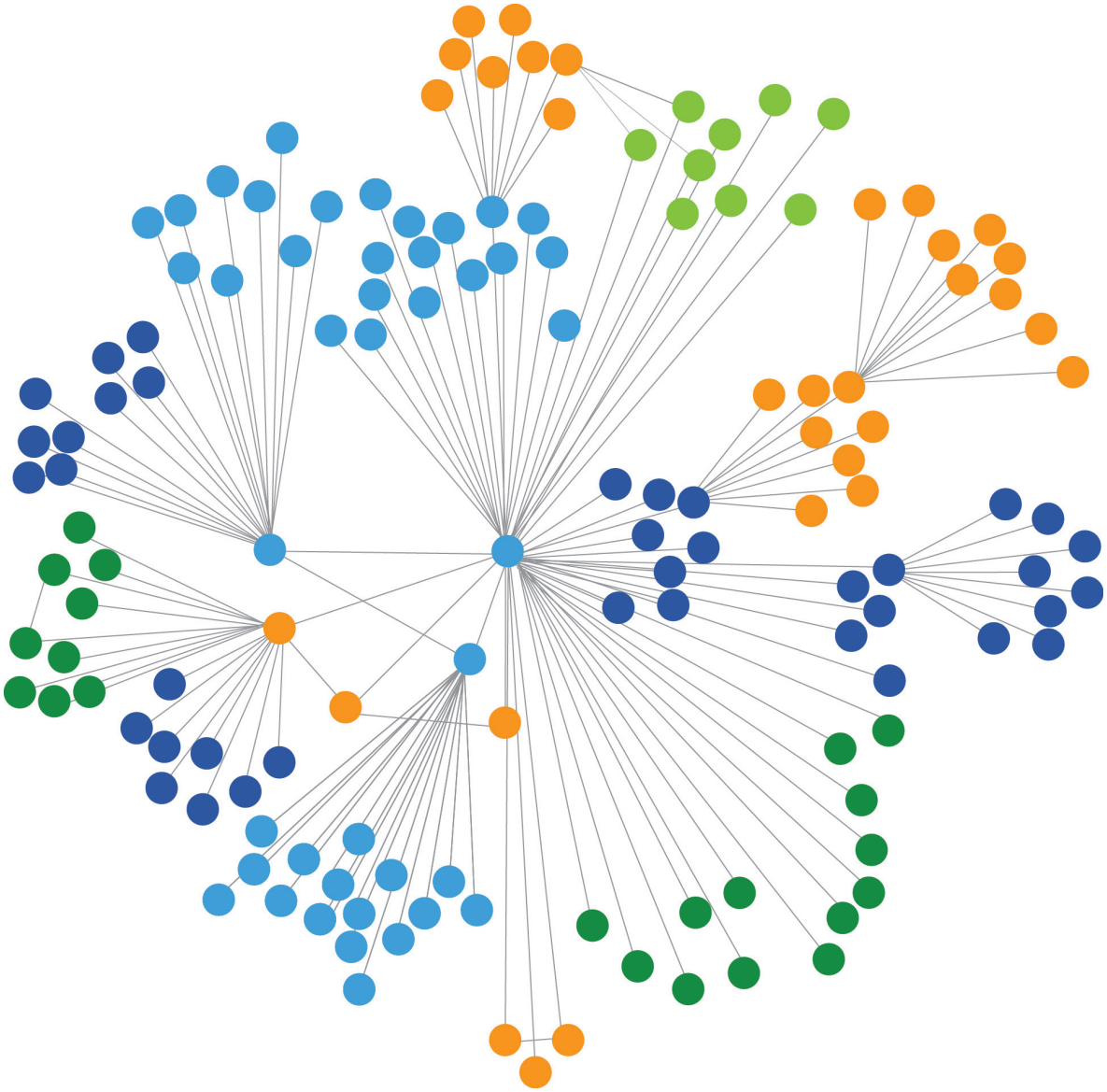
Universities UK

Health Services Research Network

CHANGE BY DESIGN: SYSTEMS MODELLING AND SIMULATION IN HEALTHCARE

Tools for health service decision makers



In collaboration with MASHnet:
The UK Modelling and Simulation in Healthcare Network

CONTENTS

Acronyms and abbreviations

A&E - Accident and Emergency
CLAHRC - Collaboration for Leadership in Applied Health Research and Care
CT - Computerised Tomography
ECOD - Emergency Care On Demand
KPI - Key Performance Indicator
Mgmt Sc./Ops Mgmt Group - Management Science/Operational Management Group
MRI - Magnetic Resonance Imaging
NHS - National Health Service
NIHR - National Institute for Health Research
PCT - Primary Care Trust
SODA - Strategic Options and Decision Analysis
SSM - Soft Systems Methods
VLAD - Variable Life Adjusted Display

Briefing produced in June 2014, version 1. To undergo periodic revision.

Overview

UK health systems are under significant pressure to respond to rising demand, with no immediate prospect of additional funding. Meeting this challenge will require more focused operational management coupled with an acceleration of innovation. In response, commissioners and service leads are increasingly turning to system modelling and simulation approaches to shape new service pathways, enhance the performance and quality of existing services, and make more informed decisions about where to direct resources.

