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MOVING FROM SPECIFIC TO GENERIC: GENERIC MODELLING IN HEALTH CARE

"All generalizations are dangerous, even this one."
Alexandre Dumas (1802-1870)

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EXTENDED ABSTRACT

1 INTRODUCTION

Most simulation studies in the health care domain are aimed at solving specific problems in particular health care facilities. The commonalities in these studies are their objectives of improving performance such as reducing waiting times or using resources more efficiently. Because they are specific, these studies guide a modeller how a specific problem can be solved.

In this paper, we discuss the development of a generic whole hospital simulation model that can be used by general hospitals in England to understand how waiting time performance is affected by various factors. The National Health Service (NHS) in the UK has a performance assessment framework that includes waiting time targets for various stages of health care provision in hospitals. We present initial outcomes of a project, District General Hospital Performance Simulation (DGHPSim) which aims to build generic hospital models with sufficient detail for this purpose. Here, the term "Generic" means that the model has a defined structure with probability distributions that can be parameterized by the user.

2 RELATED LITERATURE

The literature has very few examples of generic simulation models in health care. Most papers focus on specific parts of hospitals, especially A&E departments and out-patient clinics. Fletcher et al (2006) discusses the development of a generic A&E department simulation model for use by various A&Es in England, pointing out the difficulty of generic modelling. Sinreich and Marmor (2004) attempt some generalisations of four Emergency Departments in Israel. They used sophisticated mathematical techniques to find out similarities of the processes in these departments and suggest a metric: the "similarity measure". Paul and Kuljis (1995) presents a generic outpatient clinics model, CLINSIM, that was built for UK Department of Health. It simulates how operating policy can influence patient waiting times. The model has been used successfully by a number of clinics in UK, though is not in current use, probably because of the difficulties in providing support to new users. Another example of generic modelling in healthcare is Proudlove et al (2007), which reports a simple Excel based simulation tool to specifically assess the effect of Day of Week (DoW) and Time of Day (ToD) changes in emergency admission on in-patient occupancy. The model is based on data from two hospitals' that was used to analyze DoW and ToD patterns of occupancy. Pitt (1997) is one of the very few examples of generic whole hospital simulations. He anticipated three notions to generalize hospital simulations; a simulation engine supported by a modeling methodology to develop models of hospital units, a generalized user interface to display and control key parameters of a simulation model, and a database to populate models and to link the interface with the model. This study specifically focuses on interactivity of models with users.

One very recent study in this field is reported in Fletcher and Worthington (2007), which surveys 20 experts in the field and 350 papers in the literature to identify differences between generic and specific models in healthcare. They suggest four levels of models according to their 'genericity' based on their abstraction and transportability.

- generic principle models,
- generic framework models,
- setting-specific generic models,
- setting specific models.

Their literature survey revealed that no clear design differences and surprising amount of similarities exist between generic and specific models.

In a sense, the technical issues to be faced in the development of generic models for the improvement in healthcare systems is no different from that in other domains such as manufacturing. Pidd (1992a, 1992b) discusses some of these issues, though using earlier generations of computer software. These issues also relate to those faced in almost any modeling exercise in OR/MS, as discussed in Pidd (2004) and in Powell (1995).

3 WHOLE HOSPITAL MODELLING

3.1 Understanding performance targets in healthcare

The demand for healthcare seems to be insatiable and healthcare provision is rationed in all countries. When healthcare is provided by the free market, it is rationed by price – the poor and uninsured get less and possibly worse healthcare than the rich or the insured. In others, particularly when provided through taxation, healthcare is rationed by limiting capacity, leading to waits for healthcare than can sometimes be rather long. In the UK, most healthcare is provided by the National Health Service (NHS) and is free at the point of need, though financed through taxation. As is widely know, much inpatient NHS care is rationed by waiting lists that had grown much too long by the mid-1990s. The incoming Labour government in 1997 made it a priority to reduce these waiting times and waiting lists and instituted a policy based on targets. Healthcare providers that met these targets were rewarded and those who failed to do so were penalised.

The ongoing DGHPSim project is funded by EPSRC and aims to understand what action healthcare providers must take to meet these targets and also to appreciate what, if any, distortions, these targets introduce. The basic idea is to develop a generic whole-hospital simulation model that could be populated by data specific to a particular hospital to investigate the targets and their effects in that hospital. Hospitals are very complicated institutions and so the question of conceptual modelling looms large in this research. However, unlike the police work discussed earlier, there is no clear client group with whom to work to develop this conceptualisation. In such a situation, it is important to generate a group of committed stakeholders who can act as a proxy for a client group. Perhaps inevitably, such stakeholders may wish to use such a model to answer different questions that suit their own interests.

