Conceptualization and formulation of a UK health and social care system using System Dynamics

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Abstract

The UK health and social care systems are continuously changing over time. Other authors have previously put a strong case for usage of system dynamics (SD) in this area largely because SD address issues of system complexity and identification of feedback loops, resulting in a greater insight into this problem situation.

This paper presents research carried out in two areas of SD, firstly the conceptualizing of a problem and secondly the building of a SD model related to the dynamic problem of ''bed blocking'' in the UK health and social care domain. A case study approach has been applied to a hospital discharge department and elderly wards in a main UK hospital.

This paper provides a useful insight into issues that have occurred when conceptualizing and formulating a health and social care SD model. System behavior has been discussed as has the use of causal loop diagrams and stock and flow diagrams. Causal loop diagrams and stocks and flows have shown to play a useful part in overcoming SD difficulties. SD has proved to be a useful method in helping to gain an insight into the dynamics of a health and social care system. This is a preliminary paper, future papers will expand on this to look at policy experiments and sensitivity tests.

Keywords

SD, model conceptualization and formulation

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1. Research context and structure

This paper is about using SD to conceptualize and formulate a UK health and social care system. Essentially SD promotes the usage of a whole system perspective and is highly advantageous in helping to understand the past as well as the future.

Holmer and Hirsch (2006) defines SD as *'involving the development of computer simulation modeling that portrays processes of accumulation and feedback and that may be tested systematically to find effective policies for overcoming policy resistance'*.

This paper provides insights into the dynamic problem of ''bed blocking''. A dynamic problem of bed blocking exists when patients occupy beds unnecessarily. Bed blocking can take place among different population groups whether its children, young people or the elderly. Bed blocking is a serious problem; it results in operations being cancelled as new patients are not able to be admitted and millions of pounds being wasted (BBC, 2002a).

However in practice bed blocking is predominately a bigger problem among the elderly population. The National Health Service (NHS) and Social Services are responsible for making hospital discharge arrangements for elderly people. These hospital discharge arrangements typically involve making sure that the right care plan is in place, monitoring the needs of patients and identifying the help that patients will need when they leave hospital.

There is a clear process that exists and must be followed between Social Services and the NHS. For a hospital discharge arrangement to exist firstly the NHS must inform Social Services that the patient is ready for discharge in order for Social Services to go ahead with carrying out a patient assessment. This is outlined by the Community Care Act 2003 (Department of Health, 2003), which encourages joint working between the NHS and Social Services, referred to as a Section 2 notification. There is later notification by the NHS and Social Services once the patient's discharge date is agreed in the form of a section 5 notification.

In reality elderly people are waiting in NHS hospitals for assessments to be carried out by social services in order for them to be discharged from hospital. Bed blocking often occurs because of firstly the lack of care homes available and secondly an information delay existing between social services and the NHS, causing patients to experience delayed discharge. Bed blocking is an important problem to investigate, as bed blocking is a problem that has not gone away. The government introduced a fining policy to social services, stating social services departments are to be fined for patients that wait in the hospital unnecessarily (BBC, 2000b).

While the research area is focused on the health and social care domain this paper is a contribution to how real world problems and dynamic systems can be conceptualized and formulated in the public policy arena.

This paper starts by outlining the background to the UK health and social care system relevant to the problem situation. Following from this the research genesis, objectives and methodology have been outlined. Given the dynamic problem that exists (Department of Health, 2002) the SD approach is outlined and justification is given to using SD as an appropriate method for addressing the problem. Work is then presented on the application of SD modeling carried out by well-known educators, consultants and practitioners and on the conceptualization and formulation of the health and social care model. A discussion follows regarding issues that have arisen during the formulation and conceptualization the system. Finally conclusions, recommendations and policy implications of the research are outlined.

2. Background to the UK Health and Social Care System

The focus of healthcare is changing. There is greater emphasis on early intervention of healthcare in which people are treated and helped long before patients are admitted into hospital, to help decrease hospital intakes and prevent likely illnesses from occurring. There is an emphasis on reducing the inequality that exists between different people (or groups of people) with more social inclusion and strategic needs assessments (Integrated Care Network, 2007). It is recognized that a holistic approach is needed in which there is better commissioning of health and social care services, citizen involvement and greater opportunities for partnerships to exist.

The health and social care process is recognised as a dynamic process for those that need and want public health and social care. There is a clear link between public health and social care and integration, in which certain policies must be shared. There is a need for multiple services, in which it is often difficult for health and social care services to work together. The integration of services is thus seen as a mainstream focus, in which a whole way of working will be achieved through the joint needs strategic assessment. In achieving integration there is a need for joint appointments between the Department of Health and local authorities. For example Tower Hamlets, a London borough an administrative unit of the government and the Department of Health responsible for the overall health of the community has worked towards some joint human resource policies (Integrated Care Network, 2007).

History has shown that previously (pre 1997) people in the UK were very much responsible for there own health, however post 1997 the government have played more of an enabling role, in which a health and social care environment exists for people to make their own informed decisions. Post 1997 there was the development of service agreements in the NHS, in 2004 there was the Choosing Health policy that was to address rising inequalities by outlining key principles for supporting the public to make healthier and more informed health choices. This led to the commissioning of services in the NHS as an attempt to sort out the acute sector.

Successes in public health have shown that in 2007 there are the lowest ever infant mortality rates. There are still many public health challenges. Health inequalities are increasing in some cases, with increased obesity and teenage pregnancy. However it is evident that the services that are needed by the public and the services that are demanded need to be distinguished (Integrated Care Network, 2007).