This briefing looks at how today's modelling and simulation techniques are helping healthcare leaders develop new integrated models of care, redesign and improve care pathways, evaluate cost/capacity trade-offs, predict future demand more accurately and forecast how services will be used by patients. The techniques, applied through collaborative partnerships between service providers and modellers as well as commissioners and modellers, are proving invaluable in helping NHS leaders respond more effectively to today's complex health and social care challenges and prepare for the challenges of the future.

Key points

- Advanced analytical techniques such as modelling, simulation and forecasting are playing an increasingly important role in shaping service delivery, enhancing performance and saving resources in the NHS.

- Modelling offers a powerful way to assess risks as an alternative to piloting approaches to pathway or service redesign, enabling the mapping and quantification of potential alternative actions. Using these techniques, healthcare leaders are able to better understand how the adoption of any change impacts the larger system, the outcome of changing demand, and the optimum cost/capacity trade off.

- The process of modelling and simulation provides an ideal platform for inter-organisational exchange, learning from best practice, knowledge sharing and capturing the needs of service users.

- The emergence of new healthcare modelling solutions and resources has made these techniques more accessible to NHS organisations.

"Simulation modelling works – I've done it and the results have been impressive."

"A process simulation can not only be used to predict the acceptability and performance of the proposed solution, it can also be used to predict the cost of the solution and therefore show if the solution will also meet financial constraints. This means that... the whole quality-performance problem can be addressed from start to finish."

Simon Dodds, Consultant Surgeon, Heart of England NHS Foundation Trust

Introduction

The application of systems modelling techniques to healthcare is not new. Health planners in the 1950s used simple modelling methods for outpatient booking systems, while in the 1980s modelling underpinned the establishment of the national breast screening programme and, later, the design and delivery of NHS Direct.

Today NHS commissioners, managers and clinicians are using simple modelling techniques to support accelerated decision-making, determining what's best in terms of when, what and how care is given.

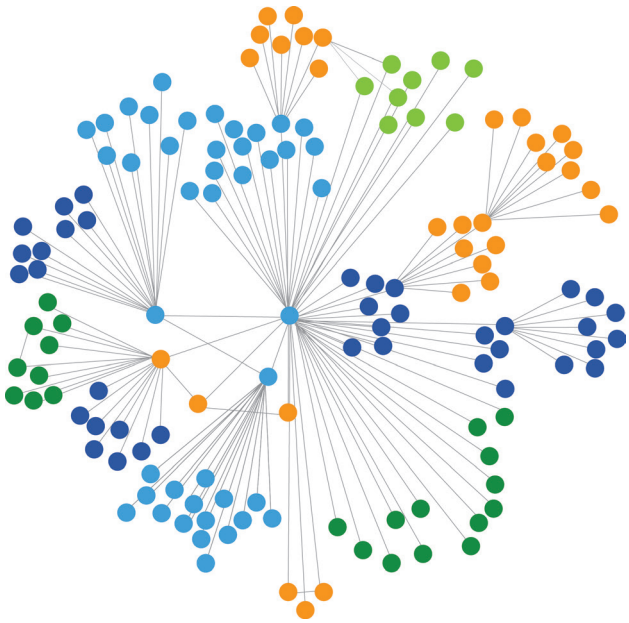
Examples where systems modelling has had a significant impact include: modelling future out-of-hours services; identifying cost improvements from diagnostic services; integrating frail elderly services by pathway modelling; scenario planning for new cancer treatments; and redesigning local trauma services using discrete event simulation.

The benefits of modelling

The NHS is facing a tough financial future. To meet increasing demand from an ageing population, address the growing burden of lifestyle related conditions, drive up quality, and respond and adapt to technological advances, it will need to do more with the same amount of money. In the short term, it is inevitable that the shape of services will change.

Over the longer term, as Sir Muir Gray, Chief Knowledge Officer to the NHS, suggests: "These problems cannot be solved by more money, or by reorganising the bureaucracy of healthcare. A new paradigm is needed, a revolution not another reorganisation." But such a revolution carries risks.

Modelling and simulation offers a credible alternative to experimental 'try it and see' approaches to service and system design. Offering a risk-free environment where ideas can be systematically tried out without the time, cost and risk involved in trying it for real - these techniques make it possible to objectively understand better complex healthcare eco-system interactions, and safely explore 'what if' scenarios to quantify risk and predict future performance.



"Modelling made it possible for us to better match our service to patient need, free up valuable resources for reinvestment in new services, and challenge delivery teams to change the way they worked. In collaborating to achieve a common goal we were able to cut service referral times from four weeks to less than ten days."

Sasha Karakusevic, Chief Operating Officer, North Bristol NHS Trust

"When managers and clinicians viewed the model and saw what would happen when the changes were implemented, it stopped everyone in their tracks. It was clear to all this was not the way forward."

