HSCMG Health & Social Care Modelling Group

UNIVERSITY OF WESTMINSTER

Applications of Operational Research in Healthcare:

Challenges and Opportunities

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www.healthcareinformatics.org.uk

Operations Research in Health Care, Lunteren, The Netherlands, 14 January 2010

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What is HSCMG?

A research group at the University of Westminster with specific objectives and skills in the following areas:

- Quantitative modelling of the process and management of care
- Evidence-based and data driven support for informed healthcare decision making and performance management
- Development of decision support tools for healthcare resources planning and management

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Health and healthcare comparisons
UK – The Netherlands

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Main causes of death

Cause of death	Percentage
Cardiovascular diseases (stroke, heart, etc)	29.3
Infectious & parasitic diseases (incl HIV/AIDS)	19.1
Cancers	12.5
Respiratory infections	6.9
Respiratory diseases	6.5
Unintentional injuries	6.2
Perinatal conditions	4.3
Digestive diseases	3.5
Intentional injuries (suicide, murder, etc)	2.8
Neuropsychiatric disorders	1.9
Diabetes	1.7
Genito-urinary system diseases	1.5
Maternal conditions	0.9
Nutritional deficiences	0.85

Source: World Health Organization (2004). "Annex Table 2: Deaths by cause, sex and mortality stratum in WHO regions, estimates for 2002" . *The world health report 2004 - changing history*.

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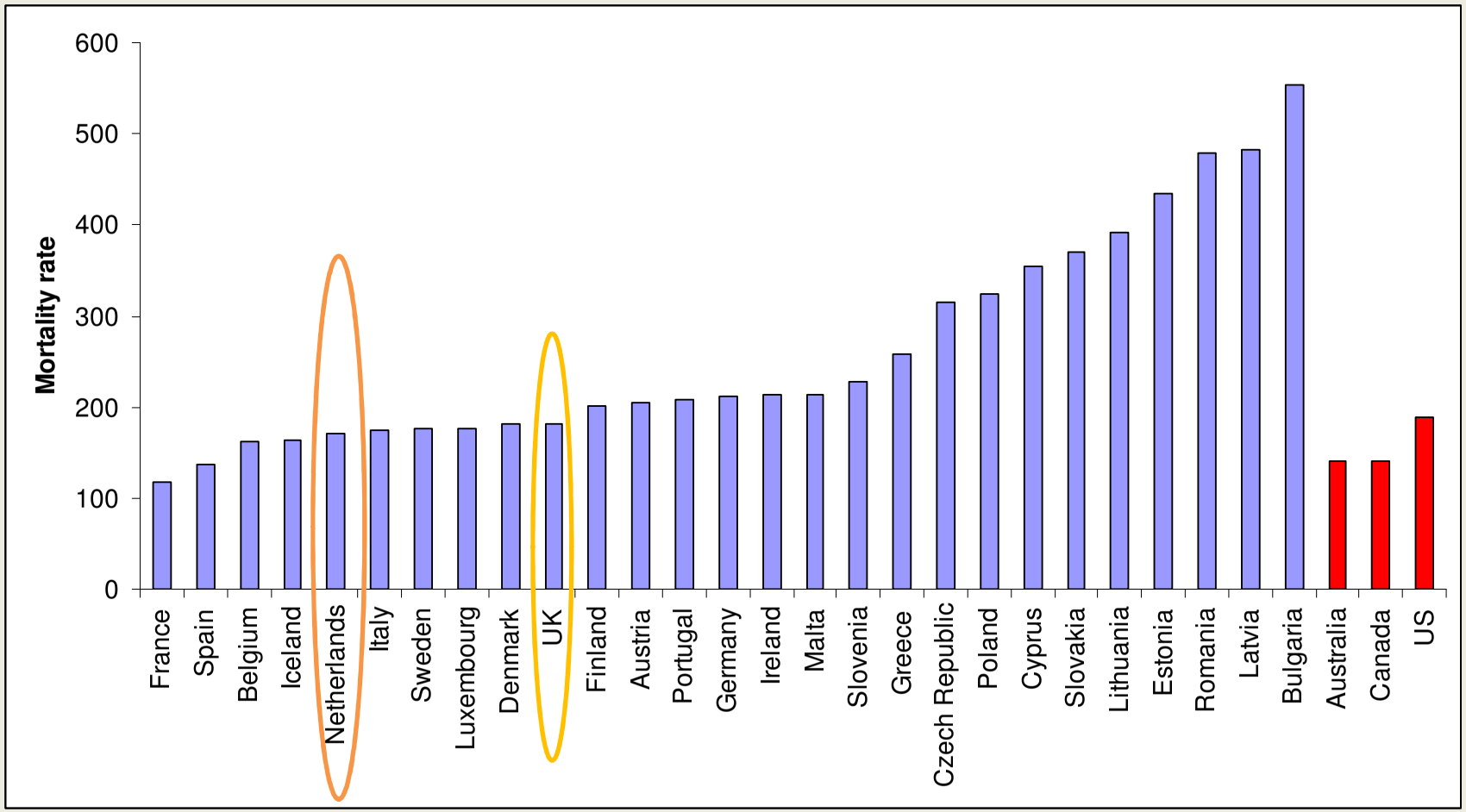
Age-standardized mortality rate for cardiovascular diseases (per 100 000 population)



Source: WHO

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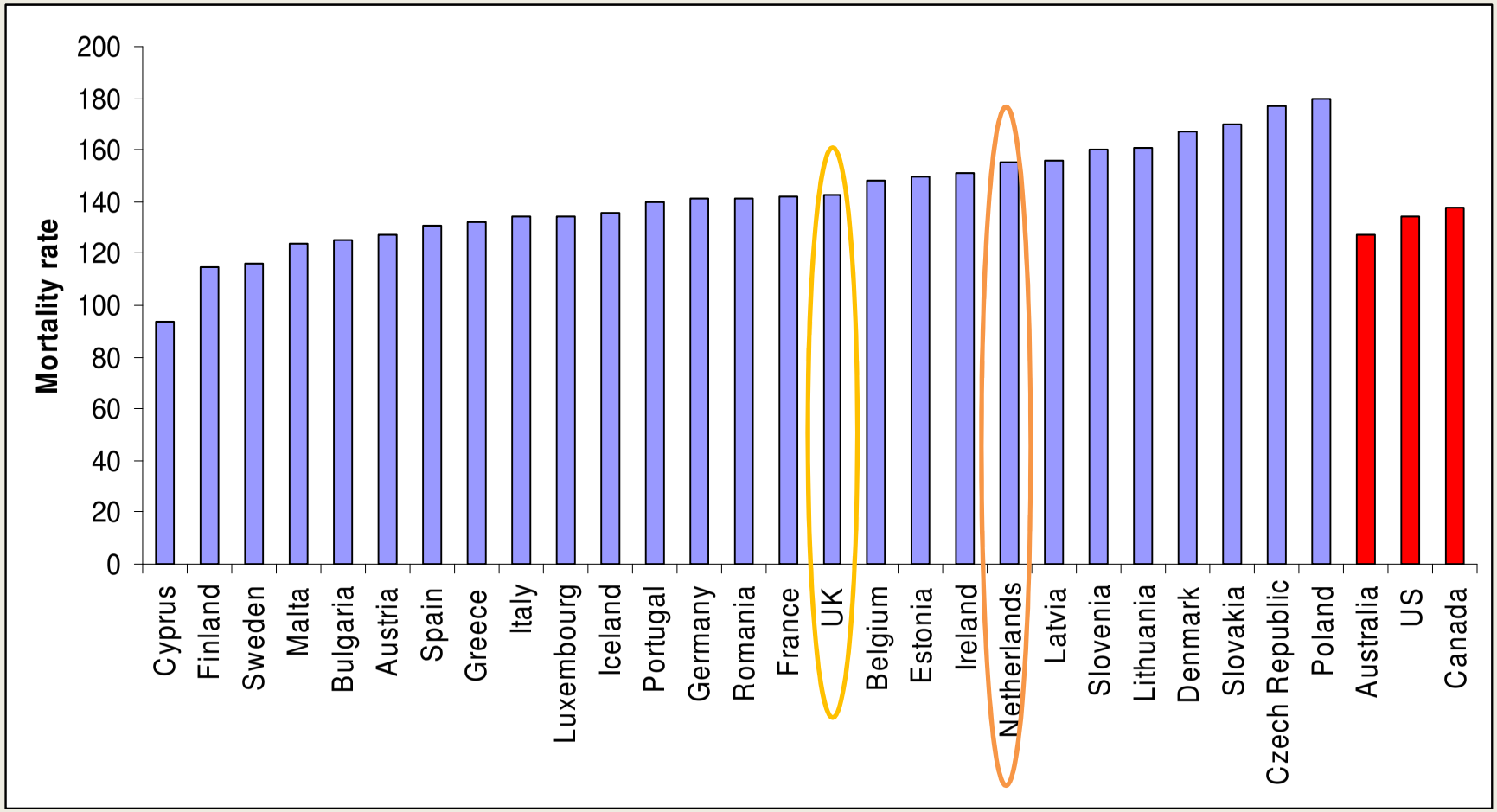
Age-standardized mortality rate for cancer (per 100 000 population)



Source: WHO

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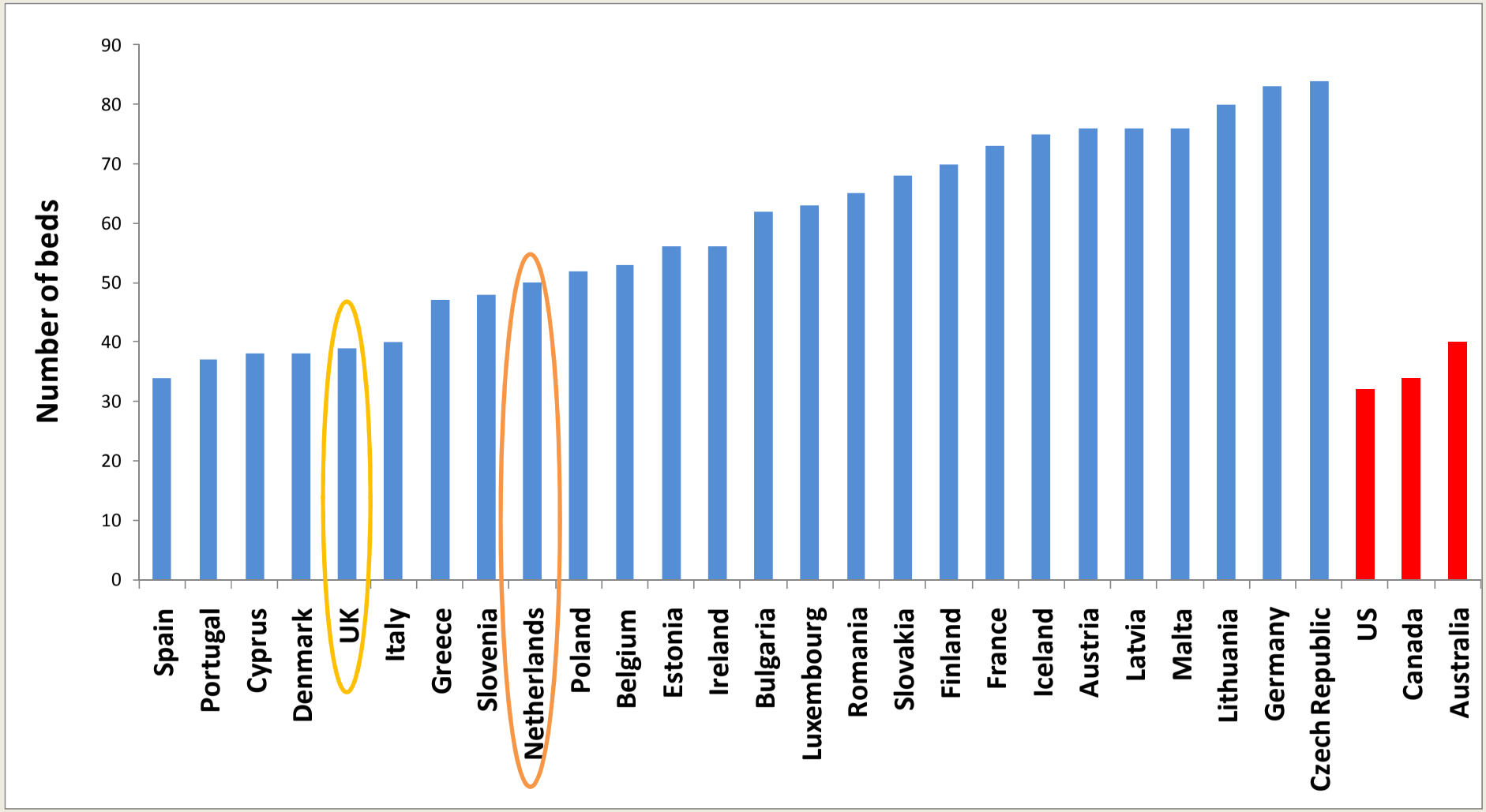
Hospital beds (per 10,000 population)



