Institution: University of Ulster

Unit of Assessment: 11: Computer Science and Informatics

Title of case study: Modelling Phases of Care

1. Summary of the impact (indicative maximum 100 words)

Acute stroke services in the Belfast Health and Social Care Trust have been reorganised using research on modelling stroke patient pathways through hospital, social and community services carried out in CSRI at Ulster. By suitably administering thrombolysis (clot-busting drugs), a stroke patient's time in hospital, community rehabilitation and nursing homes can be reduced, so that although the treatment costs money up front, it saves in the long-term and also improves quality-of-life. The work has contributed to changing stroke patient policy in the Belfast Trust as well as enhancing patient quality-of-life. It is applicable throughout the UK and beyond.

2. Underpinning research (indicative maximum 500 words)

Stroke disease places a heavy burden on society, incurring long periods of hospital and community care, with associated costs. Stroke is also highly complex with diverse outcomes and multiple strategies for therapy and care. McClean (who has been at Ulster since 1971, initially as a Research Assistant, and currently Professor of Mathematics) and co-researchers at Ulster have developed a mathematical modelling framework [1, 2] that classifies patients with respect to their length of stay. Class-specific patient flows are then characterised, and multiple outcomes, such as discharge to home, nursing home, or death, are modelled.

The underpinning research has been on-going for over 20 years:

- In the 1990's, original work on using phase-type models for patient pathways was carried out by McClean in collaboration with Professor Peter Millard (formerly Professor and now Emeritus Professor of Geriatric Medicine, St. George's, London; former President of the British Geriatric Society; and former Visiting Professor at Ulster). Two PhD students supervised by McClean were also key team members: Gordon Taylor [6] (01/94-12/96), now Reader in Medical Statistics at Bath University, and Adele Marshall [4] (10/97-09/01), now Professor of Statistics at Queen's University Belfast.
- Bed Occupancy and Modelling Software was developed and marketed to the NHS and beyond in the 1990's, incorporating work of McClean, Millard and Professor Gary Harrison (College of Charlston, USA).
- More recently (mid-2000's), to quote Professor Millard: "The phase-type models which you (McClean) developed previously have been incorporated by myself and Professor Thierry Chaussalet (Westminster University) into a modelling tool, initially for the London Merton Borough Social Services to cost and plan care provision and later also used by other Social Services in England".
- Since 2007, the model has been extended for use with stroke services in collaboration with Dr Ken Fullerton (Belfast Health and Social Care Trust) and colleagues. A PhD student supervised by McClean, Lalit Garg (10/06-03/11), now Lecturer at University of Malta, was a key team member [1, 2, 5]. In addition, a software tool for capacity planning has been developed.

The approach has used data on nearly 10,000 patients, collected from hospital databases and matched to social services databases to form a view of patient behaviour across the integrated care system [3]. The methodology has a strong mathematical underpinning, based on Markov models and phase-type survival distributions [1-6]. This research has also been supported by a number of prestigious collaborative grants, principally the RIGHT and MATCH projects, both funded by EPSRC.

The phase-type Markov model developed at Ulster for patient flow through care pathways, including phases in hospital, social services and community care, was extended in collaboration with Dr Ken Fullerton and colleagues from the Belfast City Hospital Stroke Unit, thus pioneering an

integrated probabilistic model of patient flow, with associated costs and quality-of-life metrics [1, 2]. Based on stroke patients' data from the Belfast City Hospital, various scenarios have been explored to compare the costs and patient quality-of-life for thrombolysis (clot-busting) under different regimes. Our results have shown that increasing thrombolysis participation from 10% to 50% of eligible patients can reduce cost as well as improving overall patient quality-of-life [5].

3. References to the research (indicative maximum of six references)

* *References that best indicate the quality of the underpinning research*.

