Climbing the mountain: Manna from heaven—multistage models


On the 23rd of June, an email from Gary Harrison, Prof of Mathematics at the College of Charleston, South Carolina, USA, brought manna from heaven. We first met in 1989 when I was on a mini sabbatical in Charleston. Coincidently, researching death on movement, we had confirmed an early observation made by Struthers in 1963 that an equation with two exponents describes the pattern of bed occupancy in departments of geriatrics with short stay and long stay patients.

Given the evidence Gary developed the first mathematical solution to a two compartment model of flow through departments of geriatric medicine. I well remember the time that I heard the first equation. Ac = Lv. Put simply. In a department of geriatric medicine with a constrained bed allocation, providing inpatient care for short stay and long stay patients, the conversion rate of short stay patients to long stay patients must equal the availability of beds in the long term care system. If Ac > Lv then the number of long stay patients increase and the number of beds available for short stay patients decrease. Vice versa, when Ac < Lv, admissions increase.

When Hurricane Hugo struck, our face to face collaboration ceased abruptly. However, ever since on one side of the Atlantic Gary in Charleston and Sally McClean in Northern Ireland, have step by step driven forward the development of deterministic models of care processes in health and social care systems.

Now 21 years after we first met, Gary in collaboration with Gabriel Escobar at the Kaiser Permanente Medical Care Program has developed a methodology, which shows that probability distributions are strongly influenced by the degree of physiological derangement on admission, pre-existing comorbidities, or a summary mortality risk combining these with age, sex, and diagnosis.

The data concerns the length of stay of 317,876 hospitalisations between 1st May 2003 and the 30th April 2005. 5/1/03 through 4/30/05 to the 17 hospitals in the Northern California KPMCP, serving 3.3 million members: 3.5% of admissions ended in death. The multistage mathematical model assumes that patients require varying degrees of treatment, with some patients going through more phases of inpatient care. Mathematically, the stages represent transitions in the healing process of the patient and not physical location in the hospital.

Multistage models describe the shape of the entire LOS distribution and how it is affected by initial patient characteristics. Skewed distributions and extreme outliers are not a problem, they were designed for it.

For pneumonia patients, the greater severity of illness changes the most frequent changes the most frequent LOS only slightly, but makes the distribution much more dispersed. And as the table shows, as in geriatrics so in general medicine small numbers make big differences. Simply put the longer you are in a clinical service the longer you will stay. Moreover, considering the big picture, early discharge, far from being a goal to aim for may be a false economy and a sub-optimal approach to inpatient care, even more so if one in ten come back.

References: P4 early evidence, Gary’s contribution and KPMCP, COPS and LAPS research

| Multistage model of resource use by 1000 pneumonia patients with high predicted mortality |
|------------------------------------------|-----------------|--------------|--------------|------------------|
|                                           | Percent in phase | Time in phase | Bed days | Resources used (%) |
| Stage One                                | 100%            | 0.28 days    | 280       | 3.6%             |
| Stage Two                                | 98.3%           | 1.28 days    | 1258.2    | 16.4%            |
| Stage Three                              | 88.5%           | 5.72 days    | 5060.3    | 65.8%            |
| Stage Four                               | 2.9%            | 37.03 days   | 1081.3    | 14.0%            |

Editor’s comment.
Collaboration with the clinicians in the University College Hospital Neonatal Service underpins this research. Changing patterns of parental behaviour, socially postponing birth to convenient times, and increasing use of artificial insemination, coupled with increasing technical skills in clinical care create the need. The question then becomes how, when, and where should facilities be developed to meet the need.

Abstract. Capacity planning in the neonatal health care system has become a major issue in the UK, since admission rejection in neonatal units has increased over past years due to capacity shortage. The thesis builds a capacity planning model for a perinatal network, based on admission rejection probability, with specific application to the North Central London Perinatal Network (NCLPN).

First, a decomposition method has been performed to obtain steady state behaviour for a perinatal network due to higher dimensionality and complex transfers and back transfers. Then, a standard Erlang loss model has been applied to all neonatal units in the network. Since the model cannot capture overflow, an overflow loss network framework has been developed capturing the actual patient flow in the perinatal network.

The steady state expressions for overflow and rejection probabilities have been derived for each neonatal unit of the network. Using the model, decisions on number of cots can be made for specific levels of admission rejection probability for each level of care at each neonatal unit of the network and specific levels of overflow to temporary care.

The overflow model framework assumes that inter-arrival and LoS in the neonatal units are Markovian which might be impractical occasionally. Therefore, a generalised model framework has been derived, which is based on a two moment approximation, mean and variance of the inter-arrival and LoS.

