

UTILISATION OF HEALTH AND SOCIAL CARE SERVICES BY THE OVER 65S POPULATION. A SYSTEM DYNAMICS STUDY

Dr. Rudabeh Meskarian¹
R.Meskarian@soton.ac.uk

Dr. Marion L. Penn¹
M.L.Penn@soton.ac.uk

Dr. Thomas Monks¹
Thomas.monks@soton.ac.uk

Dr Melinda A. Taylor¹
M.A.Taylor@soton.ac.uk

Dr. Jonathan Klein²
J.H.Klein@soton.ac.uk

Prof. Sally C. Brailsford²
S.C.Brailsford@soton.ac.uk

Mr. Paul R. Benson³
Paul.benson@southamptoncityccg.nhs.uk

¹NIHR CLAHRC Wessex, Faculty of Health Sciences, University of Southampton

²Southampton Business School, University of Southampton

³NHS Southampton City Clinical Commissioning Group, Southampton

ABSTRACT

This paper focuses on a system dynamics simulation approach modelling the flow of frail elderly patients in health and social care systems in the South of England, UK. A system dynamics model of this pathway is designed that enables testing and informs redesign of the pathway to enhance integrated working between health and social care agencies leading to reduced number of acute hospital admissions and fewer delayed transfer of care. Given the complexity of the model, a number of different scenarios are considered.

Keywords: Simulation, System Dynamics, Healthcare Systems

1 INTRODUCTION

This paper describes a system dynamics simulation study focusing on the flow of frail elderly patients in a health and social care system in the South of England, UK. The model was designed to help stakeholders analyse a number of options to redesign the pathway in order to enhance integrated working between health and social care agencies leading to a reduced number of acute hospital admissions and fewer delayed transfers to other health and social care providers. The project was large and complex, and raises several issues in managing the expectations and understanding of simulation clients in healthcare simulation projects and the study feasibility.

The paper is structured as follows. First, we provide some context to the problem by reviewing the aging population and traditional healthcare improvement approaches. Second, we review previous system dynamics projects in related areas of healthcare. We then provide an overview of the case study, including the model and scenarios investigated. The concluding discussion reflects on the difficulties of conducting a simulation study focused on such a large part of a health and social care system.

2 BACKGROUND

Spending on health and social care has slowed dramatically in the past few years as governments have adjusted public spending in the wake of the impacts of the global financial crisis and the following recession. In the UK, the planned National Health Service (NHS) expenditure for 2015/16 is £116bn in cash terms, which is £3.1bn more than expenditure in 2014/15. Simultaneously, councils have cut £4.6bn from the adult social care budget since 2009-10. Furthermore, they are required to make £500m of service reductions over the next year while facing £600m in extra service demand and price

inflation- equivalent to an overall cut in funding of £1.1bn (ADASS 2015). It is expected that the coming half of the century will see an increase in the elderly population due to 'the greying of the baby boomers.' (Lanzieri 2011). In the UK, the number of people aged 65 and over is projected to increase from 10.4m in 2011 to 17.79m by 2037 (Eurostat 2011).

There is increasing concern in healthcare organisations throughout the world about the consequences of an aging population and how to manage the increasing complexity of patient needs. Increases in healthcare costs are strongly associated with increasing age and it is widely projected that the healthcare of the elderly will account for an increasing proportion of health budgets in the future. In order to manage future demands and costs, commissioning organisations have started to try and estimate the effect that an aging population will have on future costs and how budgetary priorities will have to change. An important aspect of this is to gain a better understanding of how various health and social care services interact.

Hospitals have a responsibility to ensure that patients are discharged from hospital care in a safe and efficient manner (Preen 2005). This is becoming increasingly important, considering the trend towards shorter hospital stays and more care in the community (Mistiaen et al. 2000). It is evident that cost containment is a major feature of all healthcare systems, especially for acute hospital services (Schwartz and Mendelson 1991). Recent trends include decreasing the length of stay for inpatient care; reducing the number of long stay beds; moving care into the community; an increased use of day surgery; providing increased levels of acute care at home ('hospital at home'); and policies such as discharge planning (Shepperd et al. 2013). It has been shown that discharge planning strategies can reduce unplanned readmission to hospital for some patients (Phillips et al. 2004). The aim of discharge planning is to reduce hospital length of stay and unplanned readmission to hospital, and improve the co-ordination of services following discharge from hospital. Over the past decade, rates of emergency hospital readmission (defined as an unplanned readmission within 28 days of leaving) have risen; the increase has been particularly steep for those over the age of 75. Consequently, reducing the occurrence of emergency hospital readmission for older people is a key issue for healthcare providers including the NHS.

