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Modelling and heart patients

Staff at the Cardio-thoracic and Vascular Intensive Care Unit (ICU) of Auckland City Hospital have found a mathematical model of the unit's operation valuable in improving its efficiency. Jenny Rankine reports.

Unit clinical director Dr Andrew McKee says juggling staffing, theatre availability and beds is complex; "it's hard to match the resources to the demand".

A chance conference meeting in 2006 started a collaboration between statistician Dr Ilze Ziedins, above, Masters student William Chen (below) and unit staff on a queuing model that could simulate the effects of operational changes on patient numbers. Associate Professor Ross Ihaka co-supervised Chen's Master's thesis, and advised on constructing the simulation and other aspects of the project.

At the time, the unit admitted around 22 patients a week, some for elective surgery and others with acute problems needing intensive care. "The bottleneck was the intensive care unit," says Ziedins. "Around half the patients stay for a day or less, some stay for much longer. We modelled the flow of scheduled elective and other patients into the unit, with random acute arrivals and lengths of stay, simulating 24 hours and seven days a week."

The model gradually became more complicated, taking into account the cluster of arrivals around midday and after 4pm after surgery, variations by day of the week and different kinds of patients. "Since arrival rates change over the duration of a patient's stay, traditional queueing models are not helpful, and new analytical models will need to be developed," says Ziedins.

Chen wrote the simulation programme from scratch using the statistical software R (see IMAGes 3). Each simulation run was for a year of the model's operation, and this was repeated several times to obtain confidence intervals for measures such as the average number of cancellations. The initial aims were to reduce waiting times, and cancellations of elective surgery due to the arrival of people with acute problems. "The model demonstrated that we needed more staffed ICU beds to match operating theatre capacity," says McKee. "We had an average of nine and needed 12 to manage our expected number of patients."

Having an external analysis independent of clinical pressures was a powerful argument for more staff, he says. The unit now has a higher allocated staffing level, although the international shortage of clinical staff has meant not all the positions have been filled.

The aim then shifted to matching the nursing roster with the patient load. "We're working on that now using a stochastic optimisation model," says Ziedins. As rosters are done three months in advance, the evaluation cannot start until the current roster ends in mid-November. "We think improvements can be made; they may be able to treat one or two more patients a week, which is substantial over a year."

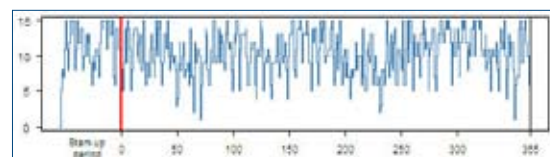
"The whole unit has been very interested," says Ziedins. "Up to 20 people have turned up for presentations; the input from them is wonderful."

"We can use the model to analyse our patterns of work," says McKee. "For example,

we can see if it would make any difference to patient throughput if we could discharge all the patients back to the ward an hour earlier after surgery."

Queueing theory is often used to analyse phone, internet and road networks, as well as customer services such as banking. "Once you think about life, almost everything starts to look like a queue," says Ziedins. It's the randomness that's important. Reducing variability can have a marked effect on how systems perform. For example, lights on Auckland motorway on ramps reduce clumping and make traffic flow less congested."

"I find this project so rewarding because it has been an opportunity to make a difference - some people might receive treatment earlier as a result," she says.



Above: The number out of 15 beds occupied overnight for a single simulation run over a year.

$$e^{-\lambda/\mu} \frac{(\lambda/\mu)^n}{n!}$$