[1] * Garg L, McClean SI, Meenan BJ, Barton M, Fullerton K (2012). A Phase-type Survival Tree-based Approach to aid Intelligent Patient Management and Healthcare Resource Planning Decisions. *IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans*, vol. 42, no. 6, pp. 1332-1345.
DOI: 10.1109/TSMCA.2012.2210211
[***This paper is included as an output in the current REF submission.***]

[2] * McClean SI, Barton M, Garg L, Fullerton K (2011). A Modeling Framework that Combines Markov Models and Discrete-event Simulation for Stroke Patient Care. *ACM Transactions on Modeling and Computer Simulation*, vol. 21, no. 4: Article No. 25.
DOI: 10.1145/2000494.2000498
[***This paper is included as an output in the current REF submission.***]

[3] McClean, SI, Millard, PH (2006). Where to Treat the Older Patient? Can Markov Models help us Better Understand the Relationship between Hospital and Community Care? *Journal of the Operational Research Society*, vol. 58, no. 2, pp. 255-261.
http://www.palgrave-journals.com/jors/journal/v58/n2/abs/2602173a.html

[4] Marshall AH, McClean SI (2004). Conditional Phase-type Distributions for Modelling Patient Length of Stay in Hospital. *International Transactions in Operational Research*, vol. 10, no. 6, pp. 565-576.
DOI: 10.1111/1475-3995.00428

[5] Barton M, McClean SI, Gillespie J, Garg L, Wilson D, Fullerton K (2012). Is it Beneficial to Increase the Provision of Thrombolysis? – A Discrete-event Simulation Model. *QJM*, Oxford Journals, vol. 105, no. 7, pp. 665-673.
DOI: 10.1093/qjmed/hcs036

[6] * Taylor GJ, McClean SI, Millard PH (2000). Stochastic Models of Geriatric Patient Bed Occupancy Behaviour. *Journal of the Royal Statistical Society, Series A*, vol. 163, no.1, pp. 39-48.
DOI: 10.1111/1467-985X.00155

Key Grants

Project: Research into Global Healthcare Tools (RIGHT)
Funder: R&D Office HPSS £266,431 (to Ulster)
Dates: 01/10/2007 - 30/09/2010
Ulster grant-holder: McClean

Project: Research into Global Healthcare Tools (RIGHT)
Funder: EPSRC (EP/E019900/1) £11,542 (to Ulster)
Dates: 01/04/2007 - 31/03/2009
Ulster grant-holder: McClean
Total project funding: £1,135,688 (Brunel, Cambridge, Cardiff, Southampton Ulster Universities)

Project: Innovation Leaders
Funder: HSC R&D Office £12,122 (to Ulster)
Dates: 01/02/2009 - 31/07/2011
Ulster grant-holder: McClean

Project: Multidisciplinary Assessment of Technology Centre for Healthcare (MATCH)
Funder: EPSRC (EP/F063822/1) £1,484,858 (to Ulster)
Dates: 03/11/2008 - 02/11/2013
Ulster grant-holders: Meenan, McClean, Dixon
Total project funding: £ 6,760,671 (Brunel, Birmingham, Nottingham and Ulster Universities)

4. Details of the impact (indicative maximum 750 words)

It has become increasingly important that the provision of healthcare should be patient-centred and deal with the entire episode of patient healthcare rather than specific elements of the pathway, e.g. emergency care or particular patient groups or pathologies. This is a difficult task as patients can take numerous diverse pathways through a healthcare facility or system, depending on their needs. Also, with increasing budget cuts, a cost-effective service is essential. The multi-phase modelling approach to pathway management developed at Ulster enables detailed analysis of both the specific elements of a patient pathway, and its overall impact on cost, patient quality of life, and clinical outcome. This research has contributed to the Belfast Health and Social Care Trust making changes to practice and policy for stroke patient management, and is applicable similarly throughout the UK:

- **Impact on public policy and services:** policy decisions have been informed by our research evidence, namely the reorganisation of acute stroke services in Northern Ireland to provide larger centres.
- **Health impacts:** for appropriate stroke patients, health outcomes have, therefore, been improved, while for others quality-of-life has been enhanced since larger centres mean better coverage and more expertise.