Simulation models create virtual worlds that offer decision makers the capability of conducting experiments and evaluating system interventions (Sterman 2000). They provide low- risk and low-cost platforms to learn and gain understanding about healthcare systems. Such modelling enables decision makers to push the virtual system to extreme conditions, extend the time of observation, and strengthen and relax assumptions, which is often impossible or infeasible in the real world (Sterman 2000). They provide immediate feedback to decision makers, allowing them to gain years of virtual experience and knowledge about the system and interventions by revealing dynamics and mechanisms that are otherwise not obvious (Sterman 2000, Sterman 2006).

3 MODELLING OF LARGE SCALE HEALTHCARE SYSTEMS

Simulation is a modelling tool widely used in operational research (OR), where computer models are deployed to understand and experiment with a system. Two of the most established simulation approaches are discrete-event simulation (DES) and system dynamics (SD) (Pitt et al. 2015). Both DES and SD models are simplified representations of a system developed with a view to understanding its performance over time and to identifying potential means of improvement.

Recently, Young (Young 2005) advanced SD as a method for improving healthcare management. SD combines qualitative and quantitative aspects, and aims to enhance understanding of a system and the relationships between different system components. Recently, SD has been applied to number of large scale, complex health care systems. For example, Brailsford et al. (Brailsford et al. 2004) report a study of the use of SD to model emergency and on-demand health care in Nottingham, UK. The paper includes a representation of patient flows through different departments in a hospital. The model covers the whole health system from NHS Direct to outpatient clinics and A&E departments.

Wolstenholme et al (Wolstenholme et al. 2004c) utilised SD at a national level to inform government policy on reimbursement for delayed hospital discharges. Their models were parameterised with the available health system data to estimate the effects of various policies such as implementing intermediate care on flow bottlenecks. They additionally assisted local health and social

care communities in the UK to interpret and apply national policy frameworks for older people (Wolstenholme et al. 2004a, Wolstenholme et al. 2004b).

SD has successfully been used as a tool in improving patient experience focusing on answering questions about different patient pathways and what might speed or slow patient flow in an acute hospital setting (Lane and Husemann 2007). More recently, Esensoy and Carter (Esensoy and Carter 2015) used SD to model the feedback structure around patient flows between the health system sectors. They specifically focused on patient handovers between health system sectors. The model was kept broad and general as it was not defined to address any specific policy question.

This paper complements this literature by presenting an SD model specifically focusing on the patient pathway of those 65 and over and their handovers between health and social care system sectors.

4 CASE STUDY

In this paper we have focused on the development of a high level model of the patient discharge pathway from an acute hospital to community based services, focusing on patient flow between various health care systems and social care.

A simulation model focusing on the provision of health and social care for over 65's across a UK city in the south of England was developed, focusing on understanding provision for the frail elderly and how this could be developed in future.

The initial phase of research was qualitative. This involved the development of a detailed “system map” showing the interconnectedness of provision for this age group. This map was shared with a variety of stakeholders, a process which not only improved the accuracy of the map but also raised their awareness and understanding of care beyond their own areas.