Daniel Chalk, Research Fellow, NIHR CLAHRC for South West Peninsula

Some of the applications of system modelling approaches in the NHS today include helping healthcare decision makers, operations managers and clinicians:

- identify best practice and develop repeatable models of care
- support commissioning by providing an evidence base for policy changes
- appraise existing healthcare structures and determine whether to retain, refurbish or dismantle a resource (hospital, service or care pathway, for example)
- forecast future admissions, likely treatment mix, expected bed occupancy and patient length of stay
- undertake service cost analysis and assess variable cost against projected demand
- evaluate workforce skill mix and undertake scheduling against expected demand
- build the business case for a specialist pathway redesign
- evaluate the impact of funding delays
- implement quality improvements
- optimise clinic/hospital layouts
- develop priority queuing systems to improve patient outcomes

But the wider benefits of the modelling and simulation process itself are also proving to be far-reaching.

Defining the real problem

Building a model of a system is a collaborative process that can generate unexpected insights that help to scope the problem that needs to be addressed, setting the agenda of what actually needs to change and why.

For example, when one healthcare team undertook a review of local arthritis care its managers identified pain control as a priority issue. Yet service users felt that fatigue was the primary issue, impacting their ability to live a normal life. This reset the outcome parameters for the service redesign.

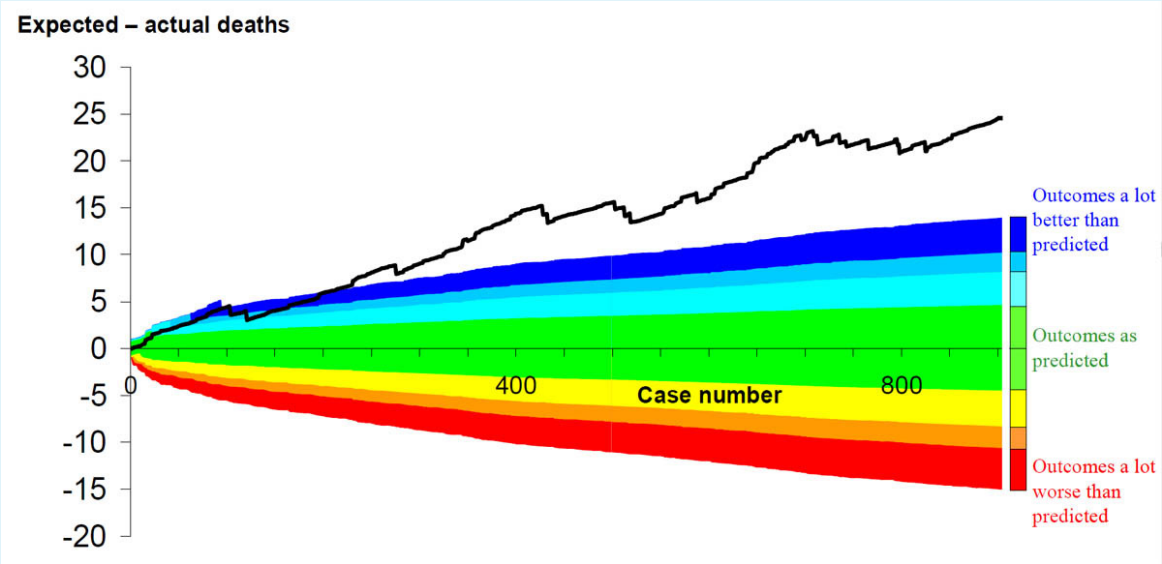
The process of building and analysing a system model is itself an ideal forum for shared dialogue, enabling ideas and knowledge to be pooled from a variety of stakeholders in order to build a true picture of how a service works in reality.

Case study one

Monitoring outcomes for cardiac surgery

A mathematical analysis and visualisation tool developed to monitor surgical outcomes in cardiac surgery now used worldwide

Figure 1: VLAD chart used to monitor surgical outcomes



Context

In the mid-1990s, cardiac surgeons and surgical units were comparing 30-day mortality rates. Some were using a risk model to ensure fairer comparison with surgeons who took on a less challenging mix of patients. UK surgeon Tom Treasure, working with the University College London Clinical Operational Research Unit, developed a way of incorporating such risk-adjustment into the time-series presentation of surgical results. A simple graphical technique was devised which is now used world-wide for a variety of clinical outcomes.

Method

The project team went through a process of repeated prototyping before settling on a simple graphical tool for the presentation of risk-adjusted mortality data in a time-series.

Outputs

The developed chart, called a Variable Life Adjusted Display (VLAD), is a running tally of the expected number of deaths minus the actual number deaths, the expected number of deaths calculated using a risk model. Subsequent versions have included colour coding to present exact prediction intervals associated with a sequence of cases and the use of chronological time rather than case number.

Impact

This work continues to be a phenomenal success. VLAD is used by most if not all cardiac surgery units in the UK and by many worldwide. The technique has been adapted to monitor other clinical outcomes such as survival following myocardial infarction, the occurrence of surgical wound infections and neonatal deaths.

Find out more: www.ucl.ac.uk/operational-research/AnalysisTools/VLAD

Engaging stakeholders

Modelling is a powerful tool for engaging NHS personnel across the care pathway in service redesign exercises, promoting 'buy in' from everyone on the need for change and acceptance of new service models or ways of working. It enables a highly collaborative approach to resolving complex challenges, bringing all stakeholders together in pursuit of a joint endeavour. This can be particularly relevant in the context of the dialogue between commissioners and providers, where systems modelling can provide an important input and evidence base for discussion and policy support.