Source: WHO

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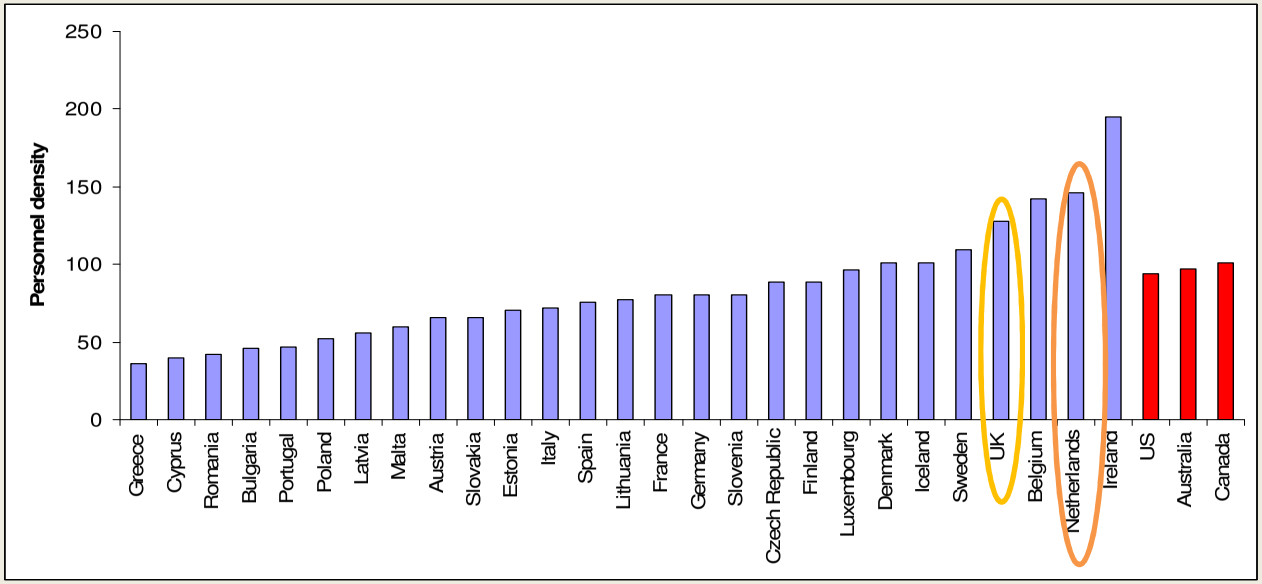
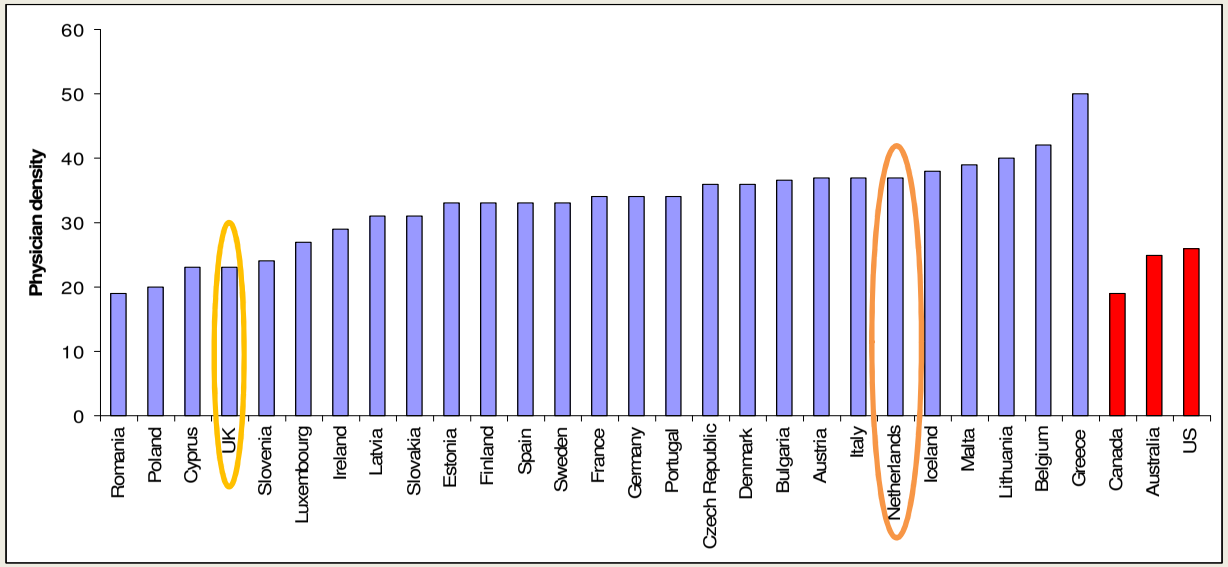
Nursing/midwifery personnel and Physician density (per 10,000 population)





Source: WHO

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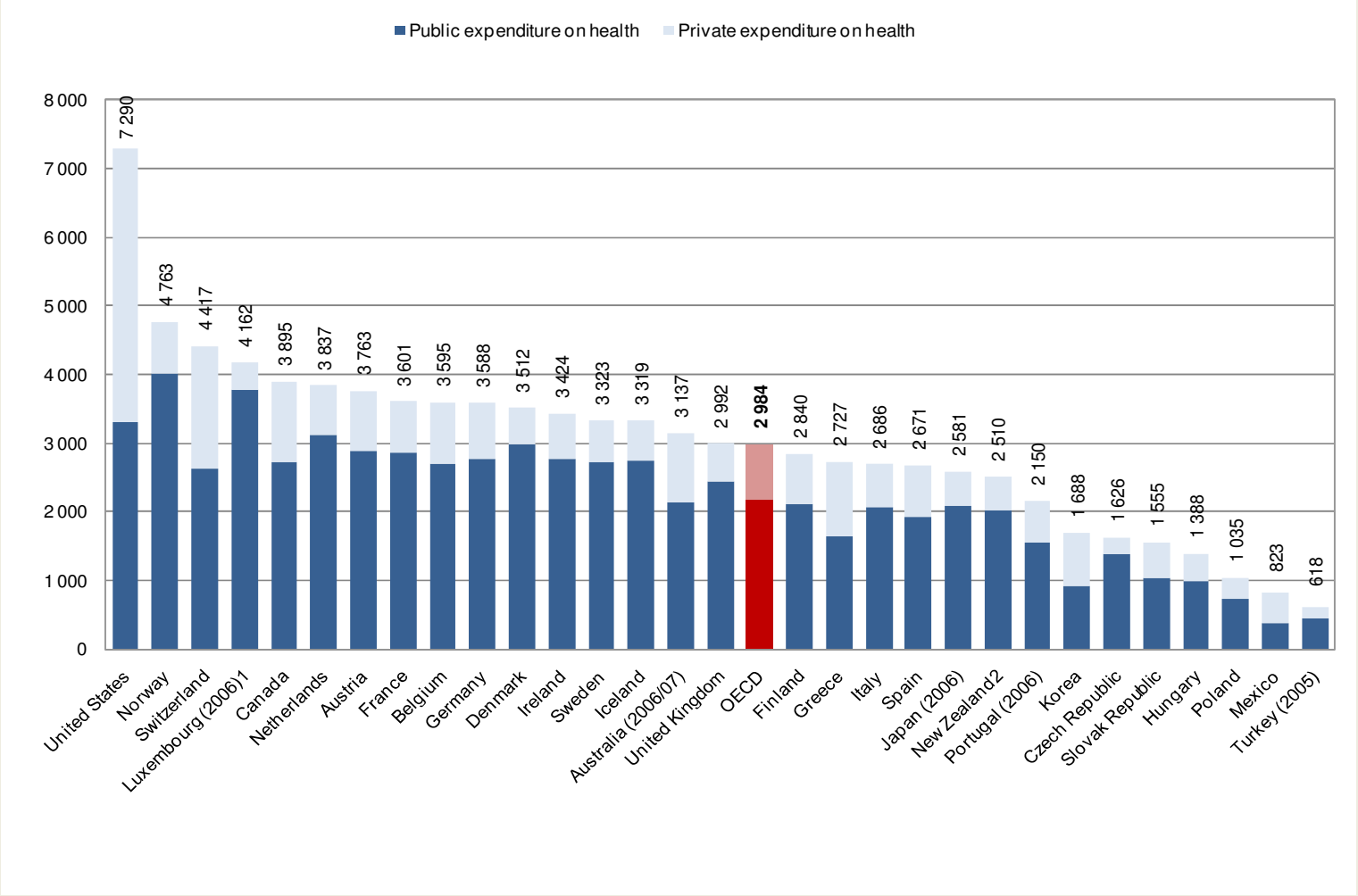
Total health expenditure per capita, 2007



1. Health expenditure is for the insured population rather than resident population. 2. Current health expenditure.

Source: OECD Health Data 2009

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Mirror, Mirror: Ranking of Six Nations

Country Rankings	
	1-2.66
	2.67-4.33
	4.33-6.0

	AUSTRALIA	CANADA	GERMANY	NEW ZEALAND	UNITED KINGDOM	UNITED STATES
OVERALL RANKING (2007)	3.5	5	2	3.5	1	6
Quality Care	4	6	2.5	2.5	1	5
Right Care	5	6	3	4	2	1
Safe Care	4	5	1	3	2	6
Coordinated Care	3	6	4	2	1	5
Patient-Centered Care	3	6	2	1	4	5
Access	3	5	1	2	4	6
Efficiency	4	5	3	2	1	6
Equity	2	5	4	3	1	6
Long, Healthy, and Productive Lives	1	3	2	4.5	4.5	6
Health Expenditures per Capita, 2004	$2,876*	$3,165	$3,005*	$2,083	$2,546	$6,102

* 2003 data

Source: K. Davis, C. Schoen, S. C. Schoenbaum, M. M. Doty, A. L. Holmgren, J. L. Kriss, and K. K. Shea, "Mirror, Mirror on the Wall: An International Update on the Comparative Performance of American Health Care," The Commonwealth Fund, May 2007