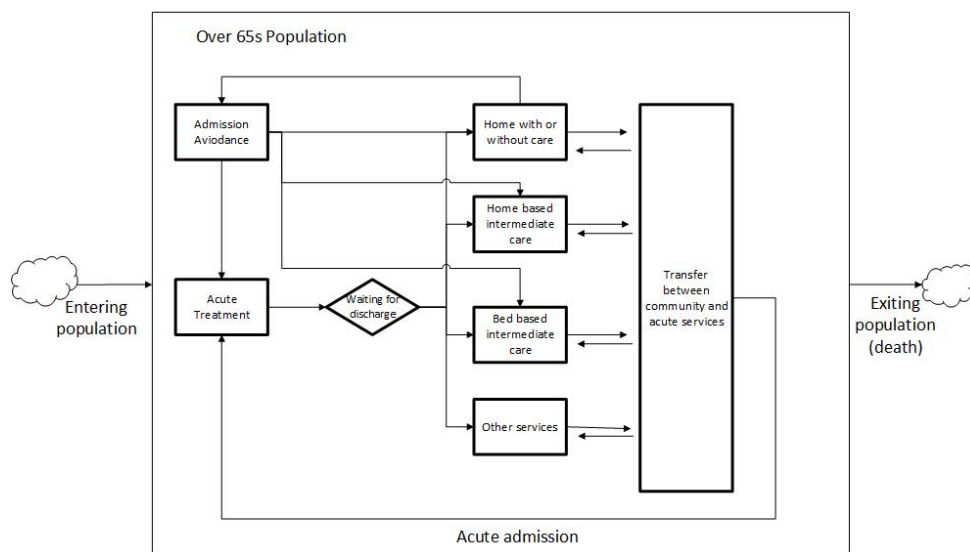


Figure 1 Simplified Overview of the System

Following this, a stock-flow modelling approach was used, where stocks represented accumulations of patients (e.g., waiting for a bed in the hospital; occupying a bed in an acute admission ward, waiting for discharge) and the flows were the admission, transfer, treatment and discharge rates. The model was created using the software package Vensim DSS version 6.3 (Vensim 2015). Stakeholders from the local Clinical Commissioning Group and healthcare provider Trusts were involved throughout the study to design scenarios, so that the model could be used to assist with thinking through the consequences of potential changes.

A simplified overview of the model can be seen in Figure 1, while Figure 2 (in Appendix) depicts the model created in Vensim. There are 12 discharge destinations built-in in the model. These could be grouped into four distinct groups shown in Figure 1. The model is built in multiple layers, these layers hold the influence diagrams for all the flows and stocks represented in Figure 2.

We did not attempt to model intra-hospital flow in detail (blue boxes), including instead the high level stocks of patients waiting for a bed, treatment and, on completion of treatment, waiting for discharge. We have also modelled a series of discharge destinations out of the hospital (green boxes). Patients can transfer between all of these community stocks as well as being admitted to the hospital.

The patient population is dynamic and includes background mortality rates and the arrival of new potential patients as people reach the age of 65. The model includes multiple layers that define the relationship between flows in and out of each stock.

As in all stock-flow systems, the contents of each stock are updated at regular intervals by solving a set of difference equations representing the inflows and outflows from that stock. Vensim presents results in the form of graphs and tables, but most of our output was exported to Excel for analysis and presentation purposes. The outputs include the waiting times; and occupancy rates for each of the stocks in the model.

4.1 Overview of the Model

In the model represented in Figure 2 we have focused on patients aged over 65 admitted to hospital and their flow through the healthcare system and social care in the Southampton area. As can be seen, the flows between each stock is controlled by the rate of flow to that stock, as well as its capacity and flows out of that stock. The blue boxes labelled “Waiting –” represent the patients occupying beds in the hospital while waiting for a place at the required discharge destination.

Below we give a detailed explanation of this model:

Acute Hospital Care: All the blue boxes are stocks within the hospital. With the exception of the first box (Waiting for Admission), all the boxes use resources such as hospital beds.

Home and Community Care: Through consultation with stakeholders, 12 discharge destinations were identified (green boxes) ranging from own home without any care, to community hospital beds and out of area services.

Admission Avoidance: Admission avoidance is defined here as a reduction in the proportion of patients admitted to hospital and not necessarily stopping patients from attending A&E.

4.2 Data

In general, data requirements are high – 130 individual data items are required in the model. This includes flow of patients to and from healthcare providers, available capacity, along with length of stay metrics. A number of different data sources have been utilised including Secondary User Services (SUS), along with nationally reported data and expert opinion, where data was not available.

As outputs, we are interested in the effect of various changes to the admission rate into the acute treatment unit along with the waiting time post treatment and pre discharge for each of the 12 discharge destinations, and the effect of capacity variations on the above.

To simplify data entry and model testing, all input variables are linked to an external Excel workbook. The outputs are also exported to Excel for analysis purposes.

As the project is still in progress, the data requirements have not fully been met and effort is being made into collection of the remaining data items.

4.3 Validation & Experimentation

The model is created using the “system map” developed in the initial phase of this project which was shared and verified by the stakeholders. Additionally, availability of data would allow for as-is scenario modelling that would further verify accuracy of the model.