The diagram below highlights the different types of health and social care services that are provided. Services fall under the categories of services that are provided to the public, those that are needed and those services that are demanded. The diagram highlights areas where unnecessary services are being used, where services are undervalued and where the frustrated public exist as the result of the public not being able to obtain the services that they need. It is important to think of these different elements of services to see if resources are being used in the best way.

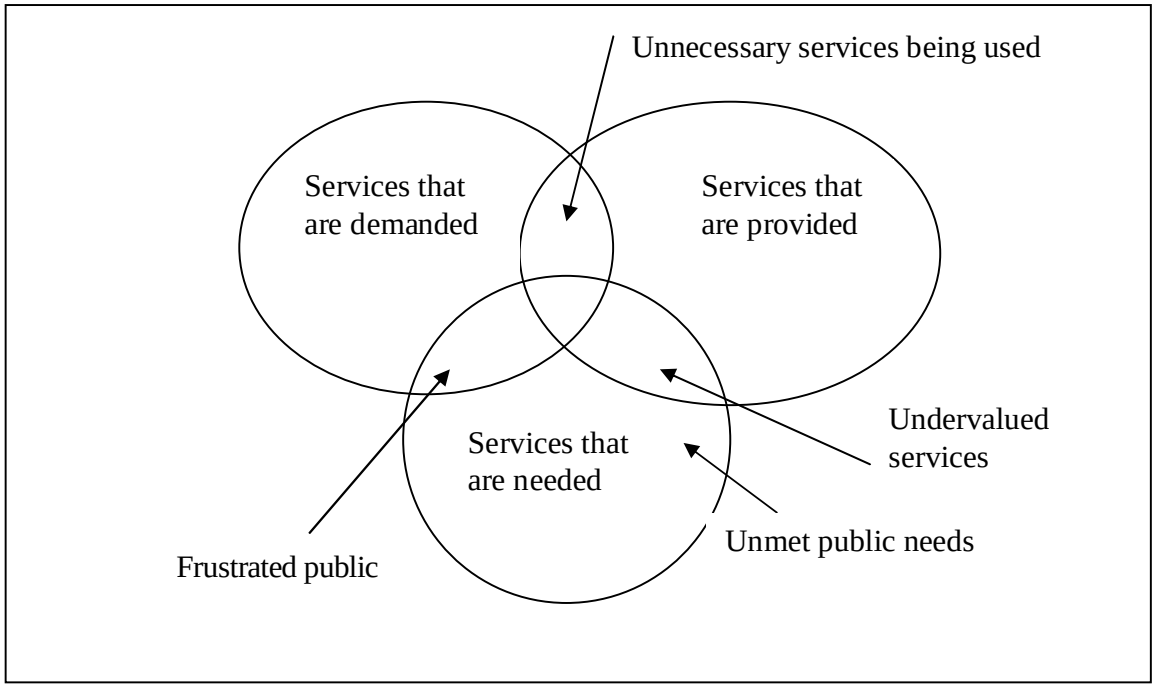

Diagram 1: Integrated Care Network (2007), Public Health and Integrated Services diagram

In the UK there have been continuous changes in government policy to push towards the integration of health and social care systems. At present these systems act as separate entities and there is little evidence of full integration between them, rather there are instances of joint working, co-location of services and some integration of specific services.

Integration has been defined as *'where organisations or services integrate into single entities allowing for greater transparency between partners and enhanced benefits for users'* (Oxfordshire County Council, 2004).

Integration is seen necessary as a means of improving services. It should provide patients with more of an opportunity for patients to receive improvements in care and gain better access to services.

3. Research genesis, objectives and design/methodology

The main aim of this paper is to present the work and thinking that has been involved in the conceptualization of the well known health and social care problem, 'bed blocking', and the issues that have arisen when building the SD model.

The research objectives are:

Objective A: To document knowledge and understanding of the health and social care system and to capture mental models. This fits in with the purpose of the SD model (see section 5).

Objective B: To conceptualize the problem of bed blocking.

Objective C: To formulate and build a SD model that represents the problem of bed blocking.

Objective D: To highlight important aspects that needs to be considered during the conceptualization of the problem and formulation of the SD model.

The research methodology has been to use a case study approach of a large NHS hospital and has involved interviewing a range of stakeholders including hospital discharge managers, an IT training staff member and a social worker. In-depth interviews were conducted over a 2-month period from June-July 2006, involving a sample size of 4 staff.

The problem situation of bed blocking was brought to light in an interview with a hospital discharge manager (Local Authority Social Services Hospital discharge manager, 2006b). The interviews have proved useful in helping to obtain the necessary qualitative data to help conceptualize and formulate the SD model. This includes gaining information on the structure of the health and social care system, where the delays exist and what the patient process is.

Quantitative data was taken from published reports, largely involving patient data such as the number of elderly people situated in that particular borough and policy data. Policy data has included patient waiting times such as the time patients wait for a Social Services assessment to be carried out. The time patients wait must be 24 hours from when the notification is sent from the NHS to Social Services to inform Social Services that the patient is ready for discharge.

4. Appropriateness of SD and explanation of the SD approach

In real world systems, particularly social systems like health and social care, we have seen that interventions in complex systems have resulted in short term success and long-term failure. With complex systems there are low-leverage policies, where by the apparently influential polices have little effect (Sterman, 2000).

