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The potential of system dynamics

A new era of strategic planning?

Key points

To make significant changes in complex adaptive organisations it is necessary to think differently and test ideas before use.

System dynamics:

- is the origin of the current trend of 'whole systems thinking'
- enables the strategic modelling of non-linear relationships within complex adaptive organisations such as the NHS
- works along pathways of care which cross organisation and sector boundaries
- complements existing planning tools such as spreadsheet models or actuarial analysis.

System dynamics is a versatile way of bringing whole-systems thinking to life in a rigorous, testable way.

System dynamics is a way of thinking about the future which focuses on 'stocks' and 'flows' within processes and the relationships between them. It can facilitate ideas for both specific solutions and generic 'new world' rules. It is a risk-free way of refining plans before implementation, and of testing ideas using computer simulation that follow patient pathways and cross health and social care organisational boundaries.

System dynamics goes beyond the scope of spreadsheets, process maps and data analysis to challenge existing thinking and help design, test and communicate sustainable solutions. It is currently being used in more than 15 local health and social care communities in the UK to simulate novel ways of achieving win–win solutions, make assumptions more explicit, and identify inconsistencies between data, process and policy.

This *Leading edge briefing* outlines the background to, the thinking behind and the toolset of system dynamics. It describes how it is applied, examines case studies and outlines its limitations. This paper was prepared by Professor E Wolstenholme of Symmetric SD, recipient of the 2004 Jay Wright Forrester Award for the best contribution to system dynamics in the last five years. It also draws on the work of the Whole System Partnership.

The challenge facing healthcare organisations

Healthcare organisations are large, complex and adaptive. They show both 'detailed' complexity (containing a large number of elements) and, importantly, 'dynamic' complexity (having many interconnections). They have long processes which often cross organisational boundaries and have their own cultures, accounting systems and performance measures. Decision-making in the

> *'In the near future I predict that all investment planning projects will be subjected to dynamic appraisal for their effects on the whole patient pathway.'*
>
> Steve Arnold, 2004

public sector is made more difficult by organisations having different planning time horizons.

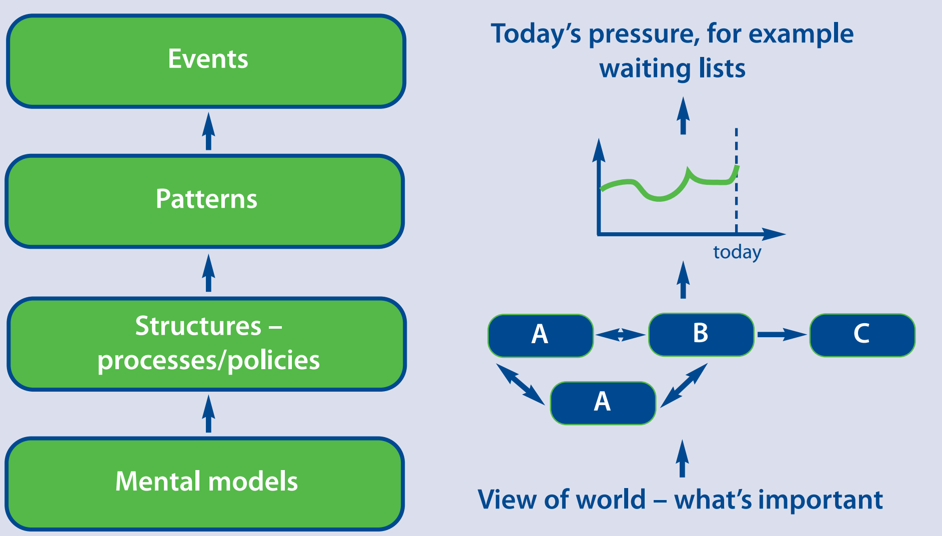
Because of our limited ability to understand the multiple interconnections, we find it difficult to manage complex adaptive organisations. Managers tend to develop mental models linking structures, processes, patterns and events, and build up a picture of how organisations work which may not reflect reality (see Figure 1.) In complex adaptive organisations this can result in unintended consequences that undermine well-intended actions, and may lead to many types of informal coping actions which in turn inhibit improvements.