The modelling and simulation review process is also increasingly proving an ideal platform for involving service users, who bring a unique perspective and expertise to the table. Involving service users makes it possible for clinicians and operations managers to realistically map patient experience; for example, gaining insights on where disconnects between departments or services occur or a better understanding of patient expectations and likely behaviours in terms of how they will use a service.

It can also enable meaningful consultation with patient groups, providing powerful evidence that can help to leverage acceptance in relation to changes to long standing services, or the closure and relocation of resources such as wards, clinics or hospitals.

Simple changes, impressive outcomes

Modelling and simulation doesn't always have to be 'rocket science'. Sometimes simple analysis and decision support tools can be highly effective in helping service teams identify low cost and fast-to-implement changes that have a big impact.

Strategic impact

Simulation, modelling and systems thinking is increasingly pushing forward national and regional healthcare strategies and helping to transform the quality and cost of NHS care delivery.

Members of MASHnet – the UK Network for Modelling and Simulation in Healthcare – have delivered a number of system models that are being used by national agencies, Clinical Commissioning Groups and local trusts to address some key challenges. These include systems models to evaluate the impact of optimised re-ablement services for social care, support implementation of the national Dementia Strategy locally and extend breast screening services in Greater London.

"Asking clinicians to evaluate the model teased information that proved as valuable as the model itself. The entire process of engaging with stakeholders to develop the system model proved the key to drawing out what the real problems were."

Colin Burton, Service Planning and Business Analyst, University Hospital Southampton NHS Foundation Trust

Table of methods

Approaches	Use	Examples
Qualitative modelling	To build a picture of the current reality of a system and to structure the problem. To inform dialogue amongst participants and help focus on key issues.	Cognitive mapping Process mapping Soft Systems Methods (SSM) Strategic Options and Decision Analysis (SODA) Causal Loop Diagrams
Mathematical modelling	To support stakeholders in exploring system trade-offs and evaluating different courses of action using quantitative information.	Regression Forecasting Optimisation Queuing Theory Markov models
Simulation	To test 'what-if' scenarios for service design. To determine levels of uncertainty. To provide visualisations and inform clear understanding and dialogue amongst stakeholders. To develop forecasts/projections of future performance.	Discrete event simulation System dynamics Monte Carlo simulation Agent Based simulation Behavioural simulation

Case study two

Derbyshire hospital relocation model

This case study illustrates how geographical modelling and location analysis can be used to assess the impact of service relocation and help forecast and plan changes (it refers to Primary Care Trusts (PCTs) which no longer exist but used for illustrative purposes)

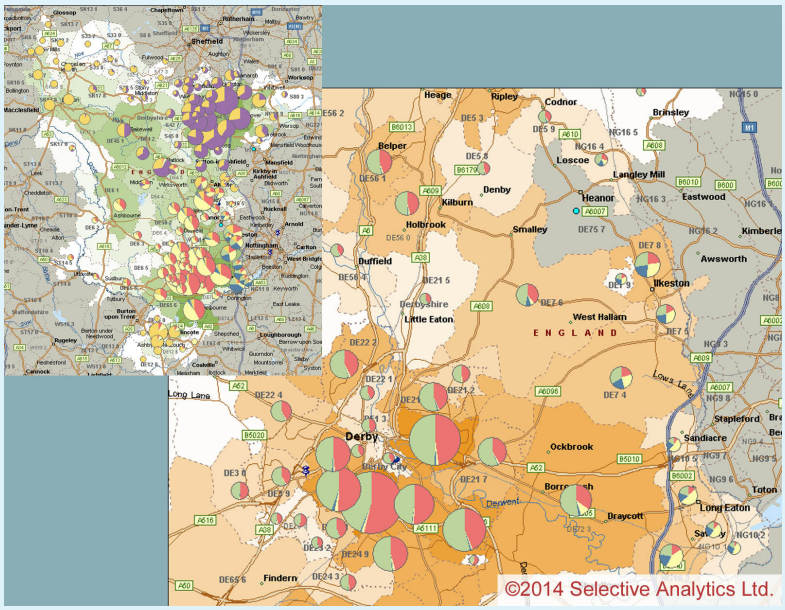
Context

Derbyshire Primary Care Trust was moving services from one hospital in Derby to another newer hospital on the other side of the city. This change extended the distance some patients had to travel and there was a possibility that some Derbyshire-registered patents on the edge of the county would migrate to the nearby Nottinghamshire hospitals. It was therefore imperative that the two PCTs had properly researched figures for the likely effect on patient attendance at their hospitals.

Method

An analysis of three quarters of a million patient activity data was conducted using a geographic modelling system. This found a number of characteristics that could be used to model the patient activity. Two scenarios were developed to predict the likely changes using mathematical models supplied by academic partners in the project. These scenarios provided a comprehensive breakdown of attendance figures showing how demand might change at each hospital following the move. A meeting with NHS commissioning staff was held at which the geographic modelling system was used to present the results using maps, charts and various tables. This allowed both parties to understand what the findings meant and how they had been obtained.