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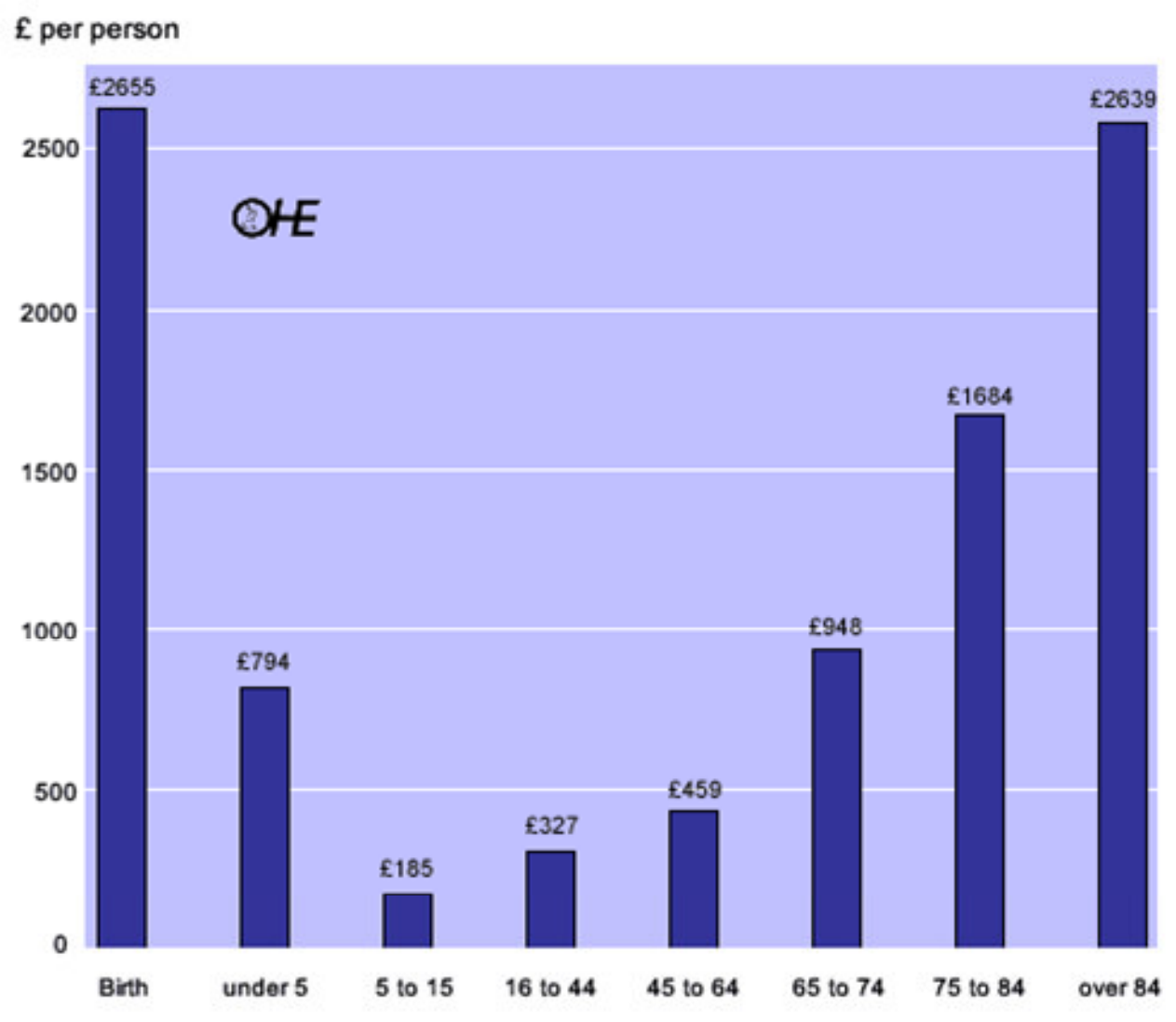
Estimated per capita expenditure by age group, England, 2002/03



Source: OHE

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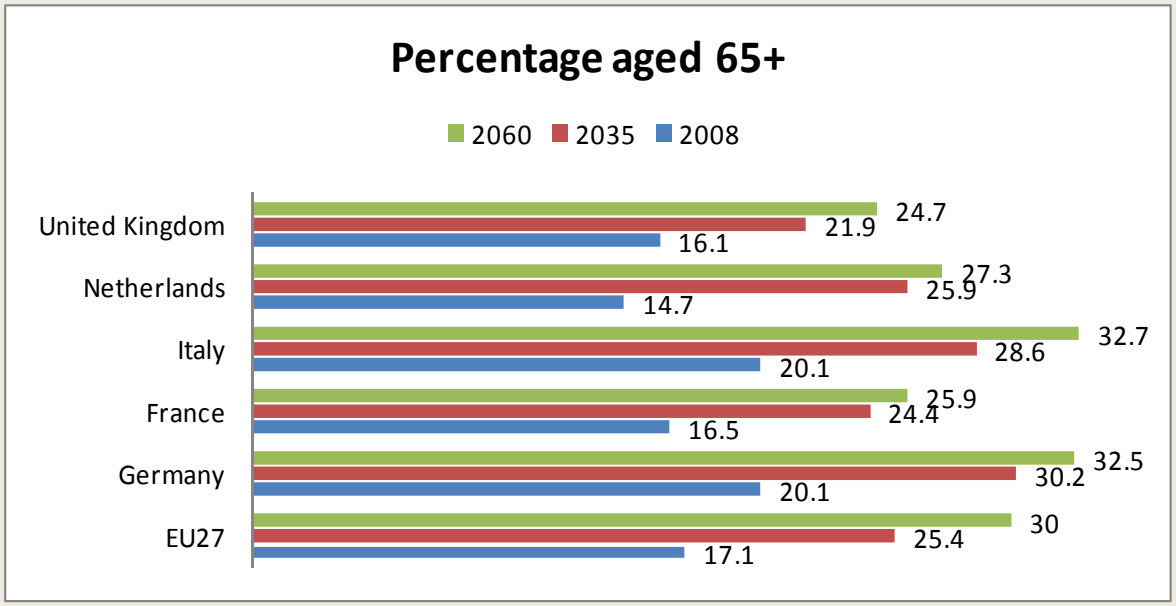
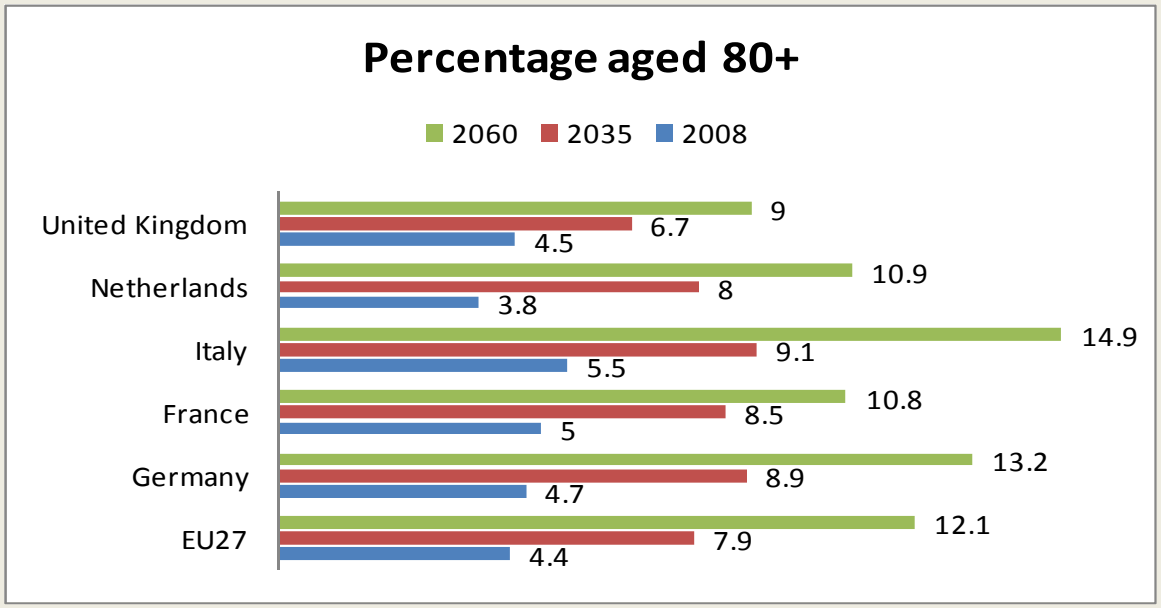
Older people projections





Source: Eurostat, Aug 2008

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The NHS

NHS core principles

When it was launched by Aneurin Bevan (minister of health) on July 5 1948, the NHS was based on three core principles:

- That it meet the needs of everyone
- **That it be free at the point of delivery**
- That it be based on clinical need, not ability to pay

Other principles have been added since dealing with patient choice, information, confidentiality, etc.

Source: www.nhs.uk

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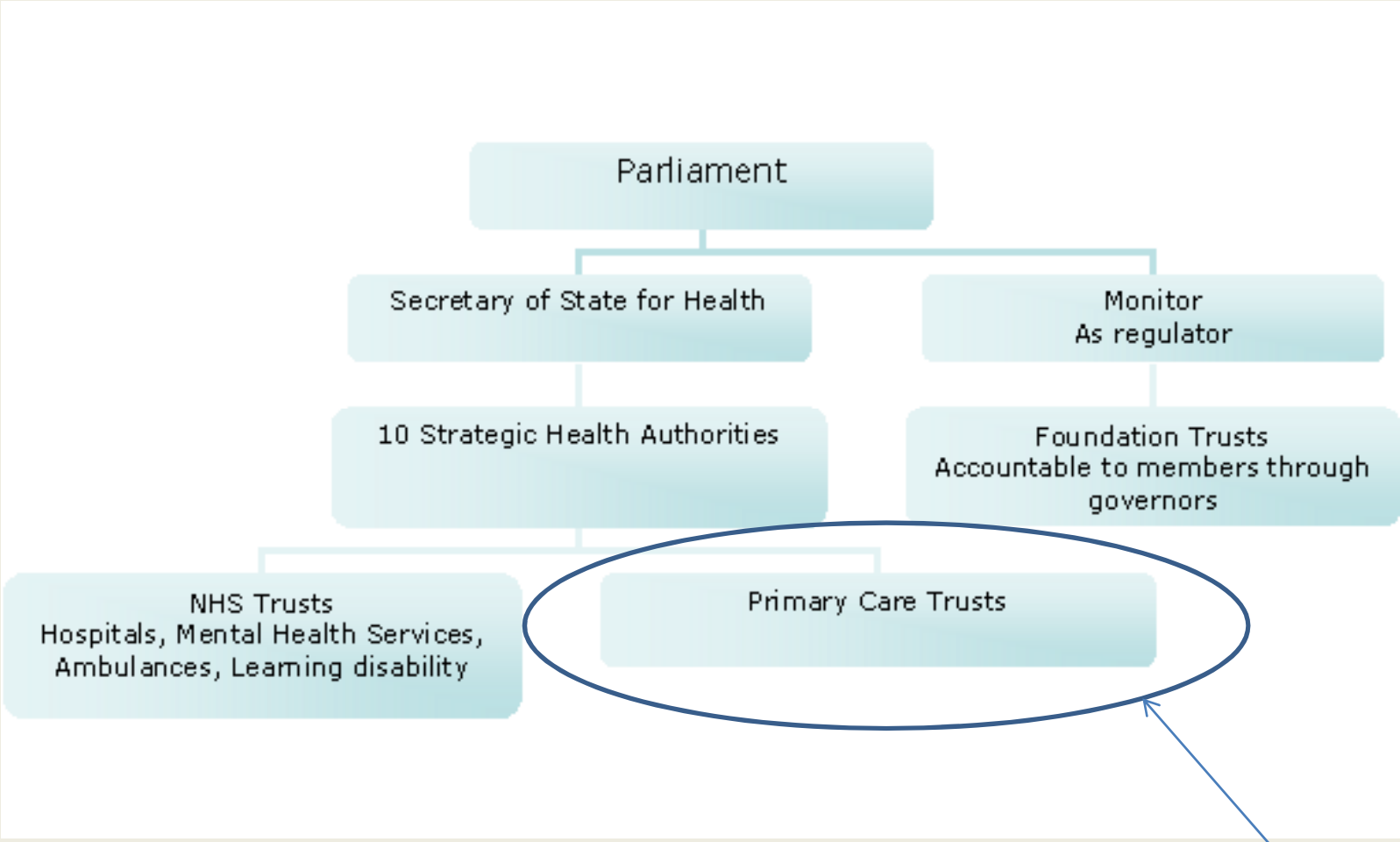
Structure of the NHS (England)



Source: www.nhshistory.net

Scale of the NHS

- The NHS employs more than 1.7m people [1.3m for NHS England]. Of those, just under half are clinically qualified, including 120,000 hospital doctors, 40,000 general practitioners (GPs), 400,000 nurses and 25,000 ambulance staff.
- Only the Chinese People's Liberation Army, the Wal-Mart supermarket chain and the Indian Railways directly employ more people.
- On average, it deals with 1m patients every 36 hours. That's 463 people a minute or almost eight a second.
- Each week, 700,000 people will visit an NHS dentist, while a further 3,000 will have a heart operation. Each GP in the nation's 10,000-plus practices sees an average of 140 patients a week.
- Budget in 2008/09 > £ 100 billion

Source: www.nhs.uk

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What is health (operational research) modelling?