The health and social care system is not in equilibrium, it is continuously changing and internal system feedback structures often experience external policy intervention. This is

due to dynamic complexity existing where by there is policy resistance from system stakeholders that are overwhelmed by complexity and fail to understand the system. These systems are governed by feedback, where by actions feedback on themselves and the behavior of complex systems is counterintuitive and cause and effect are distant in time and place.

There is a clear need for a holistic, systems approach to problem solving, which is often the exact opposite to the way most organizations solve problems. This is where SD is useful as a method of enhancing learning in complex systems (Sterman, 2000). This view was supported by the Department of Health at a recent UK conference on integrated health and wellbeing (Integrated Care Network, 2007). Public health recognizes the need for a dynamic, interactive tool to look at different facets around heath needs. Government finds it difficult conceptualising the interconnectness between social systems, which has resulted in numerous policy problems occurring. Testing policies in the real world is expensive (Coyle, 1996).

Using SD to model the complex interface between health and social care and to carry out 'what if' and 'why' analysis and for scenario planning would be particularly advantageous. Given this SD would be highly beneficial in helping to address the dynamic complexity that characterizes many public health issues (Homer and Hirsch, 2006).

Simulation is seen as necessary in situations like this where relying on feedback through the real world could be too slow and ineffective, illustrated by the time delays that exist that impact patient services. SD helps to deal with these issues of dynamic complexity and policy resistance that the health and social care domain are experiencing. Thus SD is used as a suitable approach to modeling a dynamic health and social care system.

The SD approach consists of two main steps:

a) Conceptualization of the problem
b) Formulating and testing the model

These two main steps consist of the following smaller steps.

<u>a) Conceptualization of the problem</u>
1. Define the problem
2. Identify the Stocks and Flows
3. Sketch the dynamic hypothesis

<u>b) Formulate and test the model</u>
4. Formulate the model and simulate
5. Conduct sensitivity tests
6 Conduct policy experiments

5. The application of SD modeling carried out by well known educators, consultants and practitioners

System dynamics has occasionally influenced both government policy at national level and health and social care organisational policy at local level. This approach enables policy makers to understand why policies fail and what can be done differently to yield better policy making. System dynamics has been influential in the health and social care context in developing an organization's way of thinking and the way that health and social care organisations conceptualise the whole of the health and social care system.

SD has been widely used to model health and social care problems by a range of people from educators, consultants to practitioners. Examples of some current applications of system dynamics and the impacts on health and social care organisations are highlighted below.

Case 1: Systems dynamics influencing the Government's reimbursement policy

System dynamics was used by the NHS and Local Government Association to test out the reimbursement policy, which is part of the delayed hospital discharge bill. This was in order to shed light on the complexities involved with fining Social Services over 'bed blocking' patients in hospitals in the areas of acute and post acute care.

The government were able to see from the systems dynamic model that an increase in hospital capacity during times of high demand in the acute sector would result in an increased number of people in hospital as empty hospital capacity will only be filled. This would lead to the unintended consequence of increasing hospital discharge delays. In contrast the policy of increasing post acute capacity would be advantageous to both the post acute and acute sectors. This policy decision would result in lower reimbursement fines being received by Social Services, as there is greater provision available to place discharged patients into care homes. Hospitals would experience a reduction in waiting times for patient admission as patient turnover is increased as more people are discharged from hospital on time (The NHS Confederation, 2005).

The effect of the system dynamics model on the government was to delay the implementation of the reimbursement policy and to increase funding to Social Services to increase their care capacity before this policy was enforced. The system dynamics model highlighted to the government that the most suitable policies and solutions do not always translate into the desired outcomes expected and maximum benefit to the health and social care system. The government was able to develop their thinking skills (their 'dynamic thinking') by conceptualising the behavior of health and social care organisations over time.

Case 2: System dynamics influencing a hospital's Accident and Emergency (A& E) waiting time policy

System dynamics was applied to an A & E department to ascertain why delays in A & E waiting time admissions were occurring. The behavior over time of an A & E department was investigated. The results of the system dynamics model highlighted that there was a

knock-on effect of there being reduced numbers of A & E doctors during the early mornings and evenings. This led to a 2-hour delay of patients being seen throughout the day. The results highlighted that the Patient's Charter on waiting times was unrealistic (Lane et al, 1998). If a major incident took place there would be major disruption to the utilization of staff and bed stock at hospital. The effect of the system dynamics model was to influence the A & E staffing policy by addressing the need to improve the number of specialist A & E doctors.

Case 3: System dynamics influencing the use of community matrons in the NHS

Existing Leicestershire NHS strategy has been to reduce the numbers of GPs and increase the number of community nurses. Leicestershire health community used system dynamics to investigate how best to use community matrons as a resource and how many community nurses Leicester NHS should have. These decisions are important as developing community matron competences are time consuming and expensive (Lacey, 2006). Effective usage of community matrons will ensure a higher standard of patient care as community matrons importantly have the role of self-managing people's conditions and giving people alternative health choices.

The system dynamics model highlighted that there is a lack of slack in Leicestershire's local health and social care services to cope with unscheduled care events. The model highlighted that Leicestershire NHS should have 30 more community matrons then they currently have. Leicestershire NHS's current decision to have 34 matrons was the result of the NHS not considering the effect of the change in demographics of the local population on the health and social care system (Lacey, 2006).