Traditionally, solutions to problems in complex adaptive organisations have been static in nature, sector-based and reliant on data and spreadsheets, with limited transparency of assumptions. To make significant changes in such organisations it is necessary tothink differently and test ideas before use as effective solutions may often seem to be counter intuitive and even defy logic. System dynamics provides a method of testing solutions.

What is system dynamics?

System dynamics was conceived at MIT in the late 1960s. It has now grown into a major discipline (Sterman, 2000) that is widely used in the private sector in, for example, oil, asset management, financial services, defence and consultancy. Its basis is learning to see patterns of behaviour in organisations and grounding these in the structure of organisations – their operational processes and policies. It uses software to map processes and policies at a strategic level, populate the map with data, and simulate the evolution of the processes under transparent assumptions, policies and scenarios.

Figure 1. Systemic hierarchy



System dynamics is the origin of the current trend of 'whole systems thinking' in health and social care. It provides a set of **thinking** skills and a set of **modelling** tools, as described below.

Thinking skills

A wide range of thinking skills and abilities are required to understand complex adaptive organisations. These include (Richmond, 1998):

- **dynamic thinking** – conceptualising how organisations behave over time and how we would like them to behave
- **'system-as-cause' thinking** – determining plausible explanations for the behaviour of the organisation over time in terms of past actions
- **'forest' thinking** – seeing the 'big picture' and transcending organisational boundaries
- **operational thinking** – analysing the contribution which different operational factors make to overall behaviour
- **'closed-loop' thinking** – analysing 'feedback loops', including the way that results can influence causes
- **quantitative thinking** – determining the mathematical relationships needed to model cause and effect
- **scientific thinking** – using models to construct and test hypotheses.

Modelling tools

System dynamics is a strategic rather than an operational tool. It can be used to integrate policies across organisations where behavioural feedback is important, and analyse variation. The key elements of system dynamics are shown below.

Stocks and flows
Processes in system dynamics are viewed in terms of 'stocks' and 'flows'. Stocks are measurable accumulations of physical (and non-physical) resources, for example patients, customers and work backlogs. Essentially they are delays which separate and buffer their inputs from their outputs, and are built up and depleted over time as input and output rates into them change. They persist through time and continue to influence other flows even when their inputs and outputs are switched off. Recognising the difference between stocks and flows is fundamental to understanding systems.

Organisational boundaries
Recognising organisational sectors with different cultures is key to understanding the impact of boundaries on patient pathways.

Learning through modelling
System dynamics improves decision-making by extending and sharing mental models across management teams. It demands skill in conceptualisation. Figure 2 shows the process of applying system dynamics.