Just in case you had forgotten!

What is (operational research) modelling?

- Operational Research (O.R.) is the discipline of applying optimisation and simulation methods…
  - Advanced quantitative methods, problem structuring, simulation and other analytical techniques
- …To help make better decisions…
  - Examine assumptions, facilitate an in-depth understanding and decide on practical action
- …For a very wide range of operational improvements.
  - Greater efficiency, better customer service, higher quality or lower cost …
- Most of the problems OR tackles are messy and complex, often entailing considerable uncertainty.

[*OR Society: www.orsoc.org.uk*]

What about OR applications to health ?

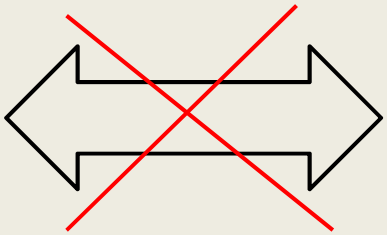
- "one of the ***unique selling points*** of significant strength within the British OR research, from an international perspective."

- "can serve as bridges between 'hard' areas like mathematics and more qualitative areas such as human resources management, knowledge management and social and behavioural sciences."

International review of the research status of operational research in the UK commissioned by the Engineering and Physical Sciences Research Council, 2004

How much academic work gets into practice?

- Various reviews of health OR modelling research have highlighted the thriving nature of the research, but have also noted the lack of implementation


To name a few

- Fone et al (2003) Systematic review of the use and value of computer simulation modelling in population health and health care delivery. *Journal of Public Health Medicine* 25(4) : 325-335

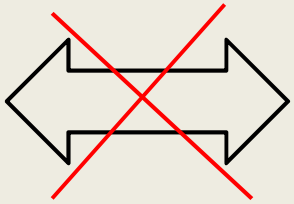
  "…we were unable to reach any conclusions on the value of modelling in health care because the evidence of implementation was so scant.!

- Burke et al (2004) The State of the Art of Nurse Rostering. *Journal of Scheduling* 7: 441-499

  "… very few of the developed approaches are suitable for directly solving difficult real world problems. Many of the models that have been presented and discussed are too simple to be directly applied to hospital wards. "

Barriers to use of modelling by health services

- Capacity
  - Lack of dedicated staff
- Perceived value
  - Recognition (lack of) at senior levels
    - Chief Execs, Consultants !
  - No experience of use/success
  - Lack of usable tools
  - Data Limitations
- Constantly shifting objectives
- Communication (lack of) between key professional groups
- Timescales
- Politics

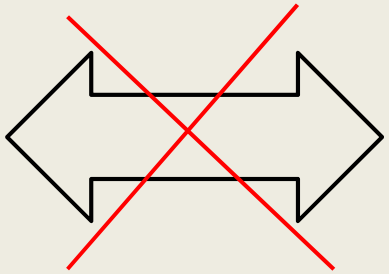


Source: MASHnet workshops

But was there ever any intention of implementation – should there be?

- The purpose of modelling may be to:
  - Solve a problem, but also …
  - Organise/structure complex decision making
  - Improve a technique
  - Educate stakeholders

    [Vissers, 1998]
- Additionally a goal/constraint for academics is to PUBLISH
- If implementation is an objective communication is essential



Some case studies from HSCMG

Application oriented – mixed objectives

- Diagnosing heart failure
- A&E simulation
- Capacity modelling of a neonatal unit
- Long-term Care / Continuing Care planning

Technique improvement/development

- Patient flow modelling
- Performance
  - Performance map for the NHS Balanced Scorecard
  - Emergency readmission criterion

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…1. Diagnosing heart failure…

- Problem
  - Determine what is the "best" way to diagnose heart failure: estimate and compare diagnosis accuracy, cost-effectiveness, and resource use of diagnosis pathways for heart failure
  - Five diagnosis pathways were considered including
    - Preliminary testing prior to echocardiography by electrocardiogram (ECG) or measurement of brain natriuretic peptide (BNP);
    - Specialist clinical assessment including echocardiography by a consultant cardiologist (taken as the "gold standard");
- Objectives
  - **Solve problem** – to some extent
  - **Educate and promote modelling approaches in Public Health**

Funded by the **Wales Office of Research and Development for Health and Social Care (WORD)**

In collaboration with the **University of Wales College of Medicine**, now part of Cardiff University

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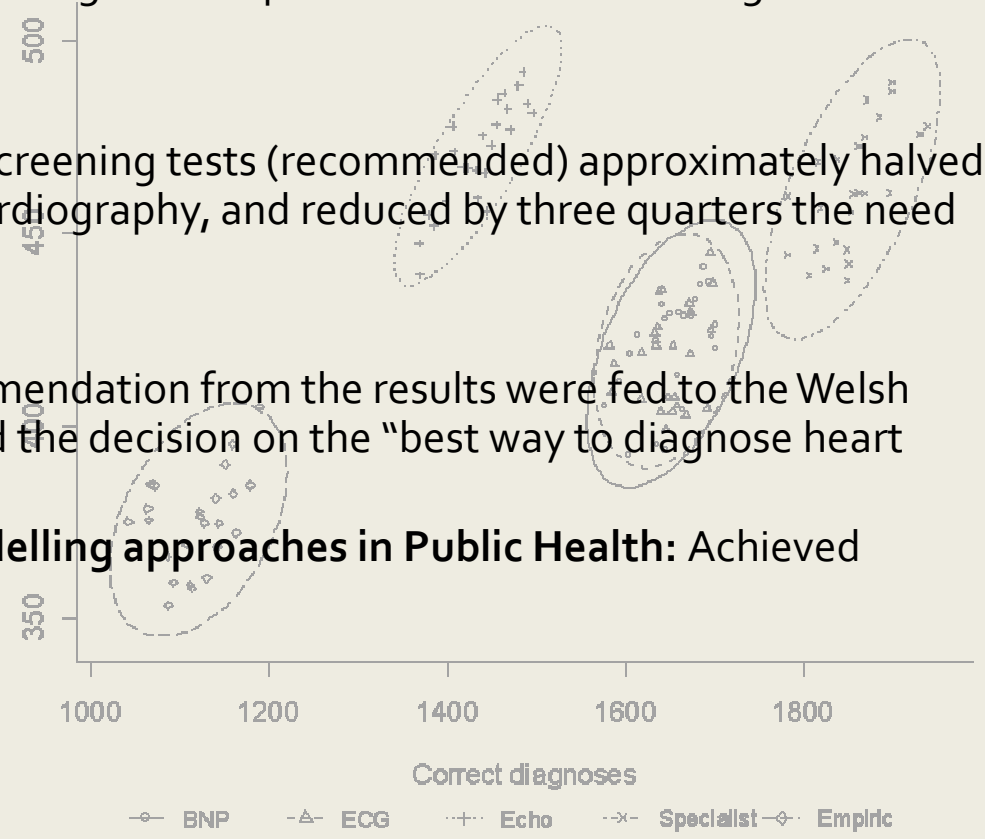
…1.Diagnosing heart failure…

- Methodology/Model
  - decision analysis (using DATA) and simulation models (Micro Saint) to mimic the progression of people presenting with suspected heart failure through to diagnosis
- Results
  - Diagnosis pathways using screening tests (recommended) approximately halved the requirement for echocardiography, and reduced by three quarters the need for clinical specialist input.
- Achievement of objectives
  - **Solve problem**: The recommendation from the results were fed to the Welsh Government and influenced the decision on the "best way to diagnose heart failure"
  - **Educate and promote modelling approaches in Public Health:** Achieved



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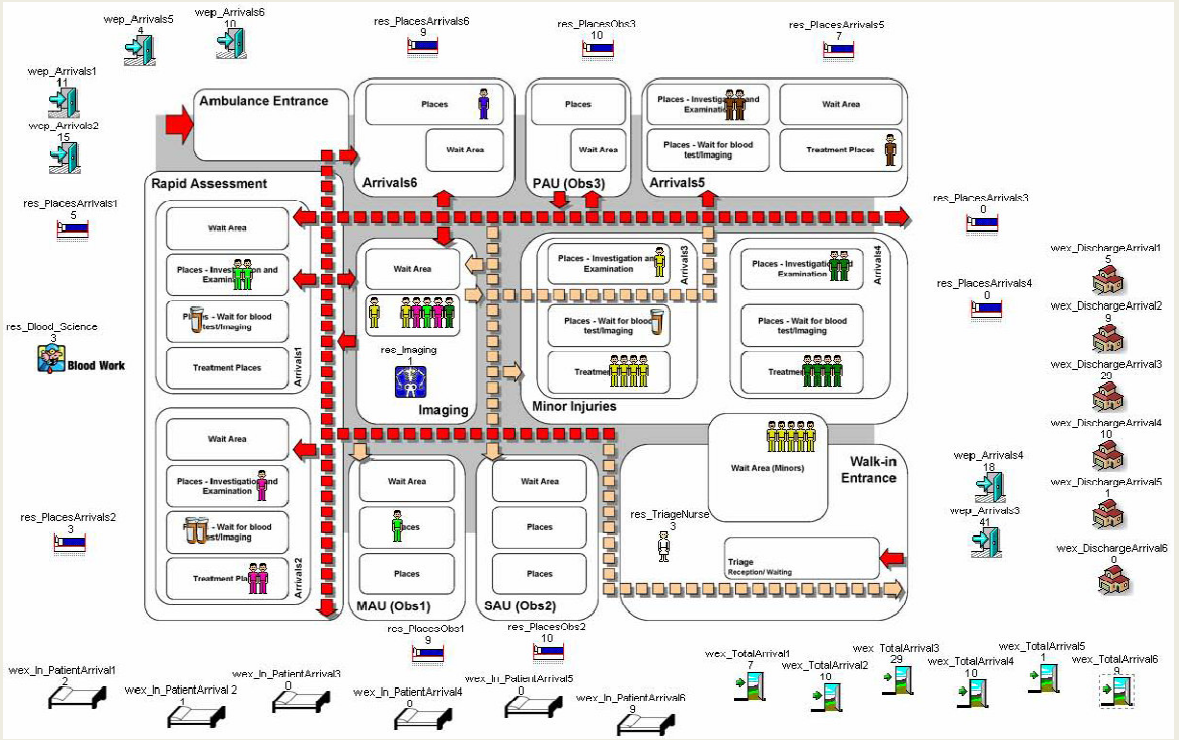
2. A&E Simulation…