Throughout the development of the model various meetings were held with the stakeholders where the model was presented and various possible what-if scenarios were discussed. The following three scenarios were proposed by stakeholders:

1. **Merging of the community crisis and reablement teams.** This scenario analyses the impact on admission and discharge rates from the acute hospital. After a stay in hospital, reablement teams assist patients in maintaining or regaining their ability to live at home. This is done through

providing support in developing new ways to manage and to do things differently. Support could be for as little as a few days or up to a maximum of 6 weeks. On the other hand, the aim of the community crisis team is to avoid hospital admissions where possible and assist with hospital discharges from the acute Trust, as well as responding to a adults experiencing either health-related or a social care crisis. The potential synergy and the consequent impact on the acute hospital admission and discharge rate was investigated.

2. **Introduction of Integrated Living Services and reduced bed stock in the community.** This includes the extension of rehabilitation and reablement services at home, as well a reduction in the number of beds for these purposes in the community.
3. **A redesigned discharge pathway.** This scenario reduces the number of options on discharge and introduces an integrated discharge team that would handle follow-on care of patients at home rather than in hospital.

4.4 Illustrative Results

As an illustration we have provided below an example where the number of reablement beds is reduced. Let's assume there are in total 40 beds available and approximately 15% of patients are discharged from the acute hospital unit to such beds in the community. We also assume that the initial occupancy rate is 75%. It can be seen in Figure 3 that when the capacity is at 40 beds, the number of patients waiting for a reablement bed is close to 1 on a daily basis. In this scenario the system reaches an equilibrium at 35 beds, which is equivalent to 87.5% utilisation. Reduction of beds to 30 causes disruption in the system, resulting in an ever increasing list of patients waiting for a reablement bed in the acute treatment unit. To further illustrate the sensitivity of this model to input data, especially the discharge rates from the acute hospital, assume the actual rate of discharge to a bed based reablement facility is 10% instead of 15% in the above example. Figure 4 shows the corresponding results. As can be seen, unlike the above example, reduction of beds from 40 to 30 does not cause any disruption to the system, as even in the case of 40 beds capacity, the system reaches an equilibrium at around 22 beds, which well below 30.

The purpose of the above example is to illustrate the type of “what-if” scenario analysis that could be performed based on the model, as well as the importance of reliable input data in such analysis.

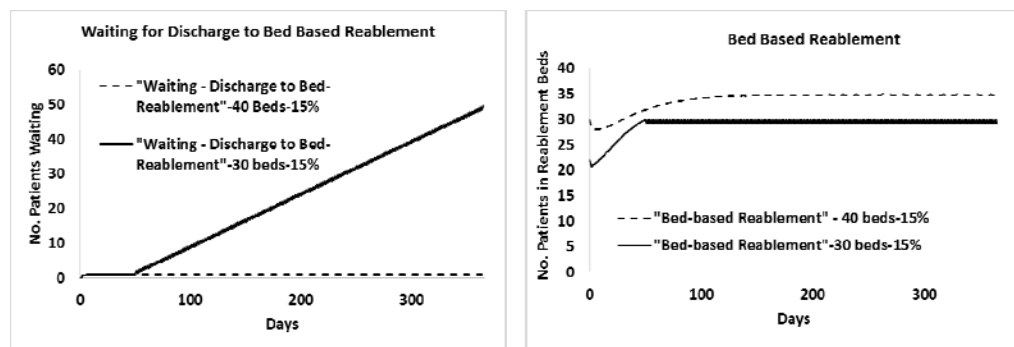


Figure 3 Illustrative results for reduction of number of reablement beds, given discharge rate of 15%.

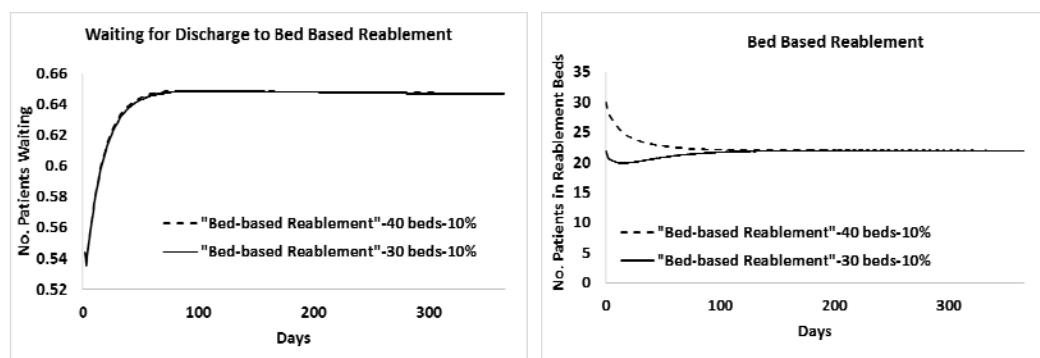


Figure 4 Illustrative results for reduction of number of reablement beds given discharge rate of 10%.