Figure 2:
Maps showing usage patterns by service type for reconfiguration



Outputs

This project provided the two assistant directors of commissioning and performance for Derby and Nottingham PCTs with two forecasts for the likely change in attendance at their hospitals. They also understood the basis on which these figures had been calculated and felt that the actual attendance was going to be somewhere between the two figures. Using this information they decided that the change was within a range they could handle without extensive changes to the current resource arrangements. They then planned in monitoring so that they could adjust resources when the service change occurred later that year.

Impact

"The final analyses have proved extremely useful in helping the PCT understand the impact of the hospital's move on its commissioning plans and how to monitor whether or not these models are accurate predictors of patient choice. During the whole programme, I have been extremely impressed by the level of commitment, support and knowledge (both of our circumstances and the optimum modelling techniques) displayed by MapPlace and their academic partners and we would certainly use them again on similar projects."

David Arrowsmith, Head of Information, Derbyshire County Primary Care Trust

"MapPlace provided a flexible and responsive service that enabled us to develop scenarios for the impact of a service location change. We will use the outputs generated from their data analysis to monitor the impact of the service change when it occurs later this year."

Tony Madge, Assistant Director of Commissioning and Performance Nottinghamshire County PCT

Find out more: http://selectiveanalytics.com/casestudies/derby/

Case study three

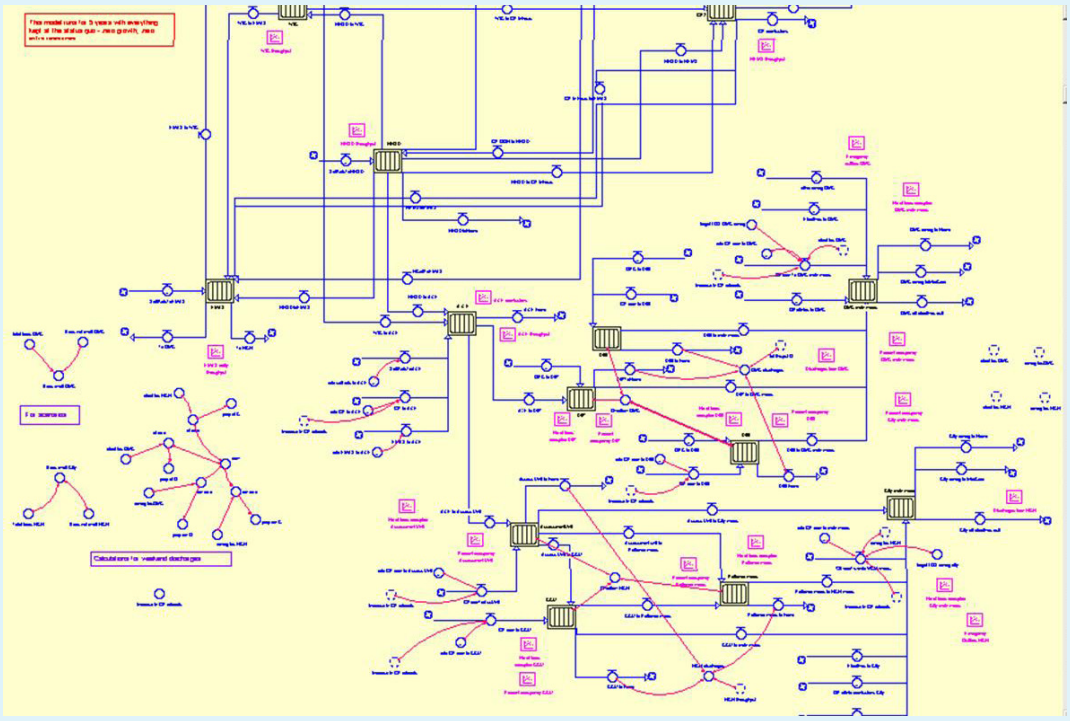
Emergency and on-demand health care: modelling a large complex system

This illustrates how system dynamics can be used to model the complex relationships between acute and community care and provide important decision support to policy makers.

Context

The project arose out of a larger study known as the Emergency Care On Demand (ECOD) project, focused on the at the time increasing pressure on emergency medical service use and consequent increasing number of hospital admissions in Nottingham. This was having a detrimental effect on, amongst other things, the waiting times for treatment amongst those attending, difficulty in managing hospital wards at greater than expected capacity, and frequent cancellations of routine admissions for surgery. The project posed four main research questions, based around identifying the current configuration of the system, more precisely defining the present level of demand, how the system could be developed, and to what extent community preferences were driving use of Accident and Emergency (A&E). Before any modelling was undertaken, a conceptual map of the system was drawn up, which was elaborated on in a series of interviews with NHS staff and patient representatives. The final process map was used as the basis for the system model.

Figure 3: Screen shot from the Systems Dynamic model



Method

Based on the initial conceptual map, the project created a System Dynamics (SD) model which represented the essential elements of the Nottingham emergency medical services as they existed at the time (2002).This choice centred on the need to model large numbers of patients, the importance of studying feedback effects, and the fact that precise estimates of KPIs were less important than overall trends.

