Practical Operations Research Applications for Healthcare Managers

Kiok Liang Teow,[1] *MSc (Industrial & Systems Engineering)*

Abstract

Operations research (OR) focuses on the application of analytical methods to facilitate better decision-making. Despite its usefulness and proliferation of papers in the academic literature, there are still major issues around getting OR models widely accepted and used as part of mainstream decision-making by clinicians, health managers and policy-makers. This article aims to raise the awareness of healthcare managers with regard to practical OR applications.

Ann Acad Med Singapore 2009;38:564-6

Key words: Decision-making, Healthcare, Operations Research

Introduction

Operations Research, also known as Operational Research (OR) or Management Science, existed as a scientific discipline since the 1930s. It is the discipline of applying appropriate analytical methods for decision making[1] such as simulation, and optimisation. Simulation gives one the ability to try out approaches and test ideas for improvement. Optimisation narrows choices to the very best when there are virtually innumerable feasible options and comparing them is difficult.[1] These techniques have been applied and proven in many industries under different names, for instance, Lean in manufacturing, Supply Chain in logistics, and Yield Management in airlines.

OR has been studied in healthcare settings since 1952.[2-4] Many OR papers on healthcare subjects have been published in both Operations Research and healthcare journals, including *Operations Research*, *Journal of the Operations Research Society*, *Management Science, INTERFACES, Healthcare Management Science, British Medical Journal*, *Clinical and Investigative Medicine, and Journal of Nursing Management.* The topics range from clinical areas such as choosing beams of radiation for intensity modulated radiotherapy treatment (IMRT) in the cancer treatment process,[5] simulation for public health,[6] to operations management such as resource utilisation and bed management.[7,8]

Despite the proliferation of papers in the academic literature, there are still major issues around getting OR models widely accepted and used as part of mainstream decision-making by clinicians, health managers and policy-makers.[4] Some possible reasons for this include[4, 9-11]:

i) Low levels of engineering/mathematical background in the healthcare sector
ii) OR scholarly papers written for OR professionals, focusing on specialised and technical topics, and not reaching healthcare professionals
iii) Lack of process-related data for modelling
iv) Lack of in-house OR expertise
v) High cost of engaging external OR consultants

Translation from theory to practice is never easy. In our local context, based on the published work, we feel that the awareness and usage of healthcare OR is probably lower compared to other developed countries. In addition, while OR may require a fair bit of mathematical background, OR is also about using 'common sense'.[12] Hence we suggest starting with low-hanging fruits: practical yet simple applications.

We hope to raise the awareness of OR by showcasing the following.

Application 1: Bed allocation by specialties

Problem: Overflow (i.e. patients lodging at another specialty) of patients in wards.

The demand of hospital's inpatient-beds by medical specialties changes according to patients' volume over time. With no adjustments to the allocation of beds, the growing mismatch will result in unnecessary patients' overflow. This will lead to poorer patient care, redundant

[1] Operations Research Specialist, Health Services & Outcomes Research, National Healthcare Group, Singapore
Address for Correspondence: Mr Teow Kiok Liang, National Healthcare Group, 6 Commonwealth Lane, GMTI Building #04-01/02. Singapore 149547.
Email: kiok_liang_teow@nhg.com.sg

travelling for healthcare workers and longer bed wait time. Hence, hospitals need to periodically review their bed allocation by specialties.

The bed reallocation exercise is typically a zero-sum game: some specialties will end up with more beds while others with fewer beds. This will need compelling justification. How can one perform this exercise in an objective manner? One outcome measurement is bed occupancy rate by specialty after re-distribution.

We can first establish bed demand for each specialty using patient-day. The exercise is to assign the beds (i.e. decision variables) such that the specialties will end up with equitable bed occupancy rates (i.e. outcome), subject to number of beds available (i.e. constraint). The structure of the problem is then clearly laid out and computation can be done with a spreadsheet.

Bed managers can fine-tune this first-cut allocation for specific specialties. For example, specialties with higher projected growth rates should be given more beds for their future needs. Paediatrics will also probably need more beds than 'average' as it does not share beds with other specialties.

Some literature considers more complicated factors, like waiting time and distance constraints.[13,14]

Application 2: Outpatient Appointment Scheduling

Problem: Long waiting time at outpatient clinics before consultation.

In Singapore, patients need to make an appointment for a specialist. In theory, an appointment system reduces patient waiting time. In practice, the waiting time can still be substantial.

Outpatient appointment scheduling in health care has been researched over the last 50 years. Various scheduling rules have been proposed in different research works.[15,16] A good appointment schedule is one that trade-offs patients' waiting time for clinics' overtime, constrained by the patient load and staffing. OR researchers use techniques such as queueing theory and discrete event simulation to propose various appointment strategies under different clinics' settings. Some of the appointment strategies can be very complex.

However, one simple guideline from these studies is to place cases with low variability of consult duration in the beginning of the session. The rationale is not to snowball the waiting time. Typically, first-visit patients have a higher variation in consult duration than follow-up patients. Hence the guideline suggests placing the follow-up patients in the beginning of the session. The clinics can further adjust this guideline according to their patients' characteristics, e.g., age and acuity.

Application 3: Queue design for stochastic demand

Problem: Queue management and design.