- Develop a "generic" interactive computer modelling toolkit to enable rapid development of computer models of A&E processes to advise health care organisations on optimal care provision and delivery



- Objectives:
  - Solve problem to some extent [an real A&E department was involved]
  - Improve technique to some extent [generic simulation model]
  - Educate the company on modelling

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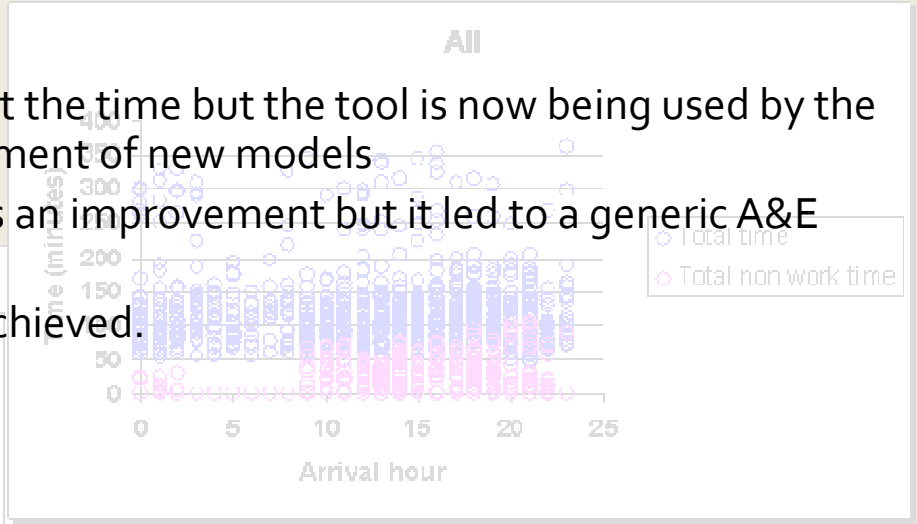
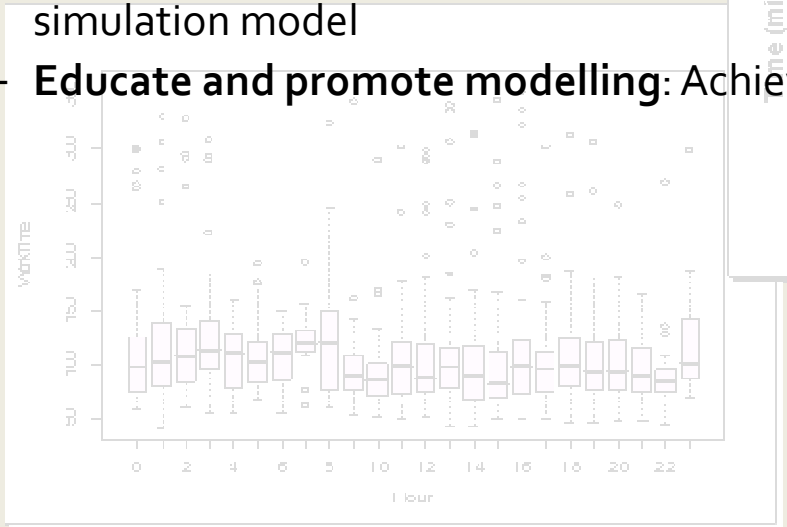
…2. A&E Simulation Model…

- Methodology/Model
  - Discrete event simulation (using Simul8) with Excel spreadsheet interface and bitmap overlay (A&E bubble diagram), along with (hierarchical) clustering on length of stay percentile distribution
- Results
  - An actual tool was developed. It was validated (partially) with one hospital
- Achievement of objectives
  - **Solve problem**: not really achieved at the time but the tool is now being used by the consultants to help with the development of new models
  - **Improve technique:** not sure if this is an improvement but it led to a generic A&E simulation model
  - **Educate and promote modelling**: Achieved.





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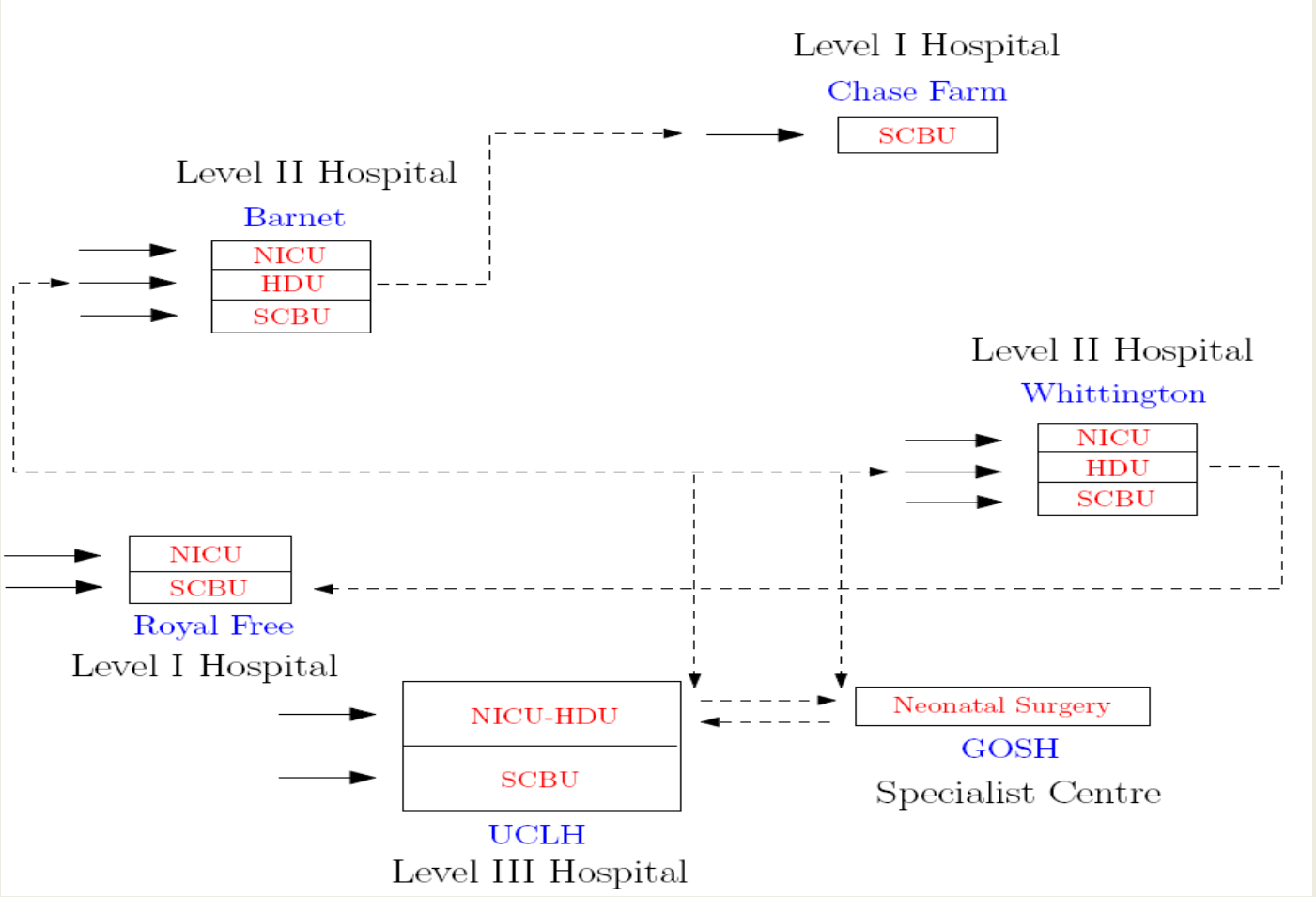
3. Capacity Planning of a Perinatal Network: A Loss Network Framework …

- To develop an analytical model for performance measure and capacity planning of a perinatal network



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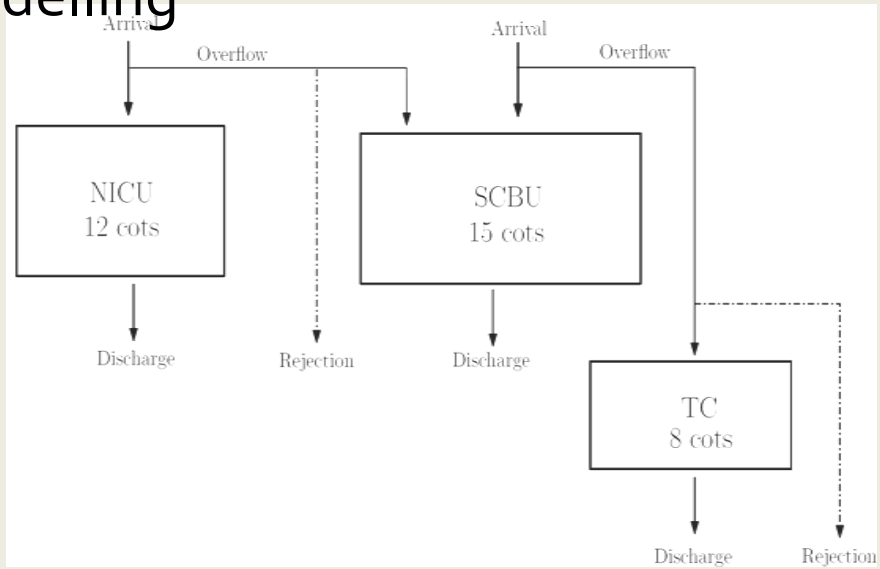
…3. Capacity Planning of a Perinatal Network: A Loss Network Framework …

- Objectives:
  - Solve problem to some extent [A level III neonatal unit and a perinatal network were involved]
  - Improve/develop techniques
  - Educate / promote modelling



…3. Capacity Planning of a Perinatal Network: A Loss Network Framework …

- Methodology/Model
  - Generalised loss network decomposition
  - M/M/c/o model with overflow
  - GI/G/c/o with overflow
  - Discrete event simulation

PF solution of *partial balance equation*

$$\pi(\mathbf{n}) = G^{-1}\prod_{i=1}^{2}\frac{\left(\frac{\lambda_i}{\mu_i}\right)^{(n_i+n_{i0})}}{(n_i+n_{i0})!}, n \in \mathbf{S}, G = \sum_{n\in\mathbf{S}}\prod_{i=1}^{2}\frac{\left(\frac{\lambda_i}{\mu_i}\right)^{(n_i+n_{i0})}}{(n_i+n_{i0})!}$$

Overflow probability

$$\begin{aligned} O_i &= \sum_{\mathbf{n}\in T_i}\pi(\mathbf{n}) \\ &= \left(\sum_{\mathbf{n}\in T_i}\prod_{i=1}^{2}\frac{\left(\frac{\lambda_i}{\mu_i}\right)^{(n_i+n_{i0})}}{(n_i+n_{i0})!}\right) / \left(\sum_{\mathbf{n}\in\mathbf{S}}\prod_{i=1}^{2}\frac{\left(\frac{\lambda_i}{\mu_i}\right)^{(n_i+n_{i0})}}{(n_i+n_{i0})!}\right) \end{aligned}$$

$T_1 = \{\mathbf{n}\in\mathbf{S} | n_1 = C_1 \text{ and } n_{10}+n_2 \le C_2\}$ $T_2 = \{\mathbf{n}\in\mathbf{S} | n_{10}+n_2 = C_2 \text{ and } n_{20} \le C_0\}$