Outputs
Projections from the model suggested that if emergency admissions continued to rise at the rates experienced, average bed occupancy levels would be unmanageably high within two to three years. The most promising intervention was found to be the diversion of selected elderly patients to specialist investigation centres.

Impact
The model was used to investigate patient flows and bottlenecks and as a tool for provoking and facilitating discussion. The Nottingham steering group for ECOD used the model to test and evaluate different scenarios of care. However, the primary use of the model was for promoting greater understanding of the dynamics of the system rather than in generating numerical outputs. The essentially generic framework adopted and the model's use of routinely collected data means that this approach can readily be adapted elsewhere.

Brailsford S, Lattimer VA, Tarnaras P, Turnbull C. Emergency and on-demand health care: Modelling a large complex system. J Oper Res Soc 2004; 55:34-42.

The value of modelling has also had an impact on the shaping of healthcare policy: for example, using a simulation model to test the consequences of charging hospitals for late discharges revealed that this would actually result in late discharge volumes growing. The findings led to a major rework of national policy.

Operational impact

Today's modelling and simulation techniques are also being brought to bear on a wide range of operational NHS challenges. These include using queuing theory to allocate and share scarce specialist mental health assessment slots between teams; applying modelling techniques to predict ambulance response times and plan rosters; and using scenario planning to allocate capacity between medical, surgical and cardiac beds on 'service lines' in paediatric intensive care.

Techniques such as discrete event simulation can build in uncertainties (such as patient preferences and future demand) and variability (such as patient and clinician behaviours) together with a more sophisticated understanding of interactions (using network analysis, for example). This means modelling is able to predict more accurately how services might be used and how savings could be made.

Case study four

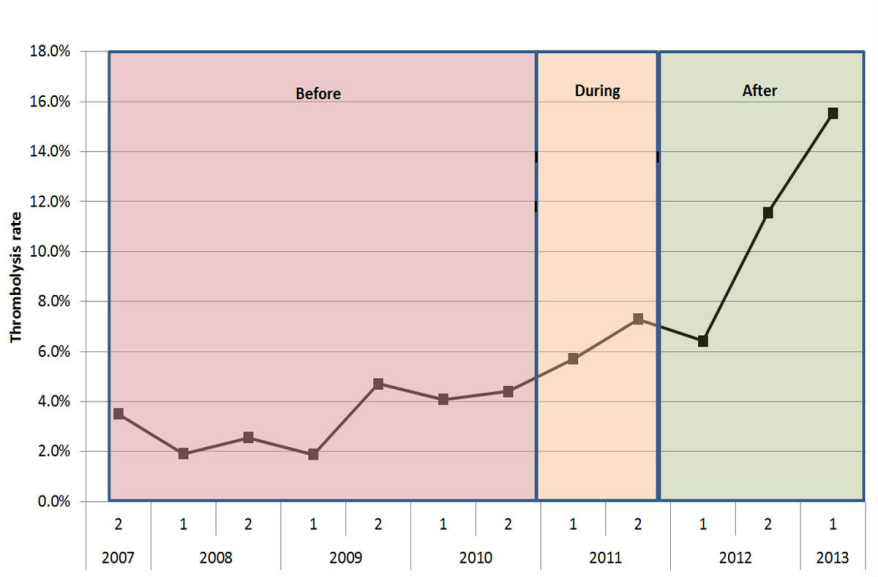
Re-designing emergency stroke pathways to maximise Thrombolysis rates

How discrete event simulation can be used to model patient pathways, demonstrating dramatic improvements in care through modelling alternative scenarios leading to implemented changes in service delivery

Context

Thrombolysis with the clot-busting drug alteplase is currently the only licensed treatment worldwide for acute ischemic stroke. The benefit is critically dependent on time from stroke onset to treatment with an exponential decay in the odds of a favourable outcome from one 90-minute interval to the next up to 4.5 hours. It is therefore crucial to minimise in-hospital treatment delays.

Figure 4:
Graph showing impact on rate of Thrombolysis resulting from project



Method

Computer simulation and quantitative analysis was used to evaluate proposed changes prior to any implementation. A key benefit of this model was a visualisation of patient pathways which provided a basis for communication and helped bridge barriers between different departments within hospitals. It allowed clinicians from the A&E department, the acute stroke unit and the South West Ambulance Trust to work together and identify optimal changes to the stroke pathway ahead of any changes to the real process.

Outputs

The pathway was modelled as it operated at the start of the study. A number of potential changes to the pathway were then evaluated using the model and compared against each other. The benefit was quantified in terms of treatment speed and used published research to convert these figures to additional patients with no disability post stroke.

Impact

The study recommended two changes that carried little to no cost for the pilot hospital:

1. Paramedics now ring a dedicated acute stroke phone number to alert clinicians to the imminent arrival of potential stroke patients. This allows emergency resources to be in place as the patient arrives to the emergency department.