Comparison of spreadsheets and system dynamics models

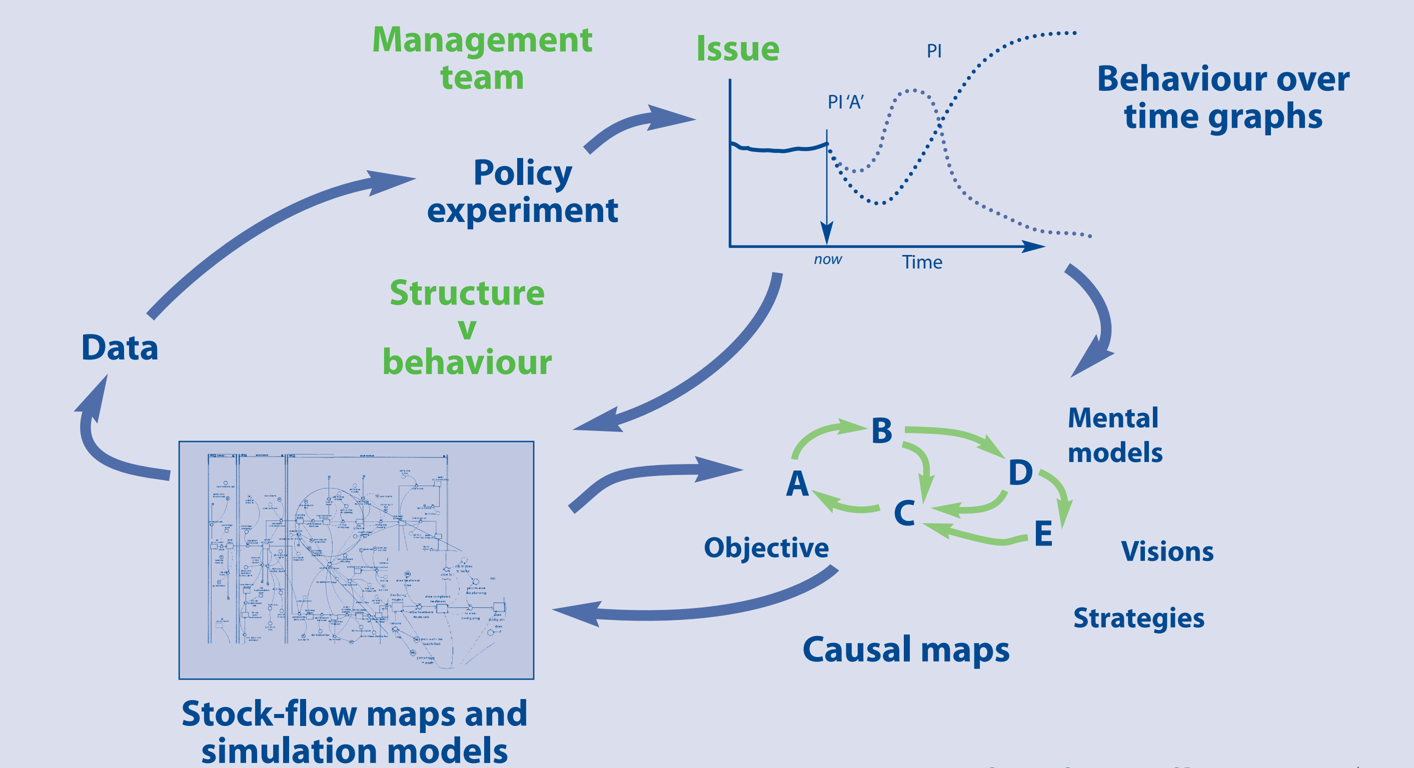
Operational tools (such as process mapping, spreadsheets, data analysis and discrete event simulation) have complementary roles in the detailed operational planning for sections of the patient pathway. For example, spreadsheets support quantitative thinking but can only be used for simple simulations. In contrast, system dynamics facilitates a more sophisticated, quantitative simulation capable of more robust and reliable outcomes. A comparison of spreadsheets and system dynamics models is shown in Figure 3.

'Recognising the difference between stocks and flows is fundamental to understanding systems'

How is system dynamics used?

Step 1. System dynamics requires a significant managerial issue and a committed, consistent management team representing all agencies involved in the issue. 'Translators', experienced in both conceptualising and formulating system dynamics models, are required to work with the management team.

Figure 2. The application of system dynamics



Source: Symmetric SD training material 2005

Figure 3. Comparison of spreadsheets and system dynamics models

Spreadsheet models	System dynamics models
Many external inputs over time	Each time point calculated internally on information feedback and policy
Does not recognise accumulations/stocks	Processes explicitly represented as stock accumulations and flows between 'sources' and 'sinks'
Input interface is matrix of cells	Input interface is map of physical structures
All calculations are instantaneous	Calculations recognise delays inherent in stock structure, so output is phased, as in reality
Opaque – 'black box'	Transparent
Applied by individual analysts	Shared by management teams
Relationships between cells largely linear	Relationships often non-linear
Does not use sectors or organisational boundaries	Represents sectors and organisation boundaries
Easy to create and use	Challenging to create and use well

Step 2. Trends in the major performance measures of the organisation, and their future trajectories – both desired and undesired – are analysed.

Step 3. The key contribution of system dynamics is then to formulate a high-level process map linking processes across organisations and populated with the best data available.

Step 4. They must be capable, when simulated, of demonstrating their ability to match the trends of Step 2 ('what is' analysis). At this stage, the rigour involved in knowledge-capture and in developing the quantitative simulation model can identify important mismatches and inconsistencies between how managers claim their organisations work and observed data, patient pathway descriptions and performance outcomes.

Step 5. Once validated, simulation models can then be used effectively to test radically new ideas ('what if' analysis).