Rejection probability

$T_1 = \{\mathbf{n}\in\mathbf{S} | n_1 = C_1 \text{ and } n_{10}+n_2 = C_2\}$ $T_2 = \{\mathbf{n}\in\mathbf{S} | n_{10}+n_2 = C_2 \text{ and } n_{20} = C_0\}$

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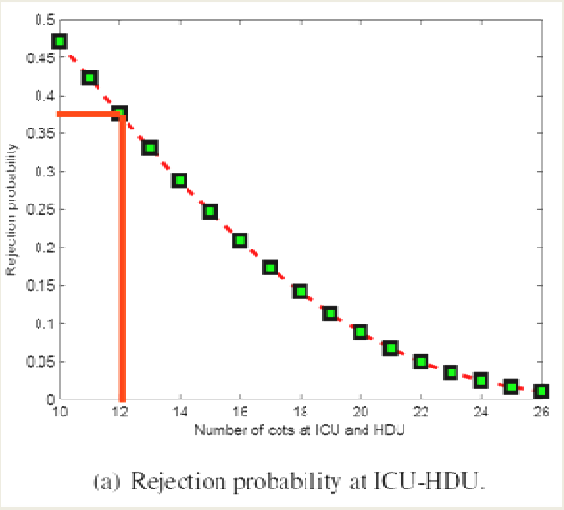
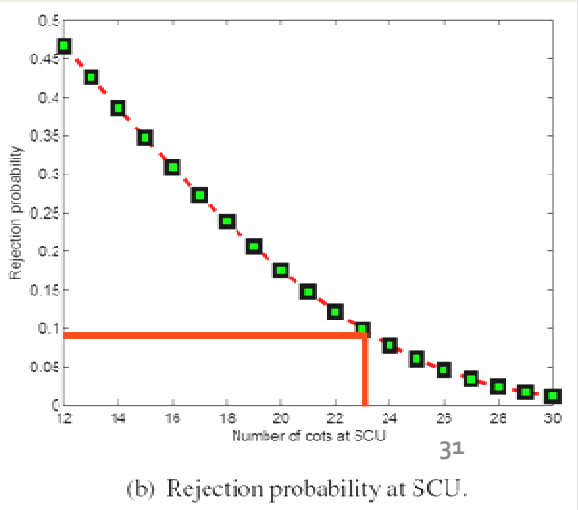
…3. Capacity Planning of a Perinatal Network: A Loss Network Framework …

- Results
  - Various models have been developed, validated, and compared
- Objectives achievement
  - **Solve problem**: to some extent. The models helped with understanding the capacity required for achieving certain levels of care. Difficult to say whether the simplest loss network model would be sufficient
  - **Improve/develop technique:** Yes; superior model, etc.
  - **Educate and promote modelling**: Achieved: increased interest in modelling among clinicians. Again the simplest model might have done the job.

Unit	No. of cots	Observed rejection prob.	Calculated rejection prob. (std model)	Calculated rejection prob. (overflow model)
ICU/ HDU	12	0.325	0.377	0.333
SCU	15	0.038	0.347	0.056*
	23		0.098	



(a) Rejection probability at ICU-HDU.



(b) Rejection probability at SCU.

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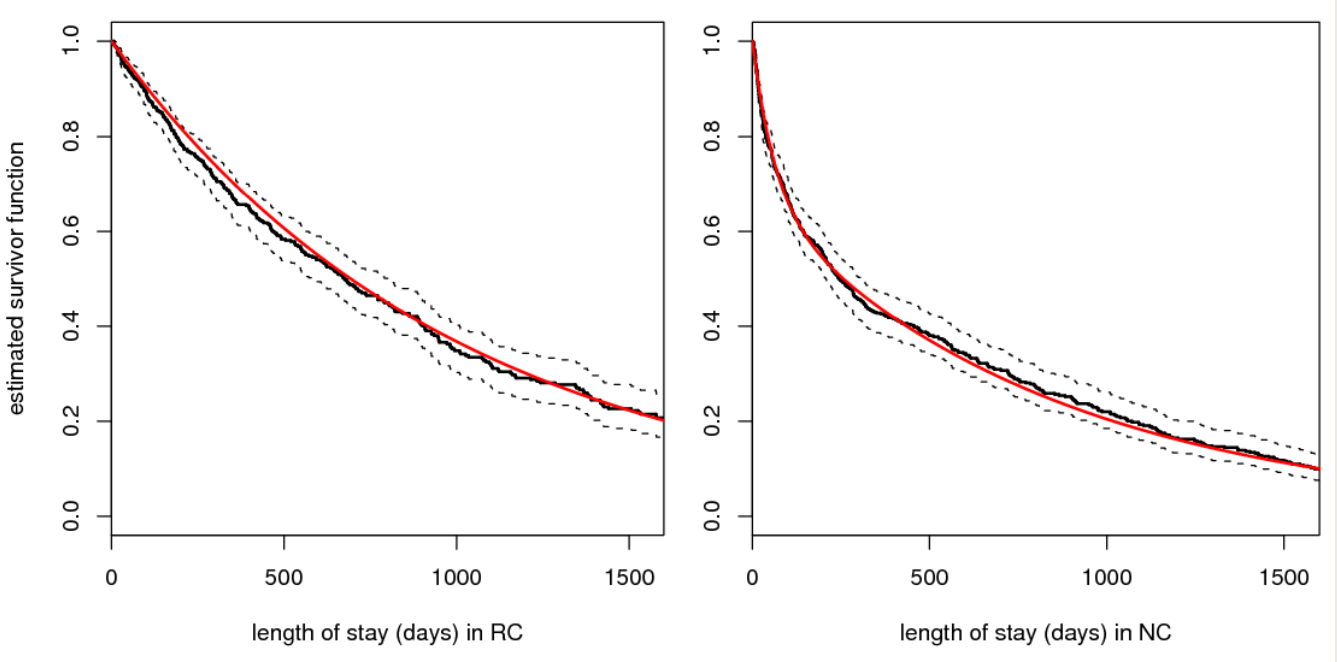
4. Long-Term/Continuing Care Planning

- To develop a methodology and tool to describe movements of residents and length of stay of residents in LTC/CC and forecast costs of "known commitments"



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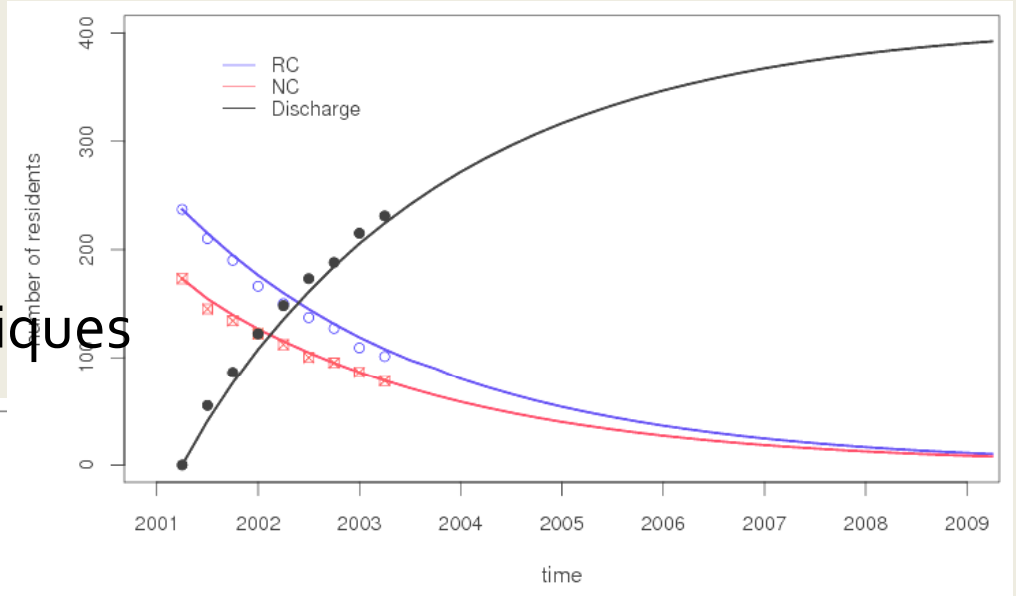
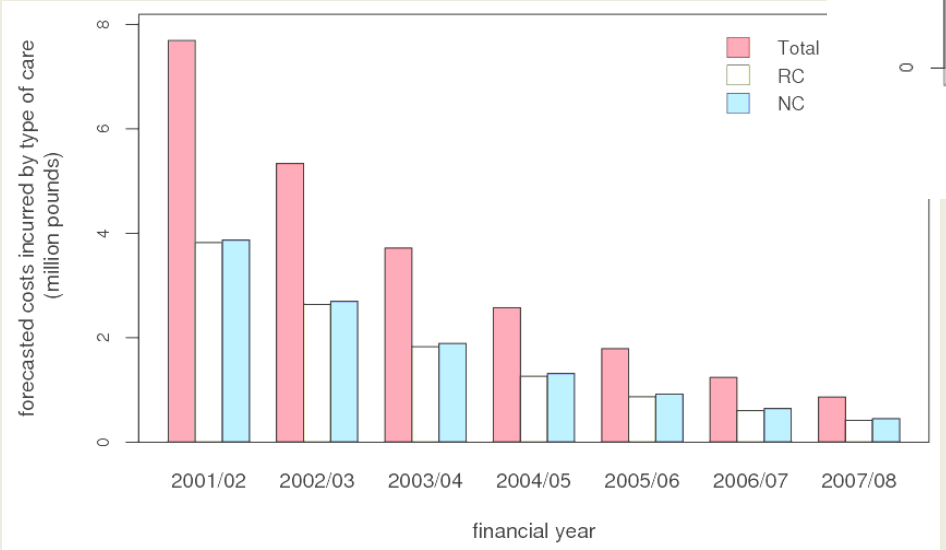
… 4. Long-Term/Continuing Care Planning…

- Objectives:
  - Solve problem
  - Improve/develop techniques





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… 4. Long-Term/Continuing Care Planning…

- Methodology/Model
  - Aggregated Markov model
  - Phase-type distributions
- Results
  - The model was developed and validated with LTC data from a London Borough Council
- Achievement of Objectives
  - **Solve problem**: to some extent. Results from the model were fed back to the Council and used for funding negotiations
  - **Improve/develop technique:** Yes; superior model, etc.

	predicted	Observed
2001/02	£6,683,000	£6,471,000
2002/03	£4,624,000	£4,385,000

And then

EPSRC

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… 4.1 Long-Term/Continuing Care Planning…FLoSC

A "user friendly" software implementation of the LoS and cost forecasting framework for known commitment

FLoSC

Forecasting Length of Stay and Cost

- Development funded by the Care Services Efficiency Delivery (CSED) Program of the Department of Health
  - **CSED Mission** - Deliver evidence-based, pragmatic, practical efficiency improvement solutions through process and system changes across multiple councils
- Target users: social service departments (or alike) of local authorities