2. Triage nurses now share information with the Stroke Unit to facilitate patient management. The latest quarter figures from the Royal Devon and Exeter NHS Foundation Trust show that since study commencement in 2011 door to treatment times have fallen from 100 to 50 minutes on average and an increase in treatment rates from 4% to 16%. In real terms this equates to 100 strokes receiving treatment per year compared to 25 at study commencement in 2011.

The research team have extended the model to work with other regional hospitals as well as the ambulance service. This project was awarded the Exeter Impact Award 2013 - George Smith Regional Partnership Category (see www.exeter.ac.uk/impactawards/winners2013)

Find out more: www.clahrc-peninsula.nihr.ac.uk/project/27-stroke-pathways---penchord/full.php

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Case study five

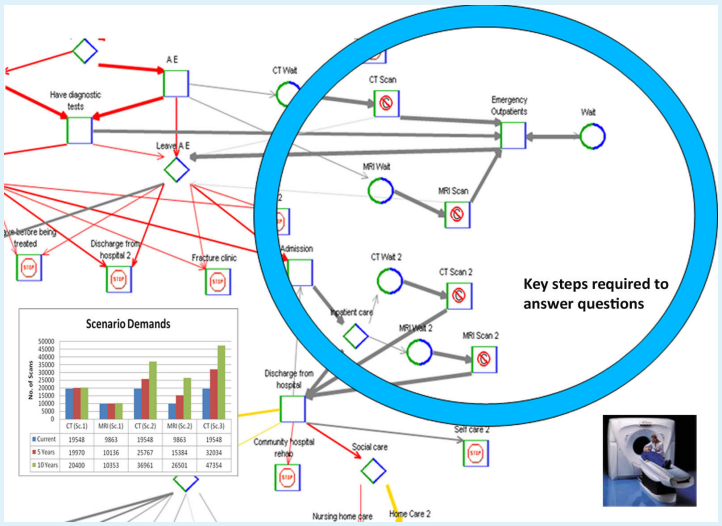
Model to save short-term scanner costs

A discrete event simulation used to assess a range of commissioning options for scanners in the Grampian region of Scotland

Context

NHS Grampian wanted to understand the effect that demographic change and new clinical practice would have on the potential demand for CT and MRI scanners over the next five and ten years. They thought they would need to buy new scanners to meet projected demand.

Figure 5: Section of Scenario Generator Model



With the cost of a new scanner at around £1million, this is a significant investment in healthcare at a time when budgets are tight. To test when new scanners would be needed, NHS Grampian decided to use the Scenario Generator tool which simulates population use of the health service and can model the impact of increasing demand on existing capacity.

Method

Various "what if" demand scenarios were modelled and showed the varying levels of demand which might need to be met.

Outputs

The model showed queues building up when Grampian's current capacity could no longer cope with the demand. NHS Grampian found that no additional capacity would be required over the ten year period if the impact of new clinical practice was not taken into account. However when the model factored in clinical processes that will use scanners rather than other procedures, Grampian found that additional capacity would be required at several periods over the ten years to cope with the demand.

The results showed that additional capacity would be needed for CT scans in three years, seven years and nine years time, and for MRI scans in five, eight and ten year's time.

Impact

Scenario Generator has provided Grampian with a means of understanding effects of forecast increases in demand for scanners on current capacity, and help them to understand when to invest.

"This project has really helped us understand how to plan to ensure we have both the capacity and finance to meet our patients' demands. We can really see the potential of using these software tools to help us plan both investment and disinvestment in the future."

Jillian Evans, Head of Health Intelligence, NHS Grampian

Find out more at www.scenario-generator.com and www.simul8healthcare.com

Why use modelling?

There are a number of reasons why modelling and simulation approaches are becoming an essential tool for healthcare leaders to address key strategic and operational healthcare delivery challenges at a regional and local level:

- More opportunities for collaborative working between modellers and healthcare leaders through local resources and research funding
- The growing availability of modelling and simulation resources that can be applied without the need to build a model from scratch
- Efforts to build local capacity to engage with these tools produce regional champions and spread expertise within the system

Healthcare leaders are looking to harness the huge increase in data within their organisations and apply the added value of modelling and simulation to data analytics to understand:

- what's happened
- what could happen
- what's best

Recently a new generation of 'user friendly' healthcare-specific modelling and simulation tools has emerged, making it even easier for service leads and clinicians to utilise these techniques when redesigning services.