In particular, to cite Dr Y [E3], Associate Medical Director for Unscheduled Care in the Belfast Health and Social Care Trust, "The modelling work (McClean) has undertaken for us has been very helpful in several ways:

- In respect of stroke thrombolysis it has demonstrated the value in terms of better outcomes and reduced cost of significantly increasing the proportion of stroke patients' thrombolysis. The reduced costs are associated with less disability, less need for rehabilitation and less likelihood of institutional care.
- In terms of supported stroke discharge, you (McClean) have clearly demonstrated further potential gains if we accelerate our moves towards earlier discharges.
- The modelling has also shown that our change of model in the community schemes with relatively more input from trained rehabilitation assistants makes the schemes accessible to greater numbers of patients at substantially reduced costs per case, but with better outcomes.
- The models have attracted interest at the highest level in the Northern Ireland Department of Health and Social Care".

Regarding significance, Dr Y [E3] says that "our use of mathematical modelling and simulation techniques, based on real-world data, to consider the effects of proposed changes before they are put in place" has allowed the service "to confidently and rapidly expand our thrombolysis rates" with "consequent impact on healthcare budgets and patient quality-of-life". "The work on stroke thrombolysis provides better long term outcomes, whilst at the same time offers modest economic benefits". As a result, to quote Dr Z [E4] (Consultant Physician, Belfast Trust): "better public awareness, better health care professional awareness and more robust systems of delivery have led to increased provision across the UK."

Dr Y [E3] is also convinced that "the modelling techniques (we) have previously employed will become vital tools enabling us to consider the likely effects, whether beneficial or harmful, which our proposed changes may bring about, both in terms of patient outcome and in terms of the health economy."

In more general terms, to quote Professor X [E2], former Consultant Physician, St. George's, London, "following the seminal mathematical work of (McClean) and Gary Harrison, a small world-wide group of collaborators have developed, refined, and validated decision support tools which measure, model and describe the process of care". While the current impact has focussed on modelling stroke patient behaviour, the underpinning research has substantial potential to influence other healthcare areas. To quote Professor W [E1], consortium PI of both the RIGHT and MATCH projects, "Professor's McClean's research under MATCH and RIGHT has helped to establish the role that management science plays in care delivery, and provided an excellent backdrop to the more operational studies undertaken on these programmes." "Since July 2010, Professor McClean has been a key member of another community taking simulation and modelling out into the wider arena of healthcare delivery - the Cumberland Initiative (www.cumberland-initiative.org). Sally (McClean) has been instrumental in bringing The University of Ulster to the core of this outreach, and we are now in danger of being highly successful, with a national centre about to be launched."

Whilst both RIGHT (Brunel, Cambridge, Cardiff, Southampton, Ulster) and MATCH (Brunel, Birmingham, Nottingham, Ulster) are consortia-led projects, the work described here was carried out as an exemplar in RIGHT and as a research strand of MATCH and is solely the work of the Ulster team. Ken Fullerton, David Wilson and Peter Millard are healthcare contributors to the work.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Factual statements already provided by key users/beneficiaries:

[E1] A factual statement in the form of a letter, provided by Professor W, consortium PI of both the RIGHT and MATCH projects, about the significance and reach of the impact.

[E2] A factual statement in the form of a letter, provided by Professor X, former Consultant Physician (now retired), St. George's, London, about the value of the decision support tools for analysing the process of care.

[E3] A factual statement in the form of a letter, provided by Dr Y, Associate Medical Director for Unscheduled Care, Belfast Health and Social Care Trust, about the impact of the research on stroke policies and patient care.

[E4] A factual statement in the form of an e-mail, provided by Dr Z, Consultant Physician, Belfast Health and Social Care Trust, about the impact of the research on stroke policies and patient care.