Scenario 1 - Throughput time*

The purpose of this scenario was to show that the system is stable and that throughput time is acceptable.

**Scenario 2 – Daily and weekly variation based on yearly data, unchanged staffing levels**

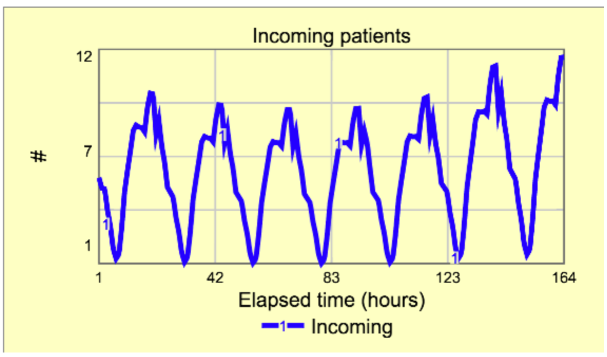



*Figure 104 Scenario 2 - Incoming patients*

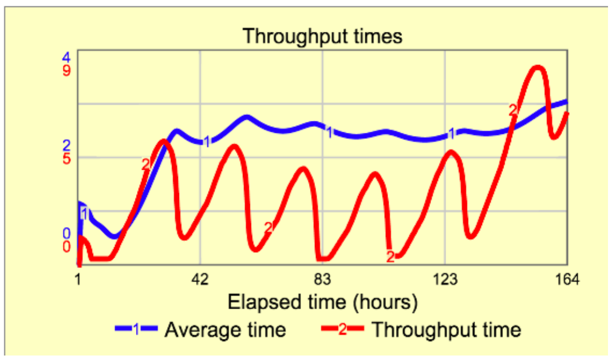



*Figure 105 Scenario 2 - Throughput time (red actual, blue moving average)*

However, adding the average variation in daily and weekly inflow leads to average waiting times peaking at 3 hours and the longest wait is almost 9 hours at the weekend.

**Scenario 3– Daily and weekly variation based on yearly data with added randomization, unchanged staffing levels**

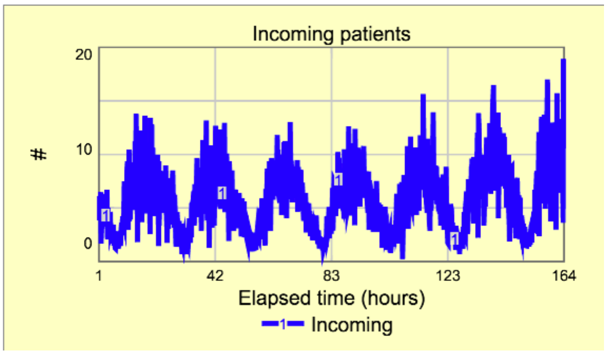



*Figure 106 Scenario 3 - Incoming patients*

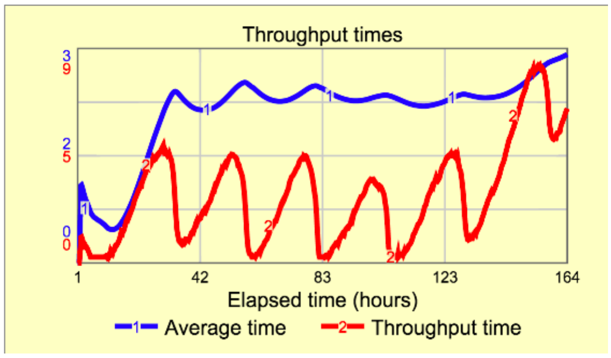



*Figure 107 Scenario 3 - Throughput time (red actual, blue moving average)*

Adding random variation changes little. I wanted to show that the basic problem is the foreseeable variation. I have often heard people in health care say that the variation is so random that it is better to have constant staffing levels so as to be able to cope with the peaks.