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University of Westminster

DH Department of Health

Care Services Efficiency Delivery

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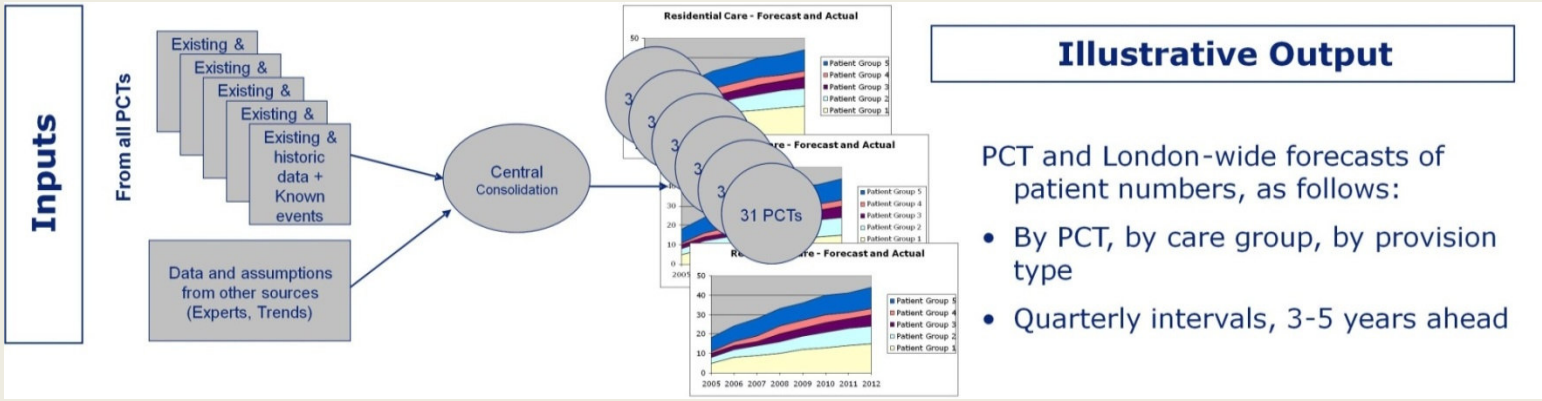
… 4.1 Long-Term/Continuing Care Planning…FLoSC

- Negative
  - The take-up is low
  - Not so user-friendly: we are not professional developers
  - Cannot really be used without any basic knowledge of underlying methodology
  - Data preparation is more demanding than expected
    - Another tool FLoSC-PAD was developed to help
  - Does not take into account new arrivals into the system
  - It does not allow users to test what if scenarios [e.g. introduction of re-ablement services
- Positive
  - Still going on…
  - New project looking at the last two points above

… 4.2 Long-Term/Continuing Care Planning…

A demand forecasting tool for NHS Continuing Care services

- The LPP commissioned Deloitte to develop a tool [spreadsheet based] that aids demand planning for Continuing Care at Primary Care Trust (PCT) and London Procurement Programme (LPP) level.
- This tool should also support PCTs and LPP in making budgetary and service commissioning decisions.
- The methods need to:
  - Estimate the length-of-stay of existing CC patients;
  - Project for new CC patients;
  - Utilise routinely collected data.



Deloitte.

NHS London Procurement Programme

… 4.2 Long-Term/Continuing Care Planning…

A demand forecasting tool for NHS Continuing Care services

- Negative
  - The tool is not used despite the rather significant investment from the LPP/PCTs
  - The tool requires far too many user inputs
  - Software bugs

- Positive
  - The NHS LPP is funding a PhD programme to develop a tool based on research evidence and PCT needs

Deloitte.

NHS
London Procurement Programme

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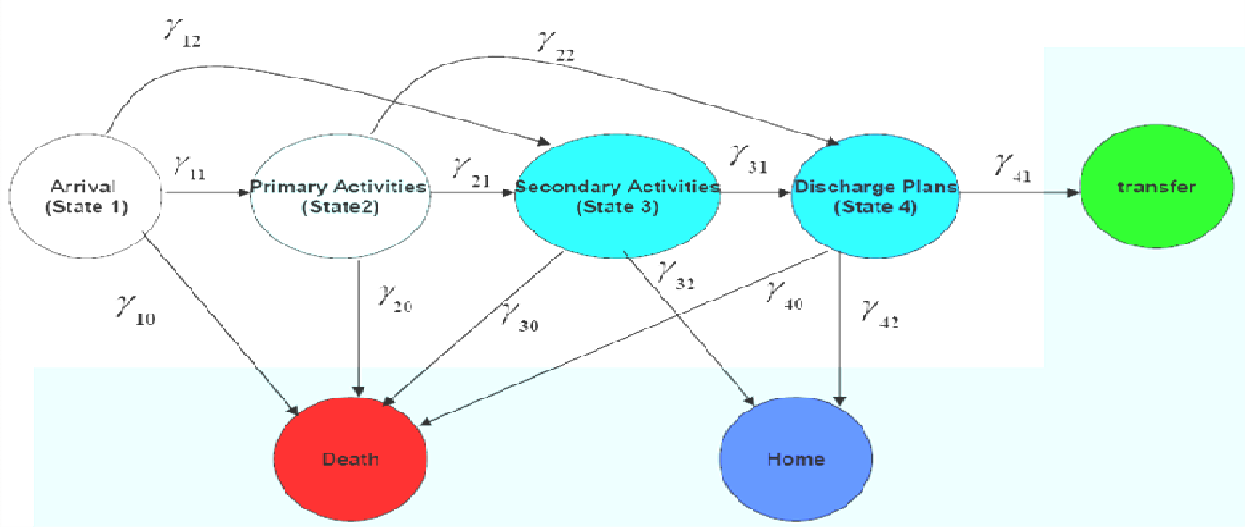
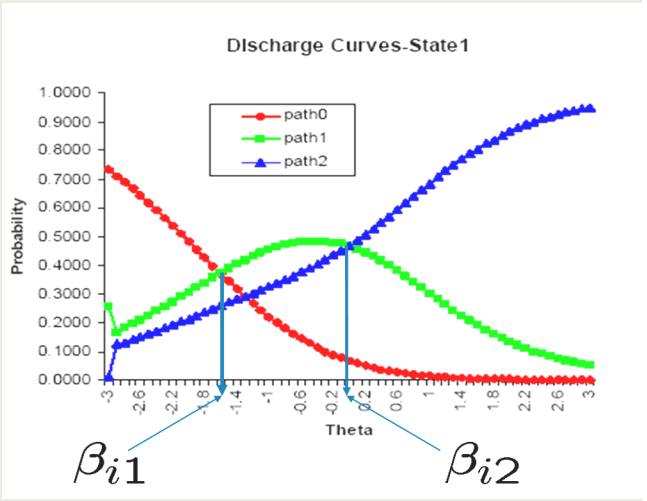
5. Patient flow Modelling…

- Model individual patient experience during the process of care
- Predict patient specific discharge probabilities
- Understand key processes and their variability which is the key to achieving improved performance.
- The modelling approach is based on advanced statistical techniques (mixed effects models) to capture patients pathways in the process of care.





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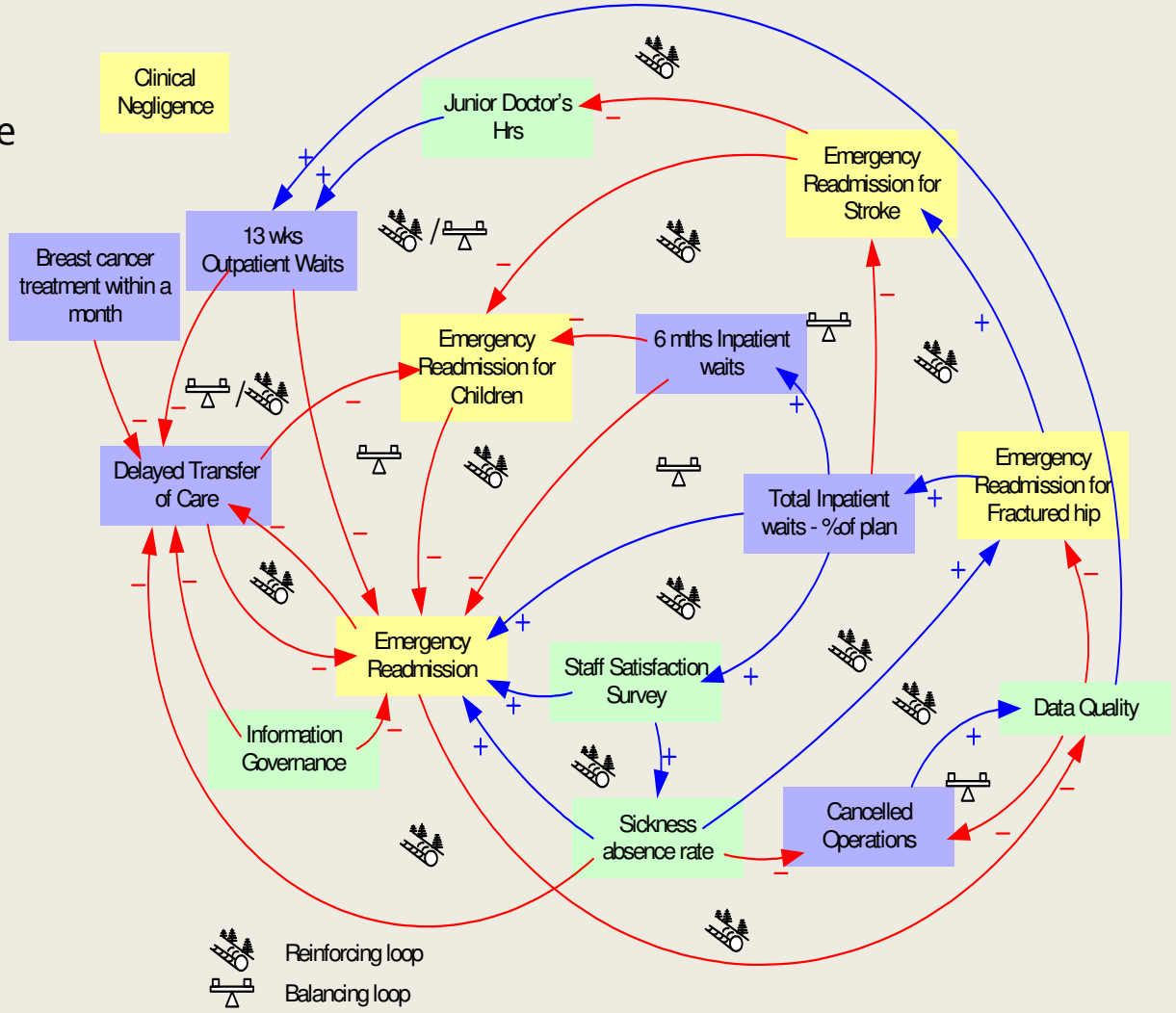
6. Performance…Balancing the NHS Balanced Scorecard

- A methodology for strategic and sustainable performance management using causal loop diagrams, structural equations modelling and discrete system simulations

- Results:
  - Traps in the NHS Balance Scorecard;
  - Managing performance is a balancing task

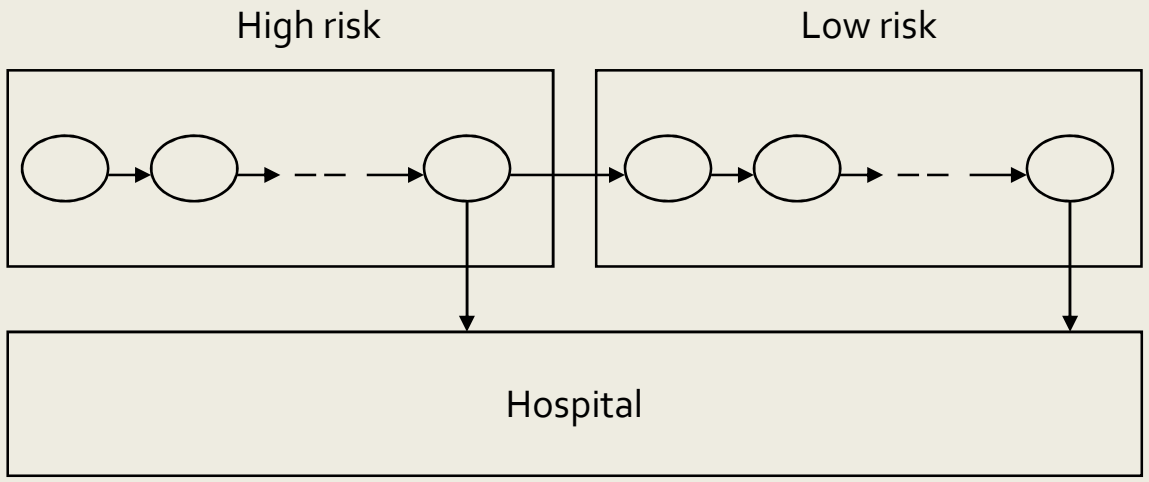


A Performance Map for the NHS Balanced Scorecard (2001/02 to 2002/03)