The effects of system dynamics influencing Leicestershire NHS's policy decisions are yet to be seen, partly due to the reason that existing decisions on community nurses have already been made. Operational managers may fear that the system dynamics model reflects their decision making in a bad light and thus do not want to be seen to enforce the recommendations from the system dynamics model. Nevertheless system dynamics has had a high impact in getting Leicestershire NHS to look at the wider health and social care system and to extend their own limited mental models.

System dynamics was useful in getting Leicestershire NHS to understand the complexity associated with community nurses and to help reduce their fear as Leicestershire NHS were able to see changes in the system dynamics model that will move Leicestershire NHS forward.

Case 4: System dynamics influencing the rollout of a Chlamydia screening programme

System dynamics has been used in disease modeling to model Chlamydia, a sexually transmitted disease. System dynamics has been useful in modeling the flow of the population that are infected and are in recovery from Chlamydia and thus in modeling the dynamics of disease transmission.

The results of the model have aided decision making in deciding who should be screened and how often people should be screened. System dynamics was useful in demonstrating the feedback between the infected and non-infected population and helped inform policy making. From the results of the model it was decided that Chlamydia screening should be targeted at females aged 16 to 20 (Brailsford, 2002). The system dynamics model was influential in identifying ways that screening could be improved at health centers which would lead to cost savings and delivery of a more effective screening programme (Toohill, 2002).

Case 5: System dynamics influencing a Mental Health Trust (MHT)

System dynamics was used by a Mental Health Trust to aid the trust in achieving the government's agenda for modernisation and the national service framework for mental health.

System dynamics was advantageous in helping the Mental Health Trust to understand the different patient flows, care pathways and policy drivers in different areas of mental health. The system dynamics model helped to introduce new ways of thinking and has implications for investment in mental health services (Smith et al, 2005). The results are significant as investment in mental services in the northwest has been below the national average (Guardian, 2004).

Repper, a system dynamics consultant, highlighted the advantages of system dynamics in this case by saying *'This modelling will show up what you can do by making changes, and reinvesting in different services, but it will also show the limits of that and what you can not do'* (Guardian, 2004).

Case 6: Using system dynamics to investigate the effects of telecare

Telecare is a community alarm service that enables elderly people in their homes to contact an emergency response service via the use of sensors to receive emergency care services when needed. Usage of telecare has been promoted as part of the government's Care Services Improvement Partnership policy (CSIP).

System dynamics was used to investigate the effect of elderly people using telecare in the provision of care services. System dynamics was useful in modeling issues such as the numbers of clients that are receiving telecare services and the overall costs involved over time. The results of the system dynamics model illustrated that the effect of telecare would reduce the number of people in institutional care (Bayer et al, 2005). System dynamics was useful in providing a systematic view for a health trust and Social Services department, looking at the effect of telecare in the health and social care sector.

In other business areas Coyle has made significant contributions to the application of SD.

Case 7: Using system dynamics to investigate the Domestic Manufacturing Company's manufacturing problem

Coyle addressed a manufacturing problem for a company producing washing machines, in which the company was unable to forecast the inflow of new machine orders. As a result it was difficult for the company in particular the raw materials department to cope with unpredictable order patterns, over and under ordering was experienced (Coyle, 1996). A SD model was constructed with the aim of analyzing the robustness of the overall policies for running the business.

The policy of introducing an information system to control the quantity of raw material was tested, as the raw material manager saw the information system as a good idea as information would be provided on how much raw materials would be needed to fill orders. The model illustrated that there were more sustained oscillations in the backlog of ordered machines and the desired backlog of machines, which were closely aligned.

However the simulation illustrated that there was not great control of the raw material stock and of the desired raw materials as the policy for the number of weeks of average production was kept the same. The company produced at the same rate regardless of the fluctuations in raw materials. Coyle highlighted that implementing new policies may not be enough to be effective in any system, as they change the whole system, and other existing policies might need to be changed (Coyle, 1996).

6. Conceptualization of a UK health and social care system

Conceptualization has centered on defining the purpose of the model, the problem situation, identifying key variables, drawing the reference mode and identifying the basic mechanisms, feedback loops. These aspects are drawn upon below.

a) Purpose of the model

The purpose of the SD model to date has been to document knowledge and understanding of the health and social care system and to capture mental models.

b) Problem Situation

The problem description is that there is an information delay between the NHS and Social Services. The NHS thus does not inform Social Services in a timely manner that patients are ready to be assessed.

A dynamic problem exists in that this information delay results in 'bed blocking'. Bed blocking occurs when patients are occupying beds unnecessarily as patients must be assessed by social services before being discharged. Thus the number of patients that are recovered and awaiting assessments is greater than the number of assessments being carried out. The problem of bed blocking is increasingly complex and dynamic and is a long-term policy problem. The problem is dynamic as the problems are characterized by variables that undergo significant changes over time.

From existing hospital discharge data the reference mode illustrates large oscillations in the patients recovered and awaiting treatment by Social Services staff (see diagram 2).