**Scenario 4 – Daily and weekly variation based on yearly data, changed daily staffing levels**

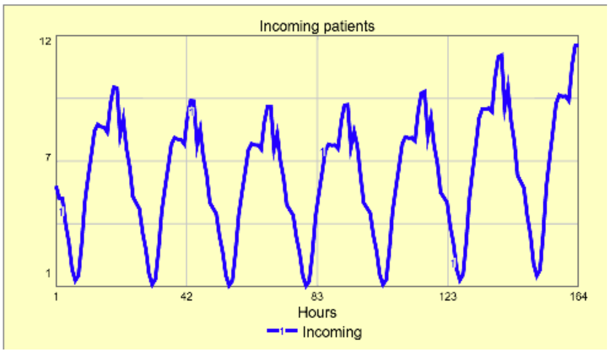



*Figure 108 Scenario 4 - Incoming patients*

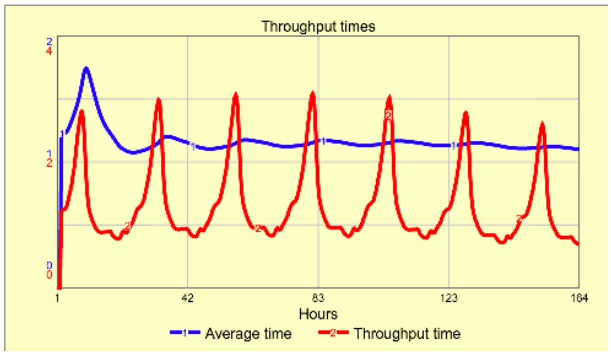



*Figure 109 Scenario 4 - Throughput time (red actual, blue moving average)*

Adapting the staffing levels to roughly match the patient inflow significantly reduces the average waiting time. Here interesting discussions came up

- The difficulties of changing staff scheduling
- The importance of having high staff levels during probable low demand to be able to cope with sudden emergencies
- Several said it was interesting but that they would want to do detailed simulations of their own unit before implementing changes.

## Internal queueing

The simplified flow model only contains one queue, in reality there are a multitude, such as

- Registration
- Triage
- Available treatment rooms
- First assessment
- Medical tests

- Medical test to lab
- Medical test analysis
- Medical test reply
- Doctor taking part of medical test results
- Transport to radiology
- Radiology
- Radiology analysis
- Radiology response
- Doctor taking part of radiology response
- Available treatment room
- Second assessment
- Transport home
- Admittance to ward
- Transport to ward

To illustrate this, I shared a previous model with three patient pathways (Figure 110)

- Red triage code, taken care of immediately
- All other triage codes except those requiring radiology
- Patients requiring radiology (22%)