7. Performance…Risk of readmission…

- Empirical evidence suggests that risk of readmission substantially changes over time
  - High soon after discharge
  - Low after a period of time in the community

- Assume that time to readmission can be captured conceptually with phases [use phase-type distribution and AIC/BIC for model selection]



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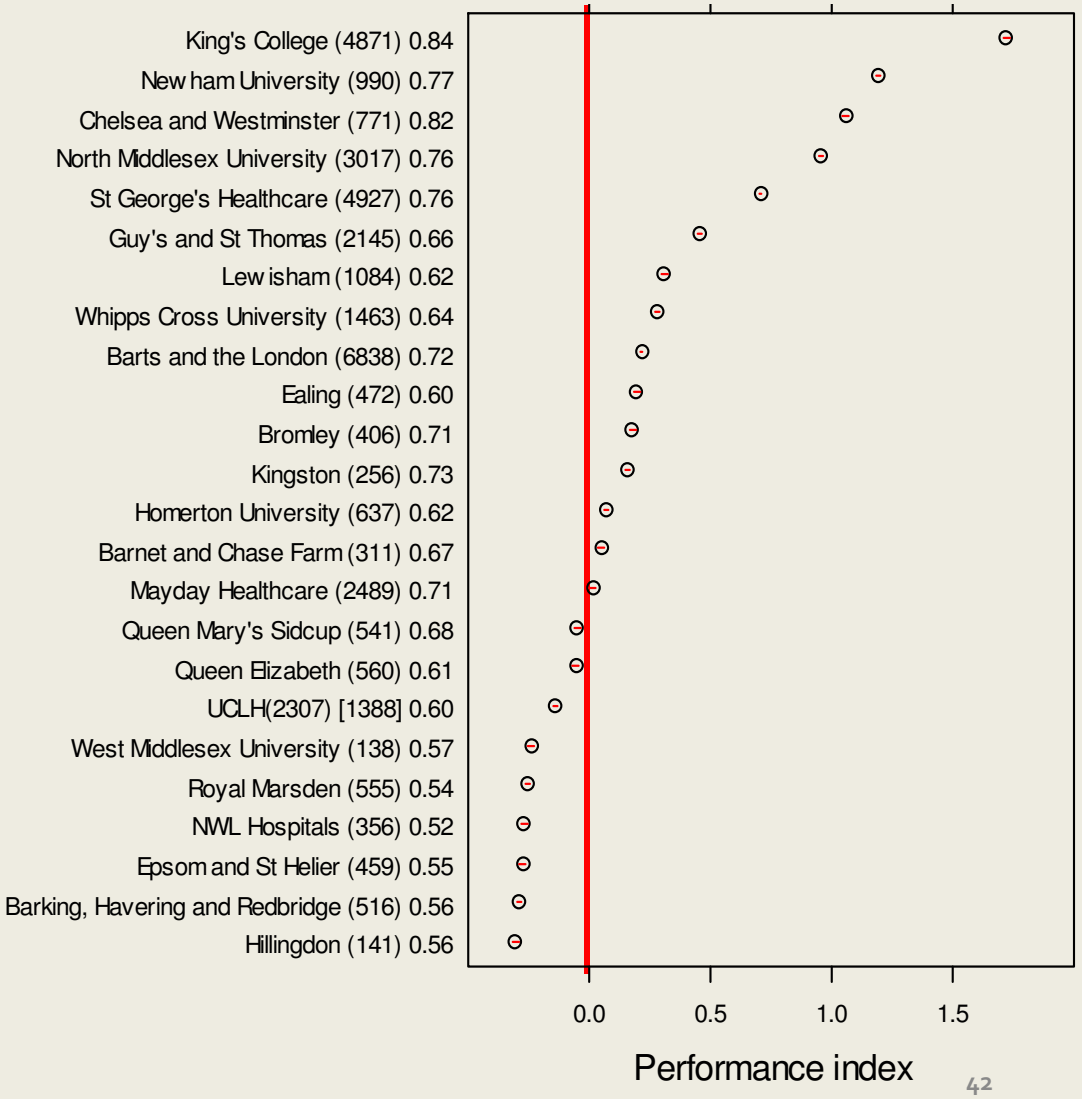
…7. Performance…Risk of readmission

- Profiling of hospitals based on patient readmissions
- Techniques: Multilevel transition models and Grid computing implementation



Conclusions

Health OR Modelling – an answer to everything?

- Not everything can be "solved" using OR;
- Often the value is in the process of modelling rather than the result
- Some models are too simple to be directly applied
- Others are too complicated to be understood and useful
- Myth about "simulation" as a solution to everything
  - their strongest appeal is the attractive GUI
- More research should be done on how to present simple [and indeed] complex analytical approaches to engage more actively with clinicians/managers
  - System Dynamics is to some extent an example to follow

Health OR Modelling – Challenges/Opportunities

- Healthcare delivery is increasingly distributed (community services, homecare, self-care, etc.)
  - New "whole systems" approaches need to be taken
    - More uncertainty
    - Time and space issues
- Healthcare delivery changes rapidly: research into capturing the present quickly becomes obsolete
- Environment….global warming
- Obesity, chronic conditions…
- And of course ….. more older people [very old in particular]

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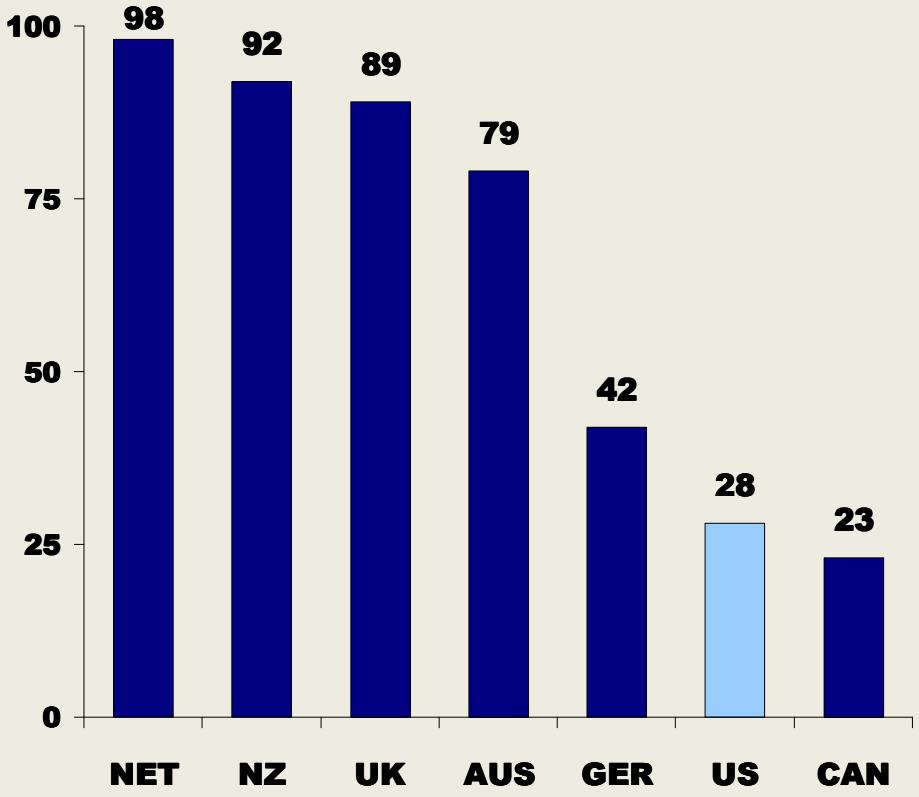
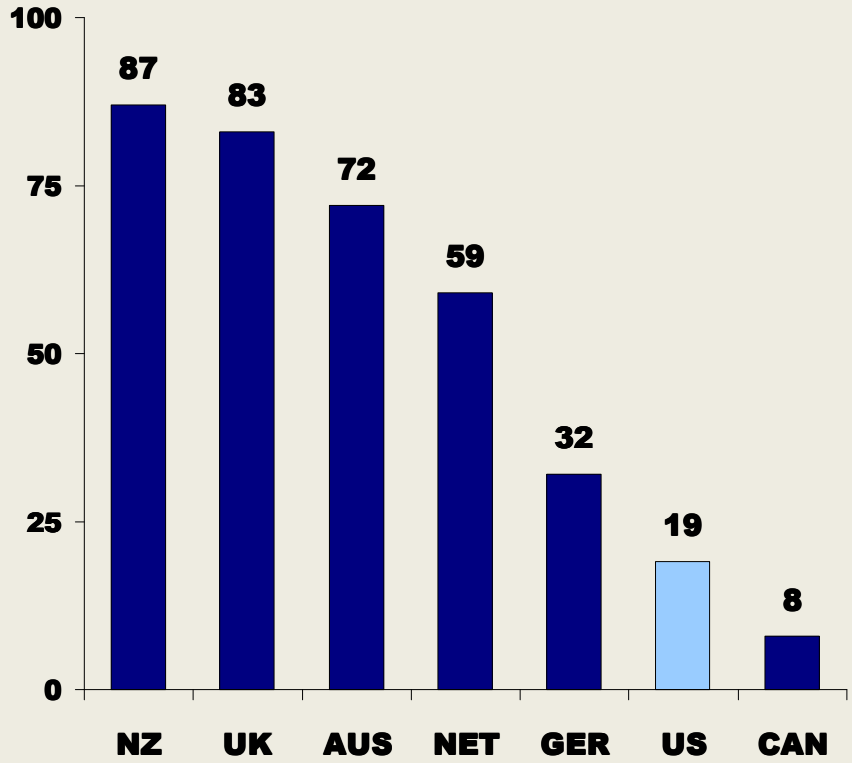
IT capacity

Percent reporting EMR



Percent reporting 7 or more out of 14 functions*



*Count of 14: EMR, EMR access other doctors, outside office, patient; routine use electronic ordering tests, prescriptions, access test results, access hospital records; computer for reminders, Rx alerts, prompt tests results; easy to list diagnosis, medications, patients due for care.

Source: 2006 Commonwealth Fund International Health Policy Survey of Primary Care Physicians in Seven Nations: Australia, Canada, Germany, Netherlands, New Zealand, UK, and US.

Health OR Modelling – Positive outlook

- The Netherlands and the UK are leading in developing electronic patient records
- But little is done with the data
- Informatics needs OR [and reciprocally]
  - Predictive modelling
  - But also service modelling
- Generic or re-usable models
- "Impact" is now being used to assess research [in the UK and the Netherlands]
  - Opportunities or challenge
  - More implementation or move away towards basic research

THANK YOU!

And Welcome to LONDON

SIXTH IMA INTERNATIONAL CONFERENCE ON QUANTITATIVE MODELLING IN THE MANAGEMENT OF HEALTHCARE

29-31 March 2010

Mary Ward House, 5-7 Tavistock Place, London, WC1H 9SN