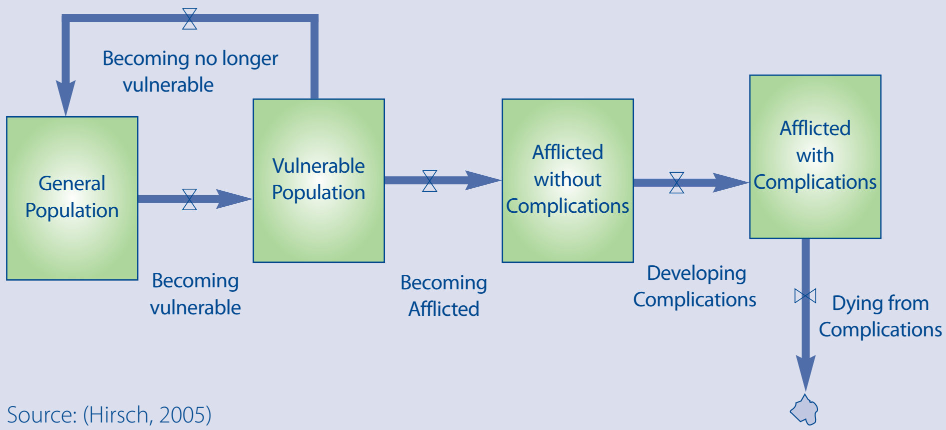
As an example of system dynamics at the highest level, the whole of health treatment and illness prevention can be shown as a stock and flow map. This health well-being process is shown in Figure 4 and Figure 5 amplifies this process to include factors which affect the stocks and flows of people through the system. The main message communicated by such a map is that delays in upstream effort (illness prevention) reinforce downstream affliction and dependency on professionals, which further undermines upstream effort.

Case study: delayed hospital discharges

System dynamics has been used to influence health and social care policy (Wolstenholme, 2004). During 2002 the Local Government Association (LGA) and the NHS Confederation commissioned a system dynamics model from Symmetric SD (some of whom were working for OLM and Cognitus at that time) to address the Government's plans for a Community Care (Delayed Hospital Discharge) Bill. The model was intended to underpin a national campaign to influence Government policy and prevent the introduction of 'fines' on social services.

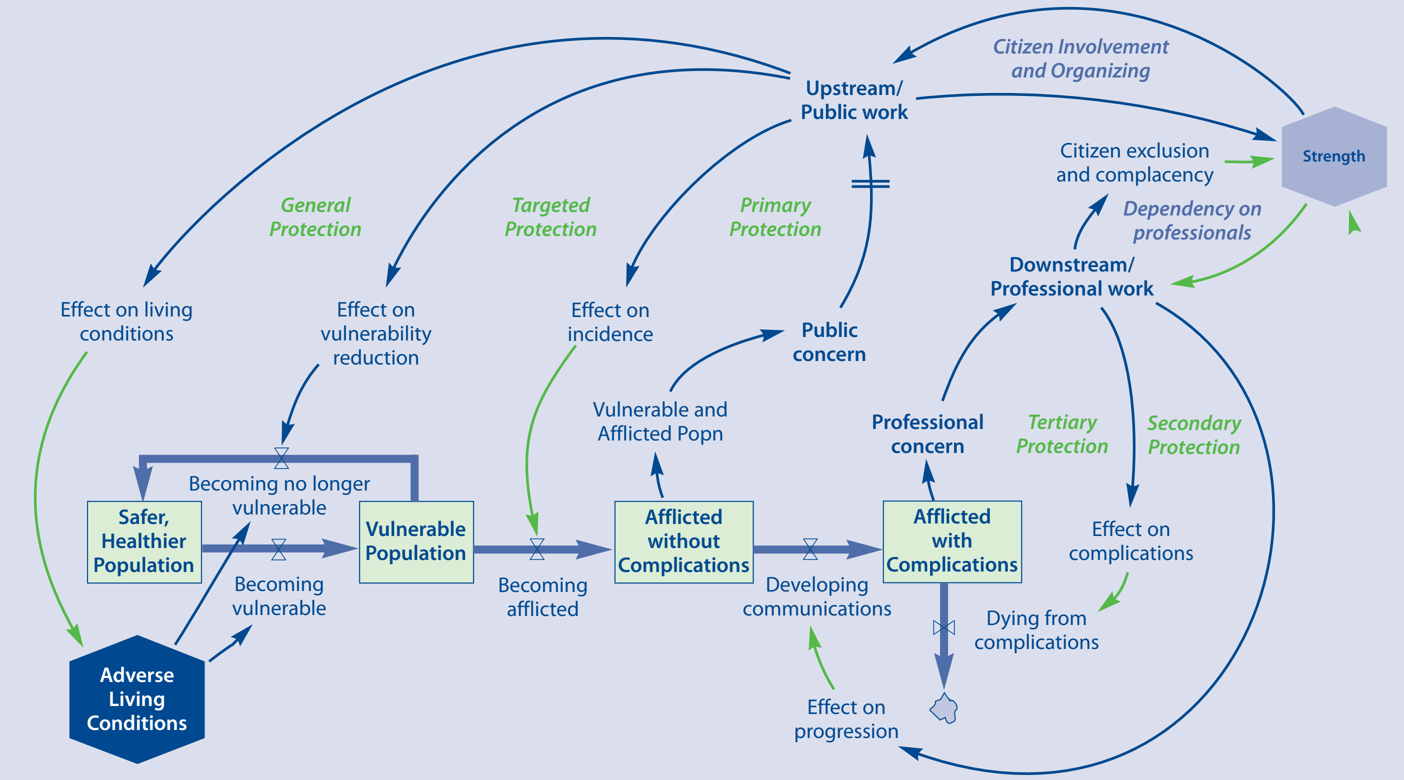
The model was developed with a group of NHS and social services department managers, using national