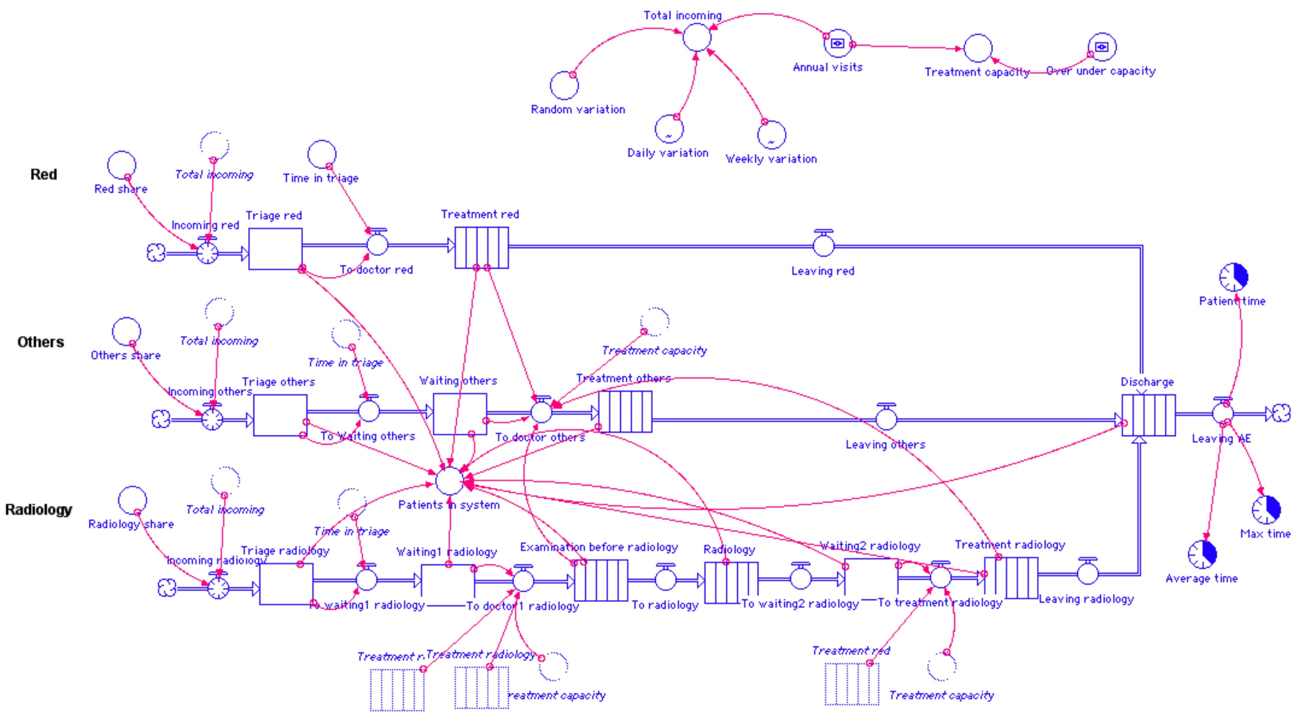


*Figure 110 System Dynamics model with radiology pathway*

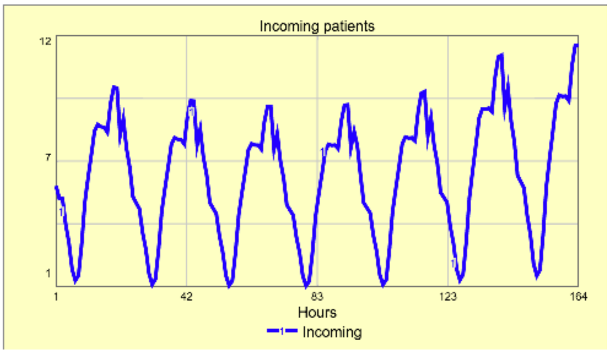



*Figure 111 Incoming patients*

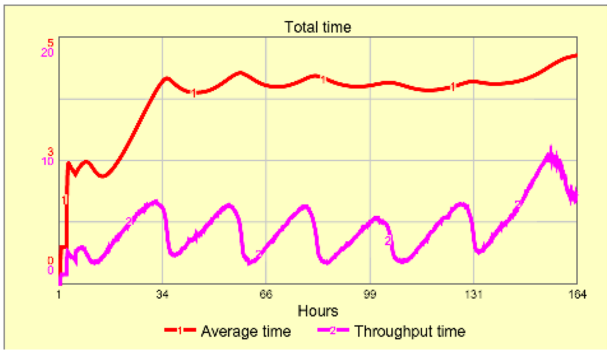



*Figure 112 Throughput time*

Even if only 22% of all patients are subject to the additional queues for radiology, the average throughput time increases by almost one hour. Once again, many of the participants expressed the need to build a detailed simulation of their own unit.

### Causal loop diagram

I had been specifically asked to draw a causal loop diagram based on my previous experiences (Figure 113).