Finally a simulation model has been developed to check the consistency of analytical results derived via the decomposition method. We believe the model developed in this thesis would help on planning capacity for neonatal units in the perinatal networks.

The model framework should be of great interest to the Department of Health (DH), perinatal network managers, clinicians, health service planners and researchers.

Length of stay and imminent discharge probability distributions from multi stage models: variation by diag

(c) Rejection probability against arrival rate and (d) Rejection probability against number of cots at SCBU-TC

PS. Asad has now returned to Bangladesh. We wish him well and every success in his research and teaching career. It was a pleasure and a privilege to know him and to witness his determination to succeed.

Chronic morbidities were not associated with in-hospital mortality, age 85 years or older and several acute conditions, but not chronic morbidities, predicted in-hospital mortality.


Significant problems in health care, such as access block and long waiting lists for elective surgery, have led to calls for keeping hospital occupancy at no more than 85%. It is elementary queueing theory that a finite-capacity system with variable demand cannot sustain both full utilisation and full availability. However, the statement that there is a single level of ideal or safe occupancy suitable for all situations is a simplistic interpretation and application of the underlying science. We argue that specific study and action are necessary to understand and deal with the problems of long waiting lists and access block in any given health care facility.


Detailed information on the operative session, the team, and the patient substantially improves the prediction of OR times, but the surgeon's estimate remains important. The prediction model may be used in OR scheduling.


Distinguishing three types of genericity and identifying 24 important features of models and the associated modelling process. Many features are common across model types, but there are also important distinctions, with implications for model development.


Predictive models that use a few key risk factors are comparable to the full models and may offer a clinically applicable strategy.


Escobar supporting papers

**Risk adjusting community-acquired pneumonia hospital outcomes using automated databases**


America Abbreviated Fine Severity Score (AFSS), 6147 hospitalised with community-acquired pneumonia in all Provide clinically relevant risk-adjusted outcomes reports to clinicians in an integrated healthcare delivery system. Concludes It is possible to apply risk-adjustment methods from research settings to operational ones.

**Risk-adjusting hospital inpatient mortality using automated inpatient, outpatient, and laboratory databases**


America. Logistic regression. Data 50% random sample of 259,699 admissions to 17 hospitals. Inpatient mortality 3.50%; 30-day mortality 4.06%; Develops a risk-adjustment methodology that maximizes the use of automated physiology and diagnosis data from the time period preceding hospitalization. Final model includes sex, age, admission type, admission diagnosis, a Laboratory-based Acute Physiology Score (LAPS), and a COmorbidity Point Score (COPS). Best model forecasting 30 day mortality c statistic 0.88

Harrison References 1991—2005

**Balancing acute and long-term care: the mathematics of throughput in departments of geriatric medicine**


**Modelling hospital and social care bed occupancy and use by elderly people in an English health district**


**Implications of mixed exponential occupancy distributions and patient flow models for health care planning**


**Mathematical modelling: how and why**


**Modelling variability in hospital bed occupancy**


First report that exponential equations fit bed census data


**Throughput in a department of geriatric medicine: a problem of time, space and behaviour**

UK
‘Optimization' stream at the OR52 Conference, Royal Holloway University of London, UK, September 7-9, 2010:  http://www.orsoc.org.uk/orshop/

POLAND
MI&E’10 Workshop on Medical Informatics and Engineering
At International Multiconference on Computer Science and Information Technology (IMCSIT), Wisla, Poland, October 18-20, 2010 http://mie2010.imcsit.org visit the MI&E’10 web site at http://www.imcsit.org/pg/319/259

Australia
IEEE CBMS 2010 IEEE CBMS 2010
23rd IEEE International Symposium on Computer-Based Medical Systems 2010
Perth, Australia, 12-15 October 2010

Stop Press  Congratulations to Shola Ademi in Thierry Chaussalet’s Group at University of Westminster. His submission for the Society's PhD Prize or 2009 has been shortlisted as one of the three winners (one winner and two runners-up). The announcement of the winner will be made at the Society's Annual Conference (OR52). Society's Annual Conference (OR52).

Nosokinetics News on MASHNET web site http://mashnet.info/resources/ The UK Network for Modelling & Simulation in Healthcare. Further details in next newsletter

Nosokinetics News is the newsletter of the UK Nosokinetics Group
Nosokinetics is the science / subject of measuring and modelling flow through health and social care systems. From the Greek, literally, noso (sickness) and kinetics (movement).
The group collaborates to organise conferences and disseminates news of our and others research and practical use of modelling to enhance decision making in health and social care systems.

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