Figure 4. The health well-being process



Source: (Hirsch, 2005)

Figure 5.



Source: (Hirsch, 2005)

data to simulate pressures in a sample health economy covering primary, acute and post-acute care over a three-year period. The model was driven by variable demand, including three winter pressure 'peaks' when capacity in each sector was stretched to the limit. It incorporated a number of mechanisms by which agencies coped during periods of high demand – for example, moving medical patients to surgical beds and early discharges with allowance for re-admissions. Figure 6 gives an overview of the sectors of the model.

The obvious solution of introducing more hospital capacity in the acute sector to relieve problems was shown to be a classical 'fix that fails' (Wolstenholme, 2003), increasing acute admissions but also compounding delayed discharges.

The model illustrated that, despite the small numbers of patients requiring post-acute care, the counter-intuitive, alternative policy of increasing post-acute capacity could provide a win–win solution for both acute and post-acute performance measures. Not only were reimbursement charges low, but by providing relief from the effects of coping actions the acute sector would reap the rewards of both low elective waiting times and higher elective activity.

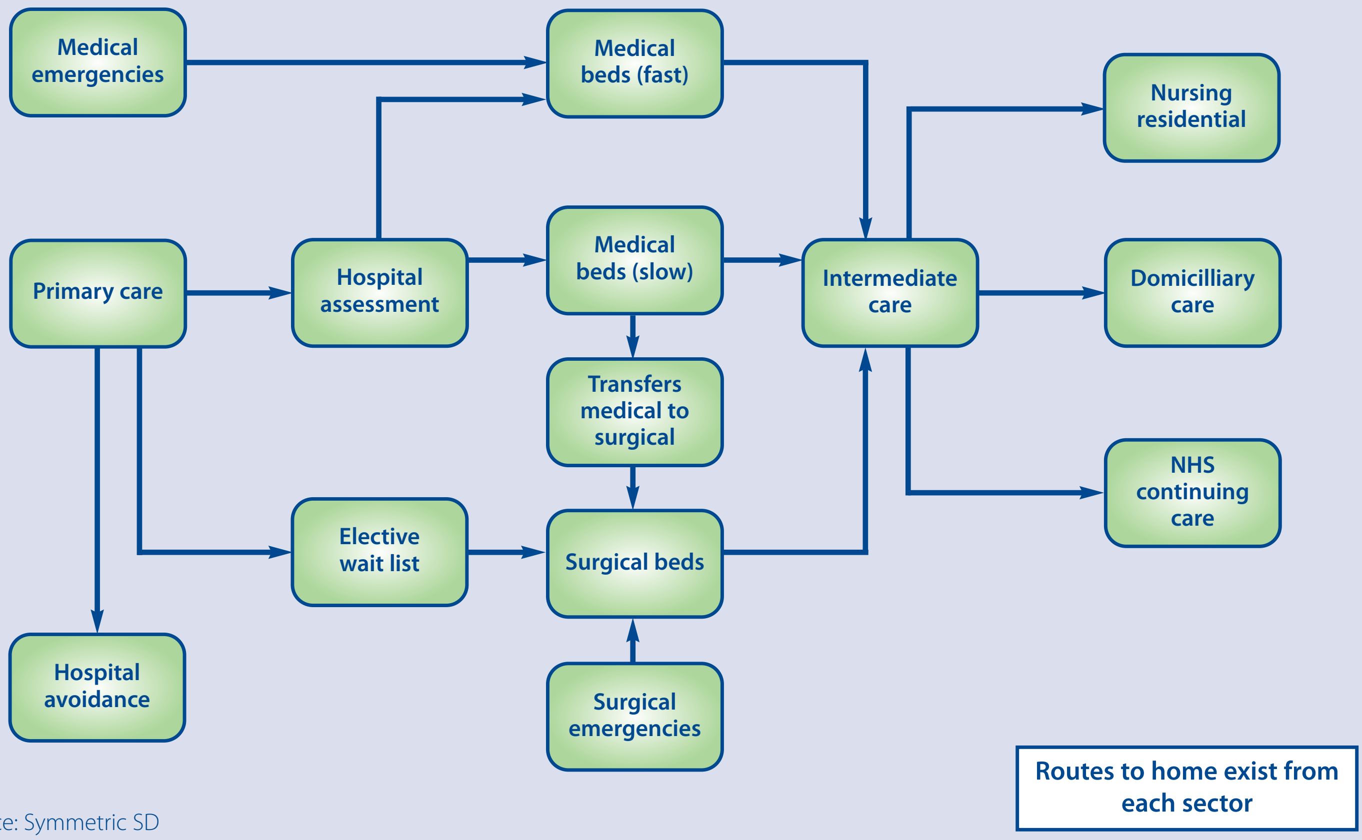
This model generated considerable political interest. It was, apparently, instrumental in causing some rethinking of the intended legislation so that social services were provided with investment funding to address capacity issues and the 're-imbursement' implementation was delayed for a year.

Case study: Using a health system simulator to test workforce planning

During 2004, Shropshire and Staffordshire Strategic Health Authority worked with the Whole Systems Partnership to improve the evidence base and intelligence underlying strategic investment decisions, in terms of both physical capacity – beds, day case capacity, outpatients, intermediate care etc – and the likely impact on the workforce, particularly in terms of skill-mix and location.