Another concept from OR (specifically, Queueing Theory) is "pooling reduces resources requirement" (or similarly pooling reduces waiting time). This principle says that given homogeneous demand and number of service providers, it is more efficient to pool the queue into a single waiting line, rather than multiple waiting lines.

An example of a multiple-queue system in healthcare is the division of wards by gender. The bed demand (patients) and supply (wards) are differentiated into 2 streams. Though the separation is necessary, bed managers know from experience that this often leads to lower utilisation of beds. Other examples include the setting up of satellite pharmacies (a small pharmacy to cater to a small group of patients), and dividing wards to subspecialties. Some may reason that there will be no impact to the queue since both demand and supply are reduced proportionally. However, it is known from Queuing Theory that the multiple-queue system is less efficient, and the waiting time will be longer. Hence if partitioning is needed, e.g. splitting of beds for infection control, administrators need to plan for additional resources to maintain the same waiting time.

Application 4: Health service capacity planning

Problem: Project infrastructure and manpower demand.

It is common for healthcare managers to project workload for physical infrastructure and manpower planning, for durations ranging from 1 to 20 years. This may be done at the department, hospital or even national level. A common method is to look at past trends, estimate the historical year-on-year growth, and extrapolate this growth rate to the future. However, there are 2 potential problems here. Firstly, we seldom see a definitive trend and the estimation of 'growth rate' is highly dependent upon the start and end points of the time intervals. Secondly, the assumption of a long-lasting trend is also unrealistic.

As healthcare utilisation is often closely related to age, a more robust way to project is to use population-based drivers. We can first derive the age-specific utilisation rate, which is the number of encounters (e.g. emergency or outpatient attendances, or hospital admissions) per population specific to each age-group (e.g. age 0 to14, 15 to 44, etc.). The trend of age-specific utilisation rates can be plotted to check for stability. In general, these rates have been found to be relatively stable. We have used this method and projected a substantial increase in inpatient demand due to our ageing population. Hence the number of beds needed for the future population can be estimated with more certainty.

Discussion

Several practical OR applications have been described in this paper. There are other healthcare areas where OR techniques will be useful, such as reducing delay in healthcare delivery, smoothing of elective admissions to reduce peak bed occupancy, and optimal deployment of ambulances.

Decision-making is complex especially when it involves a group of stakeholders. Using quantitative (OR) techniques and data help to present objective argument. Expert opinions, such as judgement on future healthcare disease burden, could then be used to fine-tune the quantitative models.

In our view, there is room for more OR work to be done in the healthcare settings. We hope this paper raises the awareness and adoption of OR applications amongst healthcare managers.

Acknowledgements

The author would like to thank the reviewers for their valuable comments, supervisor and colleagues for the inputs, and the various healthcare managers who shared their time and domain knowledge in the course of work.

REFERENCES

1. Institute for Operations Research and the Management Sciences (INFORMS). Operations Research: The Science of Better. Available at: http://www.scienceofbetter.org/what/index.htm. Accessed 7 April 2009.
2. Flagle CD. Some origins of operations research in the health services. Operations Res 2002;50:52-60.
3. Buhaug H. Long waiting lists in hospitals. BMJ 2002;324:252-3.
4. Brailsford S. Overcoming the barriers to implementation of operations research simulation models in healthcare. Clin Invest Med 2005;28: 312-5.
5. Holder A. Radiotherapy treatment design and linear programming. In: Brandeau ML, Sainfort F, Pierskalla WP, editors. Operations Research and Health Care: A Handbook of Methods and Applications. Kluwer Academic Publishers, 2004.
6. Fone D, Hollinghurst S, Temple M, Round A, Lester N, Weightman A, et al. Systematic review of the use and value of computer simulation modelling in population health and health care delivery. J Public Health Med 2003;25:325-35.
7. Revere L. Improving resource efficiency through management science. J Healthcare Manag 2004;49:323-33.
8. Proudlove N, Boaden R, Jorgensen J. Developing bed managers: the why and the how. J Nurs Manag 2007:15:34-42.
9. Butler TW. Management science/operations research projects in health care: the administrator's perspective. Health Care Manag Rev 1995;20: 19-25.
10. Blake JT. Shooting arrows in the dark: The policies and practices of waitlist management in Canada. Clin Invest Med 2005;28:308-11.
11. Proudlove NC, Black S, Fletcher A. OR and the challenge to improve the NHS: modelling for insight and improvement in in-patients flow. J Operations Res Soc 2007;58:145-58.
12. Crane AB. Management engineers: a scientific approach to pinpoint a hospital's problems and find common-sense solutions. Hosp Health Netw 2007;81:50-4.
13. Teow KL, Tan WS. Allocation of hospital beds in an existing hospital. JOL 2008;2;2.
14. Cochran JK Bharti A. Stochastic bed balancing of an obstetrics hospital. Health Care Manag Sci 2006;9:25-39.
15. Bailey N. A study of queues and appointment systems in hospital outpatient departments with special reference to waiting times. J Roy Statist Soc 1952;14185-99.
16. Cayirli T, Veral E, Rosen H. Designing appointment scheduling systems for ambulatory care services. Health Care Manage Sci 2006;9:47-58.