5 CONCLUSION & DISCUSSION

One of the core assumptions in SD is that the behaviour of the system is due to its structure and not due to external forces or factors. Although SD models can be formulated at many different levels of detail, such models in health care are most traditionally aggregated as in the model above, in the sense that they characterise the population in terms of sizes of subpopulations, rather than at an individual level. In general terms, SD can produce patterns and trends, as well as mean values as outputs from the model. The patterns and trends resulting from simulation experimentation with different policies or strategies ("what-if" questions) can be analysed to inform decision making.

Nonetheless, there are challenges to using and implementing such large and complex dynamic simulation models. Stakeholder involvement, beginning with the project scoping and continuing through the model design and evaluations, is critical to a successful project. However, identifying a representative group of stakeholders to support the broad scope of the modelling, and managing such a large group with different agendas and expectations, can be a challenging task. The same is true when it came to selecting scenarios. Stakeholders lack of experience in SD and macro-level modelling and its capability, along with the natural tendency to focus on low level operational measures instead of higher level overviews of the whole system, proved to be the main obstacles in managing the project as well as the stakeholders.

Furthermore, data requirements to parameterise the model were difficult to fulfil due to lack of access to certain data, costs associated with data acquisition, and data availability. For example, routinely collected data on outflow of patients from the acute hospital is used for financial purposes as opposed to understanding the flow of patients to community providers, and data are not necessarily in a suitable format for modelling. Nevertheless, SD models provide an advantage because their structure will not be limited by the available data and they can be used to do exploratory analyses until the additional data can be incorporated (Pruyt et al. 2014). It may be difficult at times to communicate how these models are built and the details of their mathematical structure. This can sometimes be interpreted by users (i.e., policymakers) as lack of transparency. These structures and sophisticated calculations, however, are necessary to adequately represent the problem and to obtain accurate results.

ACKNOWLEDGMENTS

This article presents independent research funded by the National Institute for Health Research (NIHR) Collaboration for Leadership in Applied Health Research and Care (CLAHRC) Wessex. The views expressed in this publication are those of the author(s) and not necessarily those of the National Health Service, the NIHR, or the Department of Health.

NHS Southampton City CCG funded the initial phase of this research that developed the qualitative map. We are thankful for the input and cooperation of the wide range of professionals who assisted with the development of the System Map and subsequently with the provision of data.

REFERENCES

- ADASS (2015). "Association of Directors of Adult Social Services in England (ADASS) Budget Survey 2015."
- Brailsford, S. C., V. A. Lattimer, P. Tarnaras and J. C. Turnbull (2004). "Emergency and on-demand health care: modelling a large complex system." *J Oper Res Soc* **55**(1): 34-42.
- Esensoy, A. V. and M. W. Carter (2015). "Health system modelling for policy development and evaluation: Using qualitative methods to capture the whole-system perspective." *Operations Research for Health Care* **4**: 15-26.
- Eurostat (2011). The European Commission: Eurostat; Population Projections. [SpringerReference](#), Springer Science + Business Media.
- Lane, D. C. and E. Husemann (2007). "System dynamics mapping of acute patient flows." *J Oper Res Soc* **59**(2): 213-224.