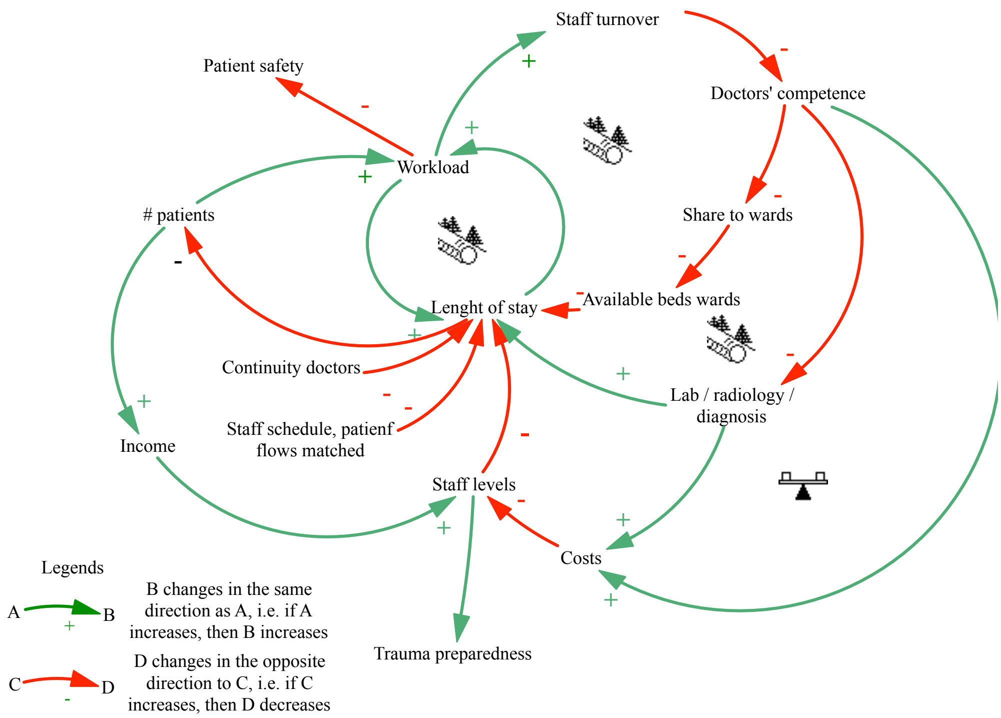



*Figure 113 Causal loop diagram A&E*

More patients lead to higher workload, in turn leading to longer waiting times, leading to higher workload …, a snowball effect.

If there are no free places in the wards, then waiting times increase.

Many hold the opinion that less experienced doctors order more tests and admit more patients to wards.

Increased workload leads to higher staff turnover, in turn leading to decreased competence and experience, leading to more tests and higher admittance rates

Many A&E departments do not have their own doctors, instead patients fill up treatment rooms and doctors regularly come to A&E and “clear the decks”. Departments that have permanently stationed doctors have shorter throughput times.

If the number of patients increases, then over time more resources are budgeted for the unit leading to more resources immediately available in case of major trauma.

It is unknown if reduced waiting times will lead to a higher influx of patients.

In my presentation, I gradually built up the causal loop diagram to facilitate understanding and discussion. The diagram caused a lot of discussion, but its conclusions were accepted.

After the meeting, I was asked to do additional modelling to show the effects of triage and required staffing levels to attain the objectives:

- Code red, to doctor immediately
- Code orange, to doctor within 20 minutes
- Code yellow, to doctor within 120 minutes
- Code Green, to doctor within 240 minutes

## Effects of triage

To ensure recognition I built on my initial basic model (Figure 114), creating four patient flows, where code red patients received immediate attention and subsequent priorities received resources available after patients with higher priority had been attended to.