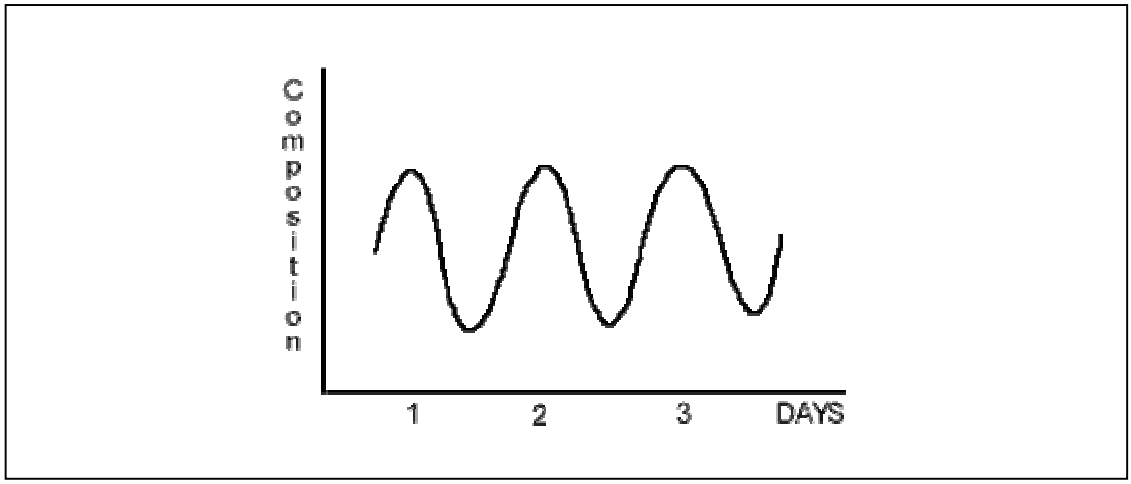

Diagram 2: Local Authority Social Services Hospital discharge manager (2006a), Reference mode illustrating the oscillations in the patients recovered and awaiting treatment

There is great motivation to address this problem. The problem is important to solve because 'bed blocking' creates resource management problems. If a suitable policy solution is not found to control the problem the result will be too many elderly people waiting for an assessment to be carried out by social workers. The flow of patients in and out of the health and social care system would be reduced. There would be continuous bed blocking by elderly people and vital financial resources will be wasted if Social Services are fined over delayed discharge.

c) Dynamic hypothesis illustrating the current model

The hypothesis is that an increase in the number of elderly people awaiting assessments will lead to more patient delays, as the adjustment time that social workers respond to is slower. This is due to the delay in Social Workers receiving the information from the NHS. This will lead to oscillatory behavior, as there are larger delays.

The dynamic hypothesis is illustrated in a stock and flow diagram below (see diagram 3), in which the black and white line illustrates the feedback loop between the NHS and Social Services.