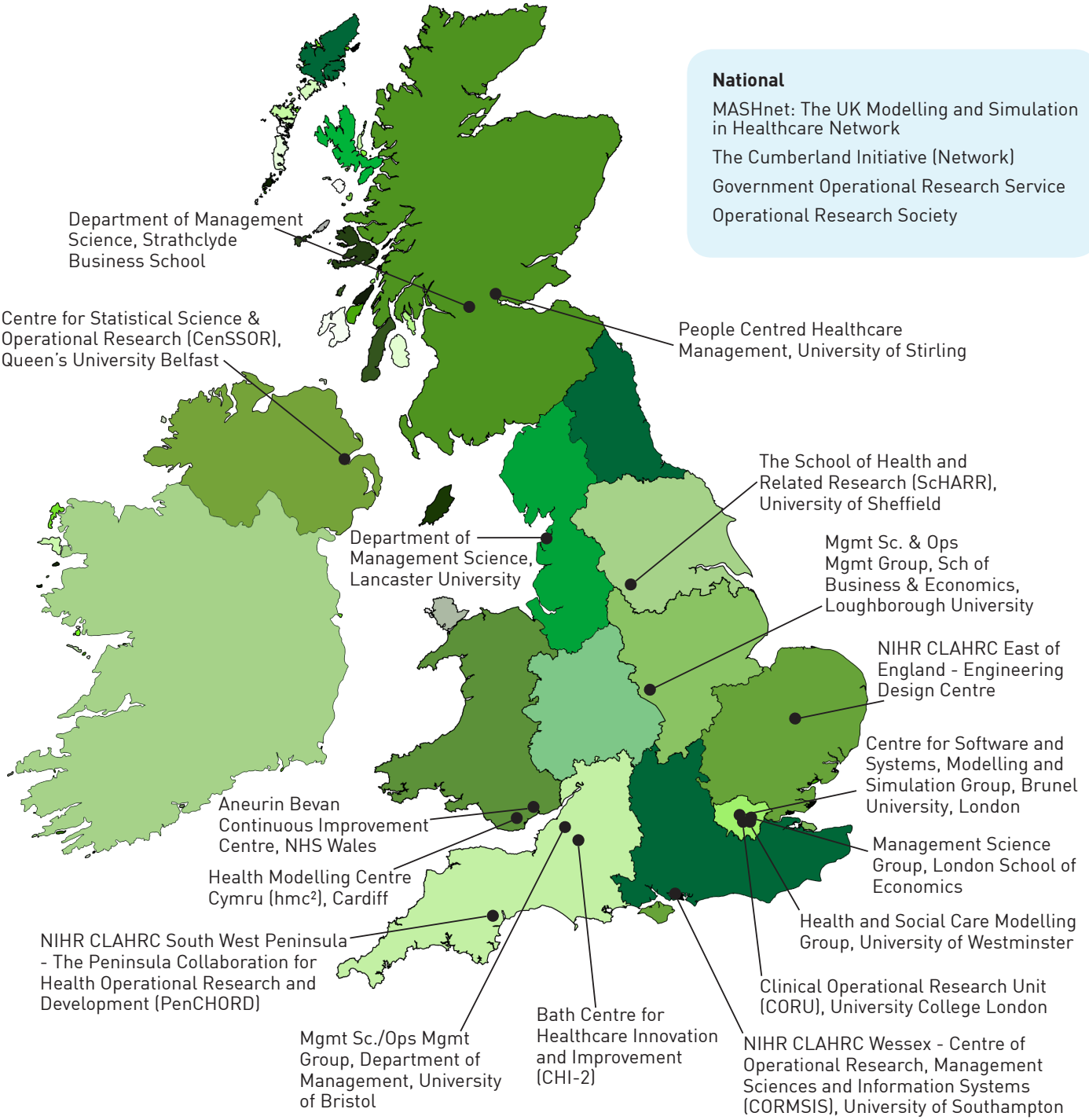
An important message for NHS professionals is that these are tools that you can use. Ownership of the models and the experience of their development is often as important as the finished models. Put simply, the 'modelling' is often at least as important as the 'model' itself. It is critical therefore that NHS staff are engaged in the process of modelling.

This highlights the importance of capability and capacity building within the health service to understand and take full advantage of modelling and simulation techniques. There are currently a range of initiatives (see the following map of resources) focused on providing resources to support skills development for NHS staff to raise awareness, build 'in-house' skills, and promote more intelligent clients in this area.

How to find out more

A wide range of information and resources about systems modelling in healthcare are available. A good starting point is the MASHnet website: www.mashnet.info or the Cumberland Initiative website: www.cumberland-initiative.org. These sites give references to further case studies, listings of books, research literature, presentations, links to relevant organisations and people, information about training opportunities and dates of upcoming events. The map on page 13 shows research groups currently active in the UK.

Map of resources



National

MASHnet: The UK Modelling and Simulation in Healthcare Network

The Cumberland Initiative (Network)

Government Operational Research Service

Operational Research Society

International

ORAHS – Operational Research Applied to Health (Society)

IFORS – International Federation of Operational Research Societies

INFORMS – The Institute for Operations Research and the Management Sciences (Institute)

Notes: This map represents research organisations and networks. It is not necessarily complete, but based on best available information. Any groups who feel they should be on the map please contact us at the HSRN.

Health Services Research Network

The Health Services Research Network (HSRN) is a membership network for organisations and bodies across the UK with an interest in health services research. We aim to connect universities, commercial organisations and NHS bodies interested in HSR. The Network is based at Universities UK.

Website: www.hsrlive.org
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Twitter: @hsrn_uk

MASHnet

MASHnet – The UK Modelling and Simulation in Healthcare Network was established in 2005 initially funded by the Engineering and Physical Sciences Research Council. Its expressed aim is to improve healthcare through the more effective application of systems modelling. Many of its activities are directed to improve communication and understanding between health service, research and commercial communities. In 2011 MASHnet became a not for profit Community Interest Company. For further information visit www.mashnet.info

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