- Lanzieri, G. (2011). "The greying of the baby boomers A century-long view of ageing in European populations." Eurostat statistics in focus **23**.
- Mistiaen, P., E. Duijnhouwer and T. Ettema (2000). "The Construction of a Research Model on Post-Discharge Problems Based on a Review of the Literature 1990-1995." Social Work in Health Care **29**(4): 33-68.
- Phillips, C. O., S. M. Wright, D. E. Kern, R. M. Singa, S. Shepperd and H. R. Rubin (2004). "Comprehensive Discharge Planning With Postdischarge Support for Older Patients With Congestive Heart Failure." The Journal of the American Medical Association **291**(11): 1358.
- Pitt, M., T. Monks, S. Crowe and C. Vasilakis (2015). "Systems modelling and simulation in health service design, delivery and decision making." BMJ Quality & Safety: 1-8.
- Preen, D. B. (2005). "Effects of a multidisciplinary, post-discharge continuance of care intervention on quality of life, discharge satisfaction, and hospital length of stay: a randomized controlled trial." International Journal for Quality in Health Care **17**(1): 43-51.
- Pruyt, E., S. Cunningham, J. H. Kwakkel and H. D. Bruijn (2014). From data poor to data rich: system dynamics in the era of big data. In : Proceeding of the 30th International Conference of the System Dynamics Society, Delft, NL, System Dynamics Society.
- Schwartz, W. B. and D. N. Mendelson (1991). "Hospital Cost Containment in the 1980s." New England Journal of Medicine **324**(15): 1037-1042.
- Shepperd, S., N. A. Lannin, L. M. Clemson, A. McCluskey, I. D. Cameron and S. L. Barras (2013). "Discharge planning from hospital to home (Review)." The COCHRANE Library(1).
- Sterman, J. D. (2000). Business Dynamics: Systems Thinking and Modelling for a Complex World. New York, McGraw-Hill.
- Sterman, J. D. (2006). "Learning from evidence in a complex world." Am J Public Health **96**: 505.
- Vensim. (2015). "<http://vensim.com/>."
- Wolstenholme, E., D. Monk, G. Smith and D. McKelvie (2004a). "Using system dynamics in modelling health and social care commissioning in the UK." Proceedings of the 2004 system Dynamics Conference, Oxford, England.
- Wolstenholme, E., D. Monk, G. Smith and D. McKelvie (2004b). "Using system dynamics in modelling mental health issues in the UK." Proceedings of the 2004 system Dynamics Conference, Oxford, England.
- Wolstenholme, E., D. Monk, G. Smith and D. McKelvie (2004c). "Using system dynamics to influence and interpret health and social care policy in the UK." Proceedings of the 2004 system Dynamics Conference, Oxford, England.
- Young, T. (2005). "An Agenda for Healthcare and Information Simulation." Health Care Management Science **8**(3): 189-196.

AUTHOR BIOGRAPHIES

RUDABEH MESKARIAN is a research fellow in Operational Research in the Faculty of Health Sciences, University of Southampton. She holds a BSc in Investment and Financial Risk Management, MSc in Operational Research and PhD in Operational Research concentrating on stochastic optimisation.

MARION PENN is a research fellow in Operational Research in the Faculty of Health Sciences, University of Southampton. She received a BSc (Hons) Mathematics, an MSc in Operational Research and a PhD in Operational Research, with a focus on hospital scheduling.

THOMAS MONKS is a Senior Research Fellow in Operational Research in the Faculty of Health Sciences, University of Southampton. He holds a BSc in Computer Science and Mathematics, MSc in Operational Research and PhD in Simulation Modelling. His specialty is simulation of healthcare systems of unscheduled and emergency care.

MELINDA TAYLOR is a research fellow in Operational Research in the Faculty of Health Sciences, University of Southampton. She holds a BSc in Psychology, MBA focusing on health service

management and a PhD in Information Systems. She is also a registered nurse and has clinical and management experience within the NHS and private sector.

JOHANATHAN KLEIN is an Associate Professor of Management Science at Southampton Business School, University of Southampton, UK. Trained as a physicist, his current research interests include problem structuring and qualitative modelling, the nature and use of knowledge in problem-solving practice, and the nature and value of evidence in decision-making.

SALLY C. BRAILSFORD is Professor of Management Science at the University of Southampton, UK. She received a BSc in Mathematics from the University of London, and MSc and PhD in Operational Research from the University of Southampton. Her research interests include simulation modeling methodologies, system dynamics, health service research and disease modeling, and the modeling of human behavior in healthcare systems. She is chair of the European Working Group on OR Applied to Health Services (ORAHs) and is an Editor-in-Chief of the journal Health Systems. She is on the editorial boards of Health Care Management Science, the Journal of Simulation, and Operations Research for Health Care.