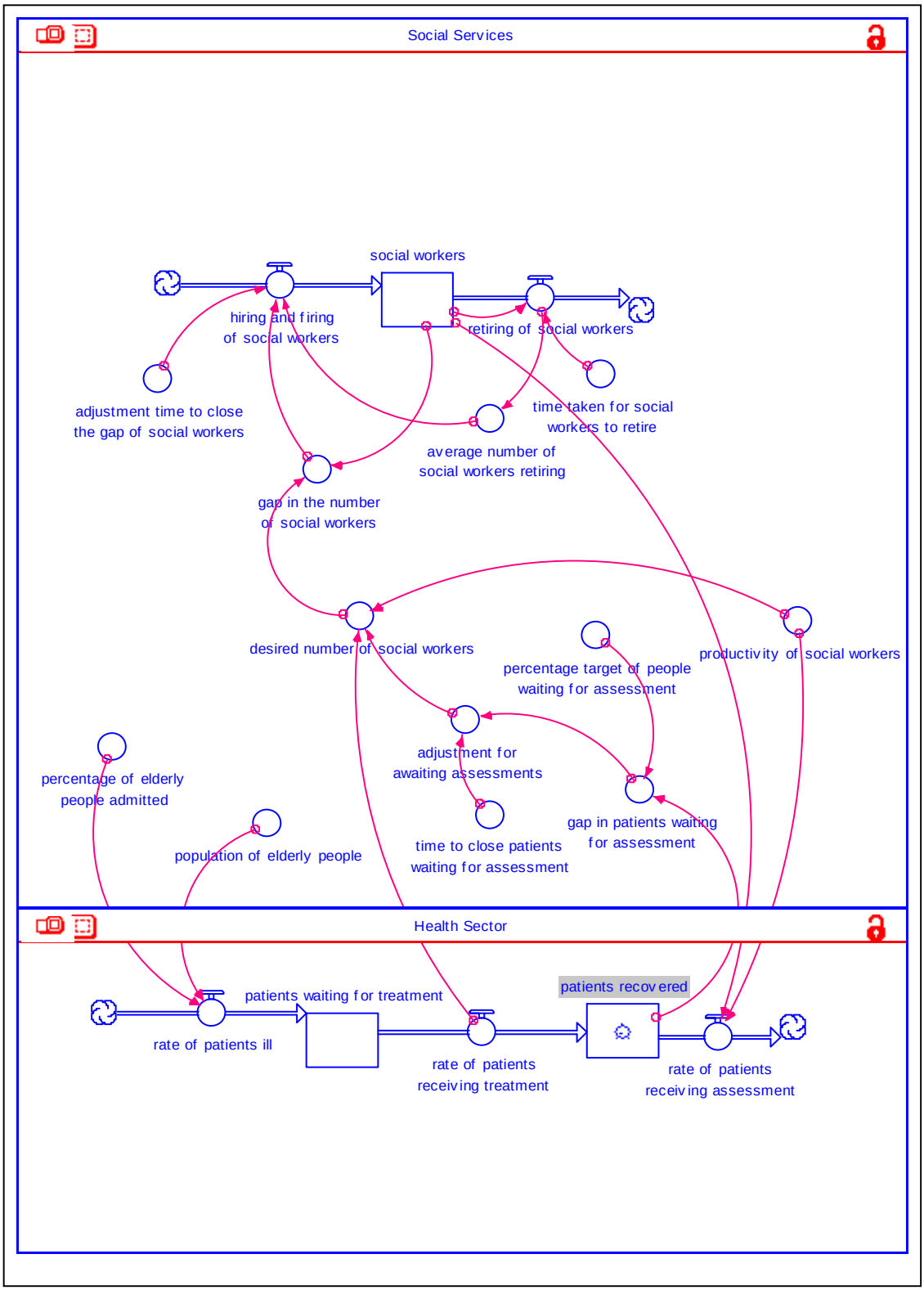

Diagram 3: Author researcher (2007) A Systems Dynamics Model showing the feedback loop between the NHS and Social Services

This is an exploratory model. For the purposes of this illustration I have made the assumption that the number of social workers contribute to the patient delays. This is illustrated by this simplified stock and flow diagram. This has shown the main relationship between the availability of social workers and patients receiving assessments, a core determinate of whether bed blocking occurs. Whilst this is an important factor, other factors like information system flows, competing policies over social worker time and political problems between health and social care are contributory factors towards patient's delays.

d) Causal Loop diagram

The following things were considered when devising the causal loop diagram.

1. Exogenous variables. The exogenous variables are those that are not affected by the system and are not included in the causal loop diagram. Only the desired goal that is exogenous is included, such as the desired patients waiting for assessments goal. The exogenous factors that are not included are:

1. The adjustment time to close the gap of social workers
2. The time to close patients waiting for assessments.
3. Patients ill

2. Feedback loops. Feedback loops illustrate circular causality over time.

The feedback loops that exist in the health and social care system are the following, in which the causal loop diagram corresponds to the problem statement:

1. **Reinforcing loop (R1).** The more hiring of social workers the higher the retiring of social workers that leads to an increase in the average number of social workers retiring, which in turn leads to more hiring of social workers.

2. **Counteractive loop (C1).** A rise in the number of social workers will lead to more patients receiving assessments, which will decrease the number of recovering patients awaiting assessments. The gap in patients waiting for assessments will decrease leading to smaller adjustments needed for awaiting assessments, which will lead to a smaller gap in the number of social workers needed to carry out patient assessments.

3. **Counteractive loop (C2).** The more patients that are recovered and are awaiting for an assessment the higher the number of patients that receive assessments. The higher the patients receiving assessments the lower the numbers of patients that are recovered and are awaiting an assessment.