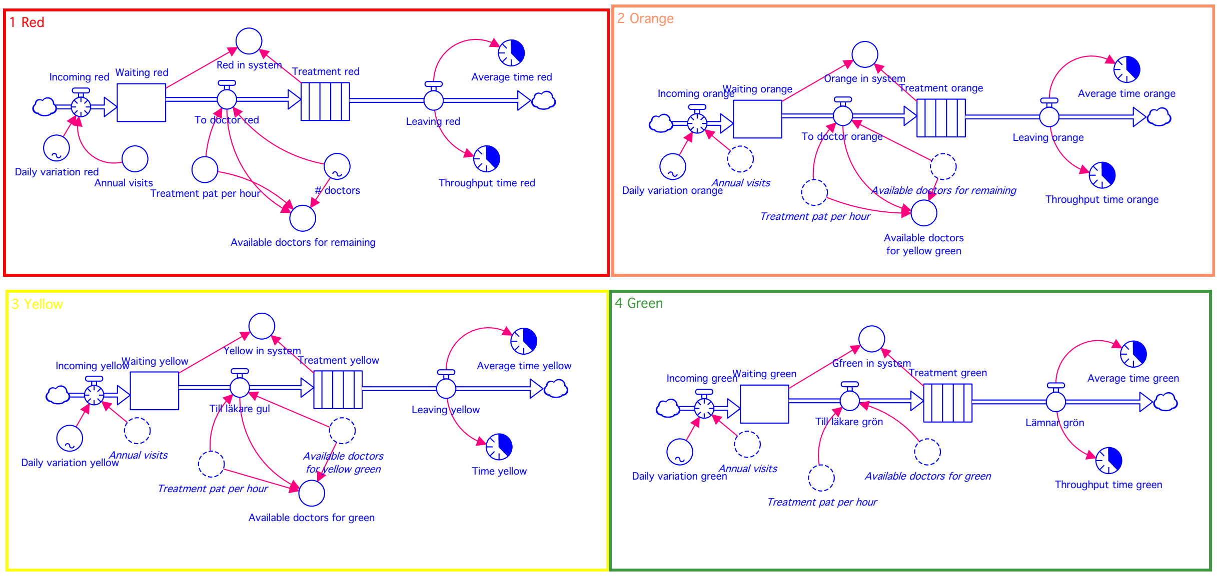



*Figure 114 Triage model*

As I built this model some early data from the statistical study became available. I used the daily distribution of patients by code. All codes show a similar pattern, increased inflow in the morning and a decrease in the evening (Figure 115).

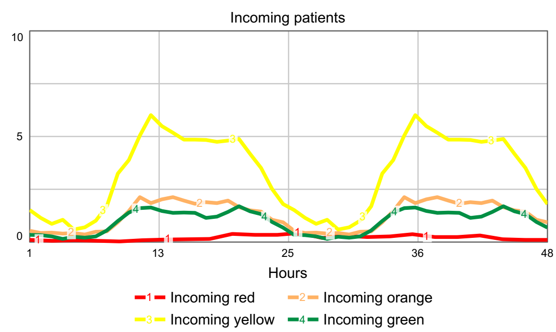


*Figure 115 Patient inflow by triage code (annual)*

These inflows were used to build and study the effect of three different scenarios. A basic scenario with the same staffing levels as in the initial scenarios above and two scenarios with medium or high adaption of staffing to average patient inflows.

### Scenario A – base scenario

Figure 116 Scenario A - Staffing doctors

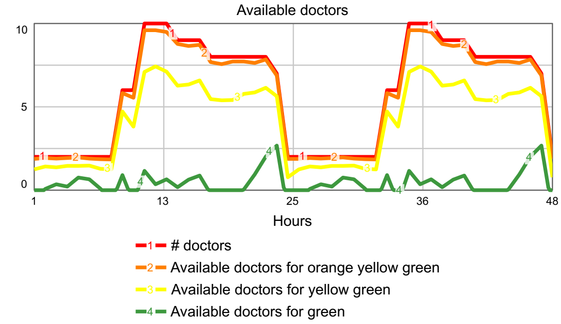



Figure 117 Scenario A - Access to doctors by triage level

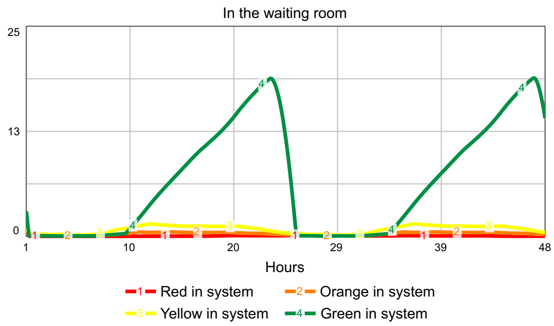



Figure 118 Scenario A - In the waiting room

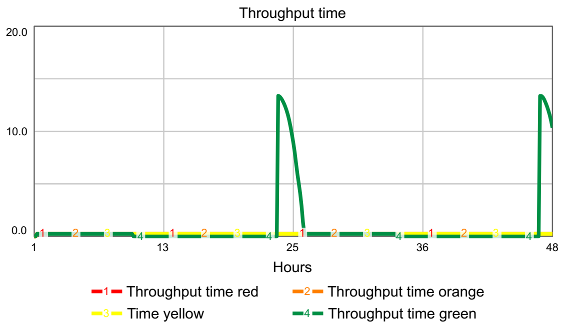



Figure 119 Scenario A - Waiting times

Even this very simple model shows recognizable effects. Non-urgent patients arriving in the afternoon have long waits. These are the cases often described in media where patients tell that they keep asking about their own wait and are told that more urgent patients have arrived.