The modelling covered the full range of hospital activity as well as intermediate care, chronic disease management and underlying community health services. It also

Figure 6. Sectors of the delayed discharge model



Source: Symmetric SD

explored key links and impacts between sectors. It was developed to be sensitive to demographic changes within the hospital sector and to reflect the different profiles of activity and initial capacity or waiting lists in the 12 specialty groupings used in the capacity planning process. The modelling profiled demand and capacity requirements over a ten-year period to 2012/13.

One output – to determine the impact of plans on workforce – has built on the assumptions underlying Wanless workforce modelling undertaken in 2001 and 2002 based on four Agenda for Change levels.

Learning from delayed discharge modelling

Common sense solutions can be misleading
Adding capacity in the acute sector without rebalancing resources across the whole pathway can exacerbate the situation and cause more delays. The implication is that increasing capacity in periods of excess demand simply fills that capacity. Adjusting flow variables is less costly and more effective.

Fines may have unintended consequences
Fines can cause the post-acute sector to cut services, so exacerbating both delayed discharge and waiting lists. The effects of service cuts may spill over into other areas. If fines are levied they need to be re-invested from a whole-systems perspective.

Interventions that can help include:

- re-balancing resources across all sectors, not just adding to hospital capacity
- balancing flows through different routes/reducing lengths of stay – better than capacity
- addressing variation in flows – particularly loops like re-admission rates.

Keeping people out of hospital is more effective than trying to get them out faster.

