Management Science for Healthcare Applications

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INTRODUCTION

Modern medicine has achieved great progress in treating individual patients. However, according to the highly publicized report "Building a Better Delivery System: A New Engineering / Healthcare Partnership" (Reid et al., 2005), relatively little material resources and technical talent have been devoted to the proper functioning of the overall health care delivery as an integrated and economically sustainable system. This report provides strong convincing arguments that a big impact on quality, efficiency and sustainability of the health care system can be achieved by the systematic and widespread use of methods and principles of system engineering. The term 'system engineering' is frequently substituted by the terms: 'management science', 'operations research', 'management engineering', 'industrial engineering', 'business analytics' or 'operations management'.

The system boundaries can be defined at different levels (scales). For example, a healthcare system can be defined at the nationwide level; in this case, the main interdependent and connected elements of the system are separate hospitals and clinics, diagnostic imaging centers, insurance companies, and government bodies.

At a lower level, a system can be defined as a stand-alone hospital; in this case the main interdependent and connected elements of the system are hospital departments, such as emergency, surgical, intensive care, among others.

Management science methodology can be applied at all system levels (scales). However the specific method can be different depending on the system scale and complexity. For example, system dynamics that operates mostly with macro-level aggregated patient categories and large financial flows can be appropriate to analyzing the nationwide healthcare system and policy issues. On the other hand, a powerful method such as discrete event simulation that operates mostly with individual patients or documents, as entities, can be more appropriate to analyzing operations of the lower scale systems such as a separate hospital. Nonetheless, the separate hospital is itself a complex system, comprised of many interdependent departments and units.

The scope of healthcare management science/engineering can broadly be defined as developing managerial decisions for efficient allocating of material, human and financial resources needed for delivery of high quality care using various mathematical and computer simulation methods.

Given variable patient volumes and variable service/procedure time, management science methodology is indispensable in addressing management issues, such as:

- **Capacity:** How many beds, operating rooms or pieces of equipment are needed for different services?
- **Staffing:** How many nurses and other providers are needed for a particular shift in a unit?

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- **Scheduling:** How to optimally schedule the minimally required staff for the particular shifts?
- **Patient Flow:** What maximal patient delays at the various points of care are acceptable in order to achieve the system throughput goals?
- **Resource Allocation:** What minimal amount of resources is required for different patient service lines?
- **Forecasting:** How to predict the future patient demand or transaction volumes?
- **Comparing Productivity of Different Units with Multiple Inputs and Outputs:** How to combine different productivity metrics into one total score for each unit?
- **Optimizing a Supply Chain and Inventory Management:** How to manage the supply chain to minimize the total procurement cost?
- **Performing Predictive Statistical Data Analysis for Marketing and Budget Planning:** What business analytics and data mining technique to use?

This list can easily be extended to include any other area of operational management that requires quantitative analysis to justify managerial decision-making. Some quantitative techniques are summarized in this chapter in Table 1 'Summary of some quantitative methods used for various applications of management science'.

Using an analogy, the entire hospital/organization is a patient; management science is a medical field with different specialties; and the management scientist/engineer is a doctor who diagnoses the operational diseases and develops treatment plans for an ailing hospital /organization and its operations.

The intended readers of this chapter are primarily leaders of organizations and, particularly, hospital/clinic leaders who are trying to improve the efficiency of organization's/ hospital's operations using principles of business analytics and management science. Practice shows (Kolker, 2012-Preface; Compton et al., 2008) that a wide gap still exists between the number of publications that urge the use of business analytics and management science and the number of administrators who still have a vague idea of the practical value and impact of these quantitative methodologies on the bottom line of their organizations/hospitals. The main goal of this chapter is to contribute to filling this gap, and to increase awareness of what is possible by providing an overview of business analytics and management science methodology and summarizing some general principles that play for operations management the role of laws of physics in natural sciences.

BACKGROUND: TRADITIONAL MANAGEMENT AND MANAGEMENT SCIENCE

There are many possible definitions of management. Here management is defined as activities for controlling and leveraging the limited amount of available resources (material, financial and human) aimed at the best possible way of achieving system performance objectives. Traditional management is based on past experience, intuition, educated guesses, simple linear projections with the average values of input variables. In contrast, management science is based on comparative outcomes of validated mathematical models of systems and their operations. Although no formal definition can capture all aspects of the concept, it follows that management science typically includes the following elements (steps): (i) the goal that is clearly stated and measurable, (ii) identification of available resources that can be leveraged (allocated) in different ways, (iii) mathematical models (analytic or numeric computer algorithms) to quantitatively test outcomes (scenarios) for different ways of using resources, and consequences (especially unintended consequences) of the different use of resources before finalizing the decisions.

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