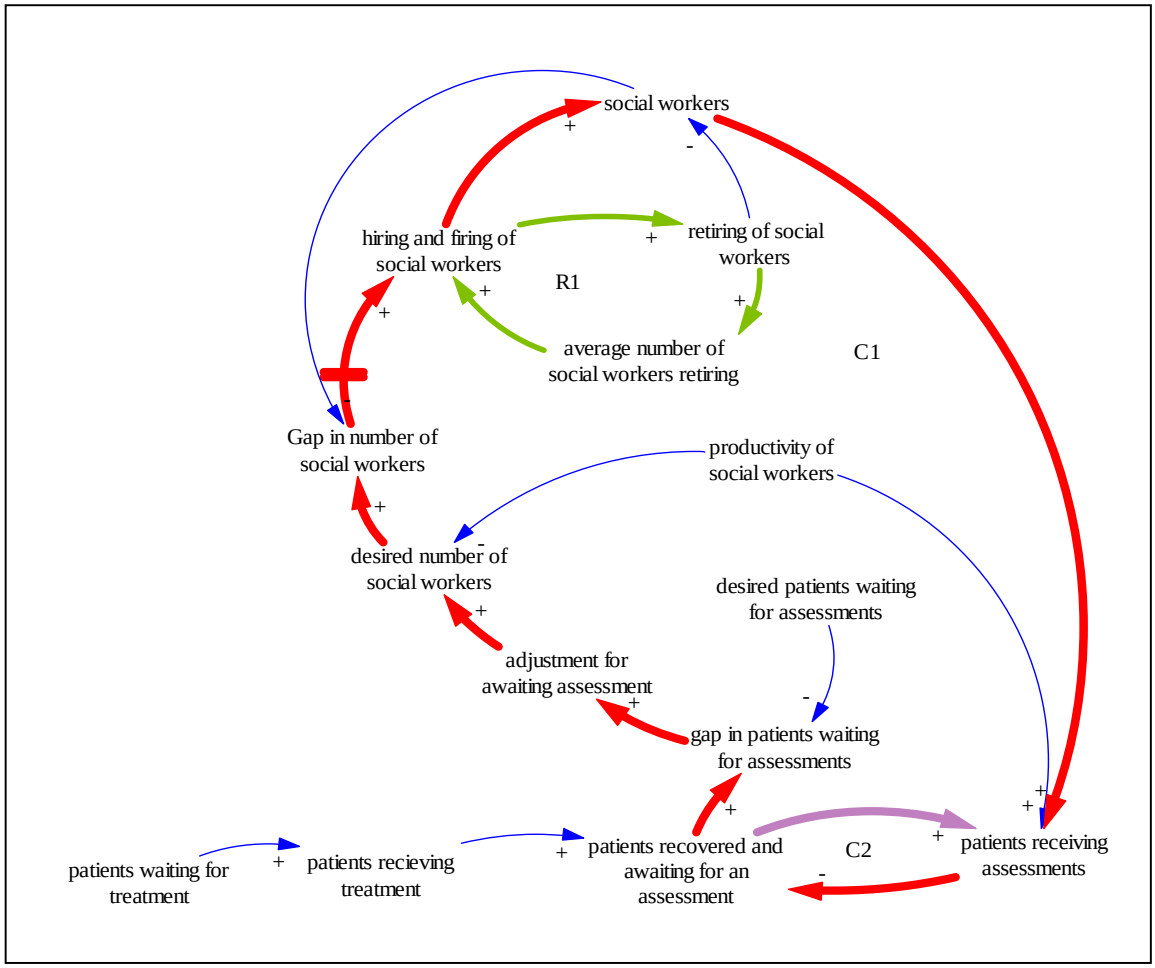

Diagram 4: Author researcher (2007), Causal Loop diagram of a health and social care

6. Aspects considered during the formulation and conceptualization of the health and social care model

The following aspects where considered during conceptualization.

a) Establishing a clear distinction between the causes of the problem from the actual problem. This can be a particular problematic area experienced by modelers as these are separated in time and space. For example it was important to distinguish the cause in this case study as being an information delay between the NHS and Social Services from the problem of bed blocking.

b) Illustrating the internal feedback loop between the health and social care system. This was crucial as this feedback loop acts as a long-term driver of the system, in which the loop provides the leverage for influencing the behavior of the system.

c) Formulating the dynamic hypothesis. The dynamic hypothesis was based on a literature review and information gathered from hospital discharge staff. Formulation has involved translating the feedback loops into equations, making assumptions and

estimating different parameter values. The following aspects were considered when formulating the health and social care SD model.

a) Representing the necessary patients flow that we are considered with in regards to the problem situation from the patient being ill to receiving an assessment. This information was confirmed at an interview with a social care discharge manager. The patients get admitted to hospital, they wait for treatment then receive treatment. Patients then recover and wait for an assessment from social services, then receive an assessment and then leave hospital.

b) Illustrating the main stocks. The main stocks considered are social workers, patients waiting for treatment and the patients recovered. These stocks are seen to play a central role in health and social care management problems and are the source of endogenous dynamics.

c) Considering the parameters. When formulating the model parameters of the model were either estimated, taken from secondary or primary data that was available about the problem situation and case study.

d) The adjustment time. The adjustment times it takes to close patients waiting for assessment and to close the gap in obtaining social workers to do assessments are considered.

e) Illustrating the productivity of workers. The productivity of workers depends upon the desired number of Social Workers and patients receiving assessments. The equations in the stock and flow diagram correspond to the causal loop diagrams.

f) Illustrating the desired number of social workers. The desired number of workers depends on the productivity of Social Workers and the patients receiving treatment.

g) Illustrating the delays. Delays such as the information delay in getting the average number of social workers that are retiring have been important to consider as delays intervene between causes and their effects.

h) Determining the gap in the number of social workers. The gap in the number of Social Workers is equal to the desired number of Social Workers minus the number of Social Workers currently employed.

i) Considering unit consistency. Unit consistency was maintained through out the building of the model, for example in calculating the desired number of workers needed to carry out assessments.

$$\text{Desired number of Social workers} = \frac{\text{patients receiving treatment} - \text{adjustment for awaiting assessments}}{\text{productivity}}$$

Units as illustrated below for the desired number of social workers:

$$\text{<<Social worker>>} = \frac{\text{patient/month} - \text{patient/month}}{\text{patient/month/social worker}}$$

For the top half of the equation patient month- patient month= patient month. Then patient/month cancels out with patient/month leaving the desired number of social workers measured in 'social worker' unit.

$$\text{<<social worker>>} = \frac{\text{patient/month}}{\text{patient/month/social worker}}$$

$$\text{<<social worker>>} = \text{<<social worker>>}$$

Unit consistency can thus advantageously be used to help work out what variables are needed in the model, as equations must be dimensionally consistent. All equations in the health and social care model had real life meaning.

8. Research findings and discussion

The research findings are indicated below, which corresponds to the earlier indicated paper objectives. This achieves the overall aim of presenting work and thinking that has been involved in the conceptualization of the bed blocking problem and issues that have arisen when building a SD model (see section 3).

Objective A: Documenting knowledge and understand of the health and social care system and to capture mental models

A case study approach was useful in conjunction with SD as primary data could be collected on the processes, delays and problem situation of the hospital discharge team.

Finding 1:

SD was helpful in helping to elicit and map my mental models of the health and social care system.

Objective B: Conceptualization of the problem of bed blocking

Conceptualization of the bed-blocking problem was achieved through defining the problem, identifying stocks; flows, sketching the dynamic hypothesis and drawing causal loop diagrams to establish the main feedback loops that exist (see section 6).

Objective C: Formulation and simulation of a SD model that represents the problem of bed blocking

Formulation of the SD model involved constructing the dynamic hypothesis, which involved including the main stocks and flows and feedback loops in order to capture the structure of the health and social care system (see section 6).

Finding 2:

When the model was simulated oscillatory behavior was experienced which was similar to the reference model, in which there are oscillations in the patients recovered and awaiting treatment.

Objective D: Aspects considered during the conceptualization of the problem and formulation of the SD model

Finding 3:

Adequate time needs to be spent in conceptualizing the problem before formulating and testing the model. Modeling has shown to be very iterative in which it has been necessary to revisit and define the hypothesis and problem differently.