### Scenario B – highly adaptive staffing

In this scenario staff levels of doctors match the average patient inflow levels on an hourly basis.

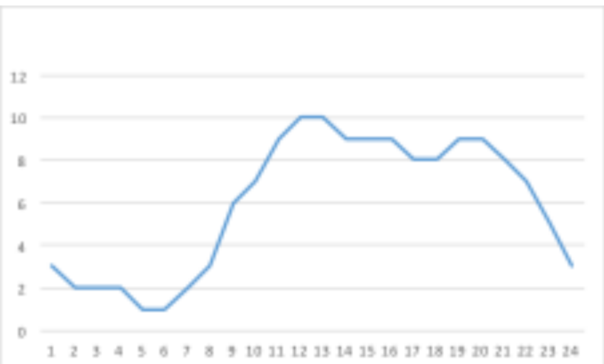


Figure 120 Scenario B - Staffing doctors

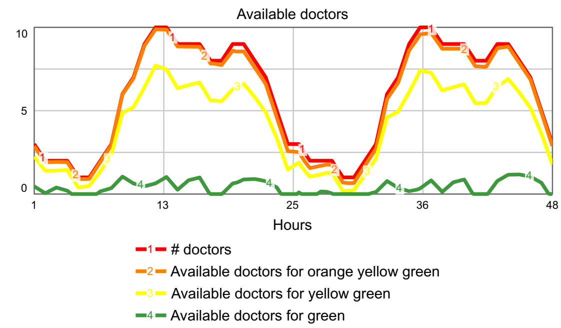



Figure 121 Scenario B - Figure 95 Access to doctors by triage level

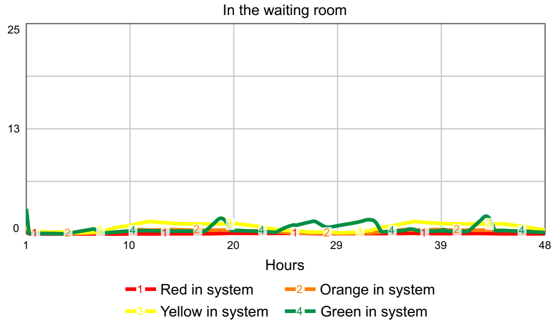



*Figure 122 Scenario B - In the waiting room*

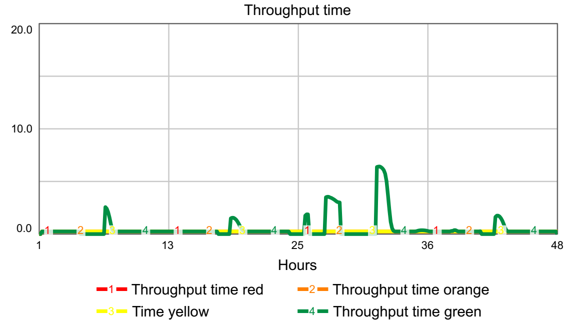



*Figure 123 Scenario B - Waiting times*

In this scenario waiting times are almost eliminated, even for low priority patients. In this scenario, the number of doctors is one at the lowest point and peaks at 10. The main project attempted to collect data on staffing levels, but discovered during the discussions that the data was not reliable. Several of the participants said that it is impossible to measure available medical resources as in many cases doctors share their work between ward, clinic and A&E. They are not clocked when they come to or leave A&E. One of the participants told me that their department almost all the time has at least one general practitioner doing part of their training there, in practice providing a free unaccounted resource. More and more A&E departments are employing specialist doctors trained for A&E, but still have to rely on some doctors "floating" between the department and other tasks.