At its simplest, a general hospital is an input:output system at which patients arrive, some according to an admissions schedule and others as emergencies. At the hospital, they receive treatment and remain there, consuming resources until discharge or, sometimes, death. However, things are of course much more complicated in practice, since the hospital will offer multiple specialties and treatments. Viewed as an input:output system, waiting times can be reduced either by demand management (diverting patients to other healthcare providers), adding capacity, or increasing throughput by using existing capacity more effectively. If the effect of government targets on hospitals is to be assessed, what form of conceptual model is needed. In this, two basic questions loom large.

- What elements should be included in the model and at what level of detail? A hospital, or even a single clinic, could be modelled in great detail by trying to represent all staff, everything that these staff do, all equipment and all its uses, and all patients and that is done to them. However, such a model would run extremely slowly and would take a huge resource to develop. By the time that it was finished, it is likely that the real world will have moved on. That is, the conceptualisation needs to be done in the light of the experimental frame and the available data.
- What relationships between elements should be included in the model? In a congested system with constrained resources, both of which apply to most general hospitals, there are bound to be important relationships between system elements. As with the question of the inclusion and exclusion of elements, the decision about which relationships to include is not straightforward. For example, many hospitals have an Accident and Emergency (A&E) Department that offers immediate treatment and also serves as a gate-way for emergency admissions. One important relationship to be considered is the link between A&E activity and those admissions. However, it would be a mistake to assume that this requires a detailed model of A&E activities; it may be enough to know that x% of A&E demand results in inpatient admissions.

3.2 Model conceptualization in DGHPSim

DGHPSim is a research project that aims to develop a generic whole hospital simulation model for use in examining the performance regime in the UK National Health Service. Much of the effort in this research project has centred around a search for the appropriate level of abstraction. At the highest level, a hospital can be simplified as an input-output system. However the inputs must be elaborated because the main streams of patients, emergency and elective, follow complex stages before being admitted. A high level conceptualisation of a hospital is presented in Figure 1.

Each rectangle in Figure 1 represents a sub model which can run independently or with the others. Clouds represent stochastic patient demand. A patient can be admitted to a hospital as either an emergency or an elective. Emergencies arrive either through an A&E department or direct from a General Practitioner's (GP) referral. GPs can also refer patients to a specialist clinic as out-patient. Some outpatients need surgery, which requires an admission either as day-case or non-day-case.

The NHS Performance measurement framework measures the delays that occur within and after A&E departments, and before and after out-patient clinics. Therefore we required sub models of A&E and Out-patient Clinics and must elaborate the inputs to the hospital. The inpatient

(Hospital) model, is mainly concerned with bed management, which is important because emergency and elective patients consume beds from the same pool, although some hospitals keep their elective beds separate. Variability in length of stay (LoS) makes bed planning complicated.

We worked with a pilot hospital in England and built the first sub-model for its A&E department. The inputs are number of patients expected by the department, service time distribution parameters of doctors and nurses, bed capacity parameters, and arrival patterns by day of week and time of day. In this work, one of our findings is the multi-tasking behaviour of medical staff, which we represent using a technique which we call "mini-doctors". This technique is especially useful when detailed data for doctors' activities are not available (Gunal and Pidd, 2006).

The second sub-model, for outpatients, uses the planned demand which is assumed to be more predictive than the emergency demand. Outpatient clinics are the main sources of elective patients. This model takes patient pathways from primary care stage into the out-patient stage. Patients may require more than one clinic and some patients require admission. Having a constrained model is problematic and we faced some challenges in generalizing processes.

The third sub-model intends to capture the complex nature of bed management within a hospital and flows of patients from and to patient wards. Different OR techniques have been used to predict bed occupancy. We choose a conventional approach using routing probabilities and "Ward Transition Matrices". We use stationary length of stay distributions for patients' duration on wards. For long tail distributions such as for Intensive Care Unit (ICU) and for elderly wards, we use hyper-exponential distributions.

For the validation of the sub-models, we adopted a black-box approach and compared model outputs with hospital performance figures. We observed good fits mainly because we estimated LoS distributions parameters, transition probabilities, and demand patterns by using the hospital's information system.