Finding 4:

Causal loop diagrams and stocks and flows have been useful when conceptualizing a problem.

Discussions of the findings are provided below:

Objective A, Finding 1

SD has helped to expand my mental models and has brought to my attention other issues of feedback, delays, nonlinearities that I would previously not have considered fully if I was using another systems thinking approach such as soft systems methodology.

Objective C, Finding 2

This system meets the minimum number of requirements for oscillatory behavior to happen, in which there are more than two stocks and a balancing loop exists.

Thus oscillations occur in this health and social care system due to:

1. A major feedback loop existing between the health and social care systems.
2. Numerous delay times being present, which are the adjustment times. The delay times are an indispensable factor.

If any of these parts of the system become constant then we would not experience these oscillations. If the delays are not long enough then this will translate into smaller overshoots and undershoots.

Objective D, Finding 3

It is important that adequate time is spent conceptualizing and formulating a SD model. Otherwise this would lead to inadequate, wrong models being made that provide no sound basis for managers to base their decisions on.

The difficulties and practicalities of conceptualizing a dynamic problem and formulating a SD model cannot be underestimated. This may be a part of why SD has not taken off to the extent other approaches have, because the complexity in conceptualizing problems and formulating models are underestimated.

Objective D, Finding 4

With stocks and flows the feedback structures become more transparent in seeing how the cause and effect feedback on each other (Haraldsson, 2006). Stocks and flow diagrams have greater tendency to be more detailed than causal loop diagrams and have allowed me to think more about system structure, in which the components are more strictly defined than in causal loop diagrams.

Causal loop diagrams have aided brainstorming and model creation. Causal loop diagrams are useful in helping to illustrate ideas from a model that have previously been created. However causal loop diagrams have numerous disadvantages in that you cannot determine the behavior of the system from the polarity of the feedback loops, as dynamics behavior is not created. Thus causal loop diagrams cannot be used to predict dynamic behavior. It has been harder for me to understand the causal loop diagrams compared to the stock and flow diagrams as it is a less specific representation to the health and social care system being modeled and the same level of detail as the equation in the stock and flow diagram have not been shown. Simulation is crucial for gaining a complete understanding and in determining the dynamics of a system.

However through SD emergence causal loop diagrams have helped to make SD more accessible to a wider audience as they have brought about simplicity and can be used as a tool for communication purposes (Richardson, 1986, Coyle, 1996). Thus there are advantages and disadvantages of usage of causal loop diagrams and stock and flow diagrams.

9. Conclusions, recommendations and policy contributions

From this modeling experience SD has provided the greatest learning in terms of understanding the problem situation better and helping me to organize my mental models. The process has helped provide a clearer insight into how the structure of a system translates into behavior. SD has proved to be a participative activity, where by one learns by trial and error. This can be very powerful in changing mental models.

Whilst SD has been useful, the next step is to apply other systems thinking approaches like Soft Systems Methodology (SSM) in conjunction with this research. SSM provides the advantage over the SD approach in giving greater consideration to the ‘holons’. These are human activity systems and are highly appropriate to consider, as these are

appropriate to the problem situation in the health and social care domain. It is very difficult to incorporate soft aspects of the problem using the SD approach, where as SSM goes further in understanding the different people involved, their conflicting objectives, perceptions and attitudes. The focus of SSM is different in contrast to SD, where by SSM's main focus is is to look at the people involved with the problem and the secondary focus would be to look at the problem. Where as the SD focus is very much vice versa where by the problem is the primary focus and little focus is given to the people involved with the problem.

Having experienced the systems dynamics process the following recommendations are made in devising a SD model.

1. **Timing.** Adequate time needs to be spent in conceptualizing a dynamic problem with the use of causal loop diagrams and stock and flow diagrams.

2. **Development of the system dynamic model.** To include the following points:

    a) There should be continuous feedback between the client and an experienced SD modeler in devising a SD model, in order to ensure that it mimics reality sufficiently and produces the reference mode behavior.

    b) A model must be continuously tested at each stage when additional complexity is added in order to understand clearly the relationship between structure and behavior of the system. This will add confidence in the model when devising the most appropriate policy to solving the problem situation.

    c) The model should be kept as simple as possible, so to address the problem situation only and unnecessary additional complexity should not be added for any reasons.

Future papers will expand on this to look at policy experiments and sensitivity tests for a particular policy of providing integrated information systems between the NHS and social services. Little is known about what affects integrated information systems have on service provision. This will be valuable to social services and health stakeholders including hospital management staff and the government who will be concerned with getting patients through the health and social care system as quickly as possible, in order to save costs, improve patient services and improve policy making nationally and locally.

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11. SD terminology

Reference mode- This is the behavior pattern that has been observed historically in the system that we are studying and is what we want to replicate. It is a graphical representation of the problem, in which are interested in looking at the dynamic problem of the interplay between stocks and flows. The reference mode would illustrate anything that is of interest to the client, for instance in a supply chain management scenario we

would draw the stocks such as the inventory, employees and also the flow variables, sales and production.

Stock and Flow diagram- This is a map representation for the reason of the behavior that you are seeing.

Dynamic hypothesis for the reference behavior- This is the hypothesis about the dynamic behavior and is the theoretical explanation. It is represented in terms of the stock and flow.

Characteristic behavior- We look for feedback loops to explain the characteristic behavior, which is not driven by exogenous feedback. We are concerned with the systems dynamics behavior that is endogenous.