**Scenario C – semi-adaptive staffing**

In this scenario, I scheduled two doctors during night-time to have higher preparedness for semi-large trauma and attempted to schedule doctors in at least two-hour slots, assuming some flexibility in sharing doctors between A&E, ward and clinic, above all ramping up levels somewhat slower in mornings to allow time for early rounds in wards.

*Figure 124 Scenario C - Staffing doctors*

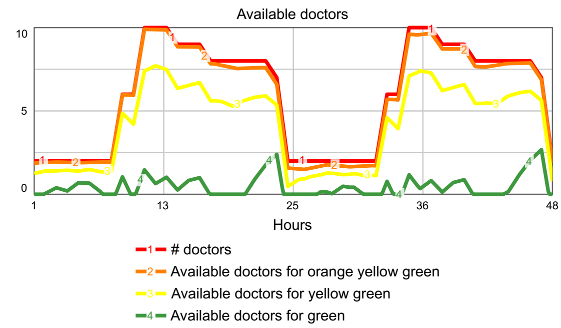



*Figure 125 Scenario C - Access to doctors by triage level*

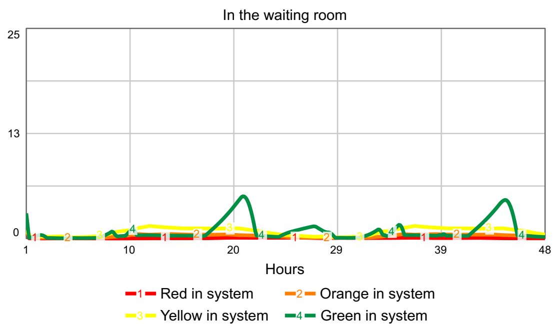



*Figure 126 Scenario C - In the waiting room*

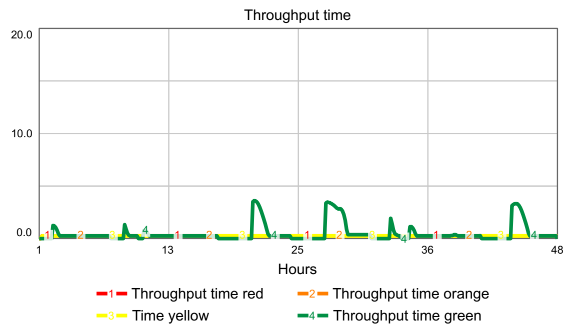



*Figure 127 Scenario C - Waiting times*

In this scenario, low priority patients in some cases have longer waits, but never more than the four-hour max target.

## Conclusions

The daily variations in patient flows lead to longer times at A&E departments as patient flows and staff levels are not balanced over time.

Staffing according to expected patient flows shortens throughput times

Many of the patients with the lowest triage priority who arrive in the evening are not examined and treated until early next morning. Increased staffing during afternoons and evenings will lead to shorter time as well as reduced staff levels and costs during night-time.

Patients are subject to many queues during their stay. If they can be reduced, then the total throughput time can be reduced.

Given that there are adequate medical resources available over time, time-shifting the resources will lead to probably the most significant improvement. In total the medical resources are sufficient as they are, but reducing queues can lead to decreased need for nurses, examinations rooms etc. as peaks are reduced.

## Reflections

My impression was that working with minimal models worked as I had hoped. People in health care are often used to process mapping, so on the surface they felt a familiarity. I did not need to spend time explain the models and could focus on key results. Once the basic model was accepted it was easy to take the step to the triage model by stating that it used the same basic flow, but each additional triage flow used what was left over from resources. However, the causal loop diagram was more complicated so I used five slides to build it up and walk the participants through it. Discussions about the core issues were relevant. When I moved to the model with a series of queues the nature of the conversation changed and instead of discussing general issues and how to solve them, the participants stated that this was interesting and that they would like to model their own unit in detail.

I had been engaged by the manager of the project leader . In hindsight, I should have been allocated more resources and worked closer with project management to better contribute to their insights and conclusions.

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