4 GENERIC PROCESSES AND PARAMETERS

In the DGHPSim project we considered two approaches to generalize our models; first, identifying common processes for the three sub-models, and secondly, the use of common types of parameters to these processes.

The first sub-model reflects the processes in a typical A&E. The Healthcare Commission (2005) reveals that patients in A&E follow a sequence of processes such as arrival, registration, initial assessment (or triage), branching for tests, second assessment on decision, and discharge. In a simulation model, types of parameters of these processes can also be generalized: for example, hourly arrival rates for ambulance and walk-in patients, process times and staff needs of triage, process times and staff needs of initial assessment, branching probabilities to tests etc. Obviously, the parameter values of these processes change in different A&Es and hence producing different performances. This sub-model is discussed in more detail in Gunal and Pidd (2006).

The second sub-model (outpatients) is harder to generalize for two main reasons. First, the types of clinics offered to patients varies in each specialty. The main constraint in an outpatient system is the clinic appointments which are offered by specialists. Every specialist has his/her own schedule in which some of their time is dedicated to out-patient clinics. A typical clinic lasts 3 and a half hours, and patients are assigned to slots according to a booking mechanism. There are three types of appointments; First time referrals, follow-ups before operation, and follow-ups after operation. Some specialties can have other types of clinic appointments regarding specific types of treatment, such as fracture clinics for emergency orthopedic patients, special ointment clinics for dermatology patients, audio-test clinics for ENT patients etc. The time allocated for each type of clinic varies and therefore the number of patients that can be seen also varies. In addition, consultants prioritize different types of patients differently.

The second problem in generalizing out-patient processes is that consultants generally keep their own waiting lists. For one specialty of one hospital, this may be possible to model. However thinking for other specialties and a whole hospital, adding this detail increases the level of complexity dramatically. Hence we are pursuing a simplified representation of individual consultant lists in our model. These two problems when modeling outpatient clinics and their effects on the rest of a hospital suggests that a family of generic models may be needed, these being (to some extent) specialty specific. The approaches taken in models such as CLINSIM (Paul and Kuljis, 1995), which focus only on patient waiting times at a clinic, will not work for the types of model needed in the DGHPSim project.

The third sub-model, the in-patient model, in a sense is the easiest to generalize its processes. In essence it is a simple input-output system; patients are admitted to a ward, stay there for some random time and then they are discharged. In addition, some patients may be transferred between wards during their stay. Correct classification of patient is crucial in determining the duration of stay of patients and the routing probabilities between wards. Routing probabilities for NHS hospitals in the UK can be derived from the Health Episode Statistics (HES) Data that is collected for all hospitals and includes data on each and every inpatient episode for each year. Using this, we classify patients by specialty, the top level classification and derive routing probabilities. There are, of course, lower level classifications than specialty, such as patients who require a specific type of operation or treatment, but this may not be necessary in the DGHPSim models.

Both the A&E sub-models and outpatient sub-models generate patients who may be admitted as inpatients. However, it may not be necessary to have a detailed, patient-by-patient simulation of A&E. Instead, it may be just as useful to generate inpatient admissions from A&E by a sampling process if the arrival rates and probabilities of admission from A&E are known. However, it is necessary to simulate outpatient interactions on an individual patient basis, since the NHS Performance Framework includes maximum delay targets from referral to outpatients through to inpatient admission, if needed.

5 MODEL USE AND PARAMETERIZATION

The models are intended for use in operational and policy level analysis, to allow the identification of possible bottlenecks in a hospital. At policy level, the models can be run for different hospitals, hence the need for generic features. The generic models are made specific by providing parameter values.

As mentioned earlier, the NHS routinely collects data from hospitals every year and publishes these as the HES data. HES is actually two very detailed databases which include inpatient and outpatient episodes of all patients that a hospital has seen during the year. These two databases include almost every detail for a hospital for our models. We can work out, using these databases, LoS, transition probabilities, arrival volumes and patterns, number of outpatient clinics visited before an admission, number of referrals by specialty etc. As yet, these datasets do not include physical bed usage and diagnostic tests. Although it is not our main interest, detailed information of A&E patients are also not in HES.

Although HES databases tell us about the past, we can investigate possible problem areas of a hospital and ways of improving them. We can investigate if the problems are related with the lack of capacity and/or the lack of good management of the capacity. Experimentation with these models will also reveal that if the performance targets set by the NHS are feasible for the hospitals in England with their current capacity.

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