PAUL BENSON is a Senior Commissioning Manager at NHS Southampton City Clinical Commissioning Group. He holds a BSc in Biological Sciences and the Diploma of the Institute of Health Services Management. He has held a wide range of roles across the public, private and voluntary healthcare sectors in the UK and has had a long-standing interest in “whole-system” approaches to healthcare planning and delivery. He holds an unpaid role as a Governor of Western Sussex Hospitals NHS Foundation Trust.

A APPENDICES

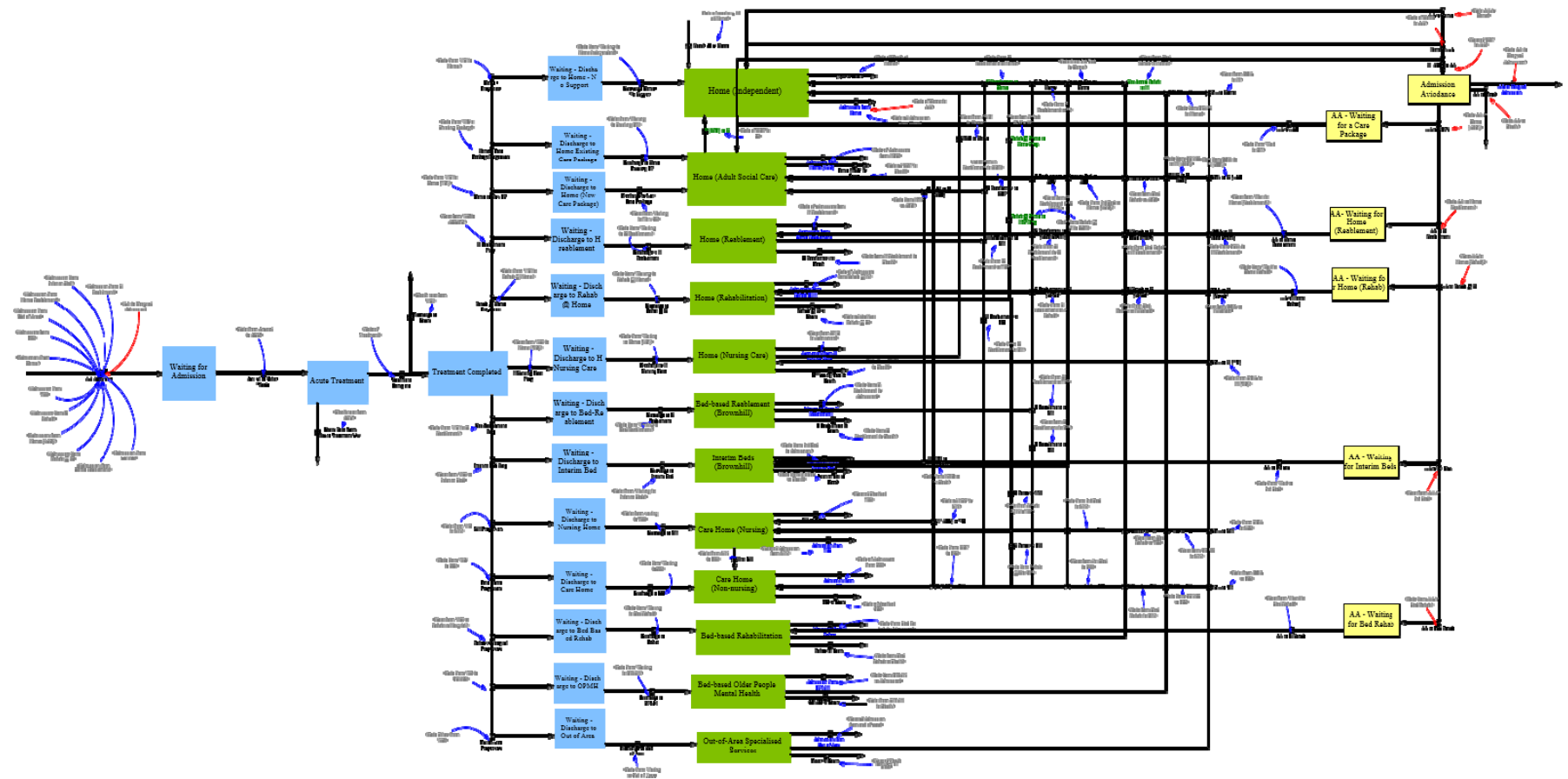


Figure 2 Overview of the model developed in Vensim.