Each resultant staff group was then linked with an appropriate 'capacity driver' within the model. Data from the model was then re-aggregated to determine the change in skills mix and location as well as to indicate direct costs to the system.

The outputs identified some significant challenges, particularly in the anticipated growth in the acute sector workforce, with only modest increases in the community workforce. The simulator outputs had suggested that more focus should be given to developing the community, and in particular the intermediate care, workforce.

Other applications

A number of other studies have used system dynamics to investigate issues arising from the application of national frameworks to support local health and social care systems. These have centred on older people's and mental health services, and differ from the specific national-level modelling in a number of ways. In particular, they have involved:

- future capacity requirements and planning hospital services in North West London SHA
- changes in depression service delivery
- development of a commissioning strategy for adult learning disabilities
- future proofing investment in buildings
- testing strategies for reconfiguring community services
- flexible use of bed-based and community services across whole-health and social care economies
- testing of commissioning options
- testing of major capital investment plans for acute hospitals in the light of pre and post-acute trends in treatment
- examination of hospital admission processes, post-acute capacity and intermediate care
- investigation of intermediate care services to assist timely discharge and for admission avoidance
- reallocation of community beds across the whole patient pathway for older people
- forensic strategy and prison healthcare
- managing mental health cases in the community, to avoid institutional care
- testing of guidelines for depression, with the Core Services Improvement Partnership (CSIP)
- disease management.

In each case the focus has been on testing the effect of the changes on the whole pathway as well as on the agency leading the change. Discrepancies that emerge from these analyses can often lead to:

- exposing the informal policies which an organisation uses when delays/stocks are not permitted, for example in A&E
- questioning the validity of data itself – for example, whether the data is a function of management action rather than an absolute reflection of the characteristics of patients
- identifying implications for information system design – that is, the data that might need to be collected for improved management of the patient pathways, rather than for traditional performance management indicators

'A number of studies have used system dynamics to investigate issues arising from the application of national frameworks to support local health and social care systems'

- highlighting conflict between achieving sustainable outcomes and applying short-term coping actions when demand pressures are high.

Maps and models are constructed in relatively inexpensive purpose-built software (for example, i*Think* and *Powersim*) for desk-top computers. The key is to produce the simplest model possible, consistent with maintaining its transparency and having confidence in its ability to cast new light on the issue of concern. This means keeping the resolution of the model at the highest level, so distinguishing it from most spreadsheets and process maps.

Should you use system dynamics?

Those using system dynamics have experienced a change in perceptions and thinking; many are progressing towards embedding it as a planning tool to support traditional approaches.

Of course, to perform effectively, system dynamics must both be well-informed and used correctly. It is best applied as a strategic tool and is not necessarily the most appropriate approach for operational issues which lack repeatability and have no obvious patterns. For it to work well requires:

- defined issues which have proved resilient to more conventional approaches

- a motivated and consistent management team composed of both issue experts and modellers; for best implementation this team must own both the models and their insights
- an openness to radical change and data sharing
- a minimisation of defensive attitudes and a willingness to challenge the status quo.

Overall, system dynamics is proving to be a very versatile way of bringing whole-systems thinking to life in a rigorous, testable way. It can challenge and question existing practices and data, and can help design and test alternative ideas for improvement over a wide range of performance measures.

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Further information

Symmetric SD: www.symmetricsd.co.uk

System Dynamics Society: www.systemdynamics.org

The Whole System Partnership: www.thewholesystem.co.uk

NHS Confederation *Leading edge* briefings are designed to reflect and stimulate new thinking. If you would like to share your views or would like more information on the issues covered in this briefing, please contact Sylvia Wyatt at **sylvia.wyatt@nhsconfed.org**

The Future Healthcare Network

The Future Healthcare Network (FHN) is a learning network which is addressing the large gap between our current state of knowledge about the shape of healthcare and what will be required by 2010 and beyond. FHN is made up of organisations that are at the leading edge of thinking about future developments of health services in the UK. FHN welcomes acute trusts, PCTs and 'whole-system' members who are facing system change and/or major capital investment.

FHN is part of the NHS Confederation which represents the majority of NHS organisations across the UK. Membership of FHN is only available to members of the Confederation.

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