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O.R. Applications

Combining simulation and goal programming for healthcare planning in a medical assessment unit

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Abstract

This paper describes a detailed simulation model for healthcare planning in a medical assessment unit (MAU) of a general hospital belonging to the national health service (NHS), UK. The MAU is established to improve the quality of care given to acute medical patients on admission, and to provide the organisational means of rapid assessment and investigation in order to avoid unnecessary admissions. The simulation model enables different scenarios to be tested to eliminate bottlenecks in order to achieve optimal clinical workflow. The link between goal programming (GP) and simulation for efficient resource planning is explored. A GP model is developed for trade-off analysis of the results obtained from the simulation. The implications of MAU management preferences to various objectives are presented.

Keywords: Health service; Simulation; Goal programming; Resource management

1. Introduction

Operational research techniques such as simulation and goal programming (GP) have been used to analyse various healthcare delivery systems such as the study of NHS walk-in centres [2], accident and emergency departments and outpatient clinics [9], monitoring performance of surgeons [10], the deployment of health facilities [16], strategic resource allocation [4], planning and management of bed capacities [7] and the analysis of hospital waiting lists [1].

There has been an extensive amount of simulation applied to the healthcare sector in recent years. For instance, Eldabi et al. (EPY) [6] quote Royston [18] who finds over 3500 Google Scholar hits pertaining to the term 'Health Simulation' in the period 2000–2004. This is an approximate threefold increase on the previous five year period. Despite this growth EPY use the literature and expert opinion to make the claim that 'the immense potential of simulation has not yet been realized in practice'. Whilst analyzing the expert opinion to understand why this is the case, they highlight the need to mix modelling techniques more readily.

Medical assessment units (MAU's) have been set up in many acute healthcare trusts in the United Kingdom as the visible result of investment in acute medicine. Different aims and objectives have influenced the size, staffing and structure of the various units. MAU's act as a focal point for the rapid assessment of acutely ill medical patients referred to hospital by general practitioners or by the accidents and emergency departments (A&E) under agreed protocols [5]. The critically of an efficient post A&E patient flow framework is highlighted by Proudlove et al. (PBF) [15] who call for 'clear analysis and effective modelling... to disentangle flows to establish root causes of problems and demonstrate the effects of better management'.

There is a need to develop models to examine and understand the resource requirements of MAU's and to

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provide a framework or develop standards that hospital developers and clinical managers could consult.

Delays within MAU's stem from the unmatched number of patients' discharged to the number of incoming patients. There is an increase in the workload of doctors and nurses possibly caused by insufficient numbers to meet the demand for assessment. The number of unoccupied beds has a significant impact in patient delay. Patients waiting to be transferred to other hospital wards after their assessment cause bed blockage which in turn prevents new patients being admitted. For patients referred by general practitioners this can lead to ill and unstable patients waiting in their homes.

This research was initiated by the perception of clinicians that the MAU at Queen Alexandra Hospital (QAH) is improving patient care, but that it will be unable to cope with the predicted increase in workload. A comprehensive simulation model is developed and tested to determine optimal staffing requirements for the MAU and to minimise bottlenecks in the system to improve patient flow. A goal programming model is then built to analyse the results of the simulation from the multi-objective perspective of the hospital management. This study aims to unleash the potential of simulation in this situation by combining it with the multi-objective technique of goal programming. This allows the relative strengths of simulation (capturing and modelling patient flow) and goal programming (meeting multiple targets over a range of conflicting criteria) to be brought together in order to aid the hospital management in their decision making. The study in this paper also aims to work towards the PBF agenda in helping the hospital management to understand their patient flow and hence make more effective decisions.

2. Data collection for simulation

Data collection is one of the biggest tasks in solving a real problem, it is one of the most important and difficult problems in simulation and it provides the driving force for a simulation model [3]. The data used for the simulation could not be obtained from the database system of the MAU since it lacked detailed and specific information required for the simulation.

The interest was not solely in the type and number of resources on the MAU but also the various activities doctors and nurses are involved in and the average length of specific activities. Thus doctors and nurses were observed while performing their duties. Robinson describes three categories of data differentiated by two factors, availability and collectability [17]. The first category is a data that is available, secondly there are some data that is not available but collectable and finally some data are not available and not collectable. The type of data required for the simulation fell under the second category. It needed to be collected by observing doctors and nurses on the MAU and monitoring the time activities take on average to perform. See [13] for further information on the type and methods of data collection.

For data collection by observation, approval was obtained from the Local Research Ethics Committee. A fifty page application form was submitted to the Isle of Wight, Portsmouth and South East Hampshire Local Research Ethics Committee for consideration.

3. Model description

The simulation model is developed in Micro Saint, a visual interactive modelling system [12]. Through Micro Saint, useful information about processes that might be too expensive or time-consuming to test in the real world is gained. A version of the model network is shown in Fig. 1. The rectangular tasks are networks within which are various other tasks to be performed. The first network is a 'patient generator' network that generates two types of patients that are admitted to the MAU, (A&E and GP referral patients) all of whom go to the reception as shown in Fig. 2. The generation of patients from either A&E or GP follows an exponential distribution and there is usually a wait for a bed to become available in the MAU before patients are admitted. For the patients that are generated and moved to the reception, those requiring beds for the MAU length of stay (LoS) form about 95% of the total population, while those with no bed requirement except chairs make up the remaining 5%. Patients with bed requirements are assigned a bed before going through the reception, and the available bed numbers are decreased according to the numbers assigned. On completion of a patient's LoS or treatment, the patient is either transferred to other hospital ward or discharged home and the bed becomes available.

Patients can follow different paths in the model depending on were they are being routed to. Patients can either see a nurse or a doctor, a tactical decision based on the availability of doctors and nurses, however for 95% of the time patients are likely to see a nurse first. The stacks in front of each task are queues and shows when patients' wait for that task. Data from these waiting points is important and will be analysed to evaluate the system performance.

Patients that follow to see the nurse enter into the nurse clerking network, where the nurses clerks the patient and documents the diagnosis ready for the doctor. After the nurse clerking when it's determined that preliminary tests are needed immediately before the doctor sees the patient, tests are done on the patient. The patient then follows through to the TEST network. This tests generally involves taking blood samples from patients for investigation or performing ECG.

After patients have had their blood investigations requested and their ECG's done, they are then seen by any available junior doctor. Usually by the time the junior doctor is ready to attend to patient, the results from the investigations would be ready and this aids in the diagnosis of the patient's illness.