Modern medicine has achieved great progress in treating individual patients. This progress is based mainly on life science (molecular genetics, biophysics, biochemistry) and the development of medical devices, surgical techniques and imaging technologies. However, according to a report ‘Building a Better Delivery System: A New Engineering & Healthcare Partnership’ published jointly by National Academy of Engineering and Institute of Medicine in 2005, relatively little material resources or technical talent have been devoted to the proper functioning of the overall healthcare delivery as an integrated system in which access to efficient care should be delivered to many thousands of patients in an economically sustainable way.

As this report strongly points out in its Executive Summary, a real impact on quality, efficiency, and sustainability of the healthcare system can be achieved only by using methods and principles of healthcare delivery engineering. At the same time, this report states in an unusually blunt way, “In fact, relatively few healthcare professionals or administrators are equipped to think analytically about healthcare delivery as a system or to appreciate the relevance of engineering tools. Even fewer are equipped to work with engineers to apply these tools.”

Thus, it is often difficult for many administrators to appreciate the role of management engineering methodology to the healthcare delivery process analysis. On the other hand, engineering professionals do not always have enough knowledge of healthcare delivery processes or the role of the physicians in making management decisions. Healthcare has a culture of rigid division of labor. This functional division does not effectively support the methodology that crosses the functional areas, especially if it assumes significant change in traditional relationships.

A systematic way of developing managerial decisions for efficient allocating of material, human and financial resources needed for delivery of high quality care using quantitative methods is the scope of what is called healthcare management engineering.

It is now imperative for healthcare administrators and executives to become familiar with the quantitative decision-making techniques and tools offered by management engineering. Fixing the healthcare system requires decision-makers who are ‘bilingual’ both in hospital operations and in management and system engineering principles.

While there is much work to do, especially at the hospital level, some changes addressing the recommendations for the dissemination of management engineering and system thinking are already under way. There are some journal publications in which the role and importance of management engineering in developing efficient decisions is discussed. However, many of them lack concrete, specific examples of practical applications and decision-making methodology. Therefore these publications are somewhat declarative.
The objective of this book is to illustrate the powerful methodology for making predictive efficient managerial decisions in different areas of healthcare, as well as fundamental management engineering principles for healthcare settings.

The distinct feature of this book is that it provides an international exposure to this challenging area. Researchers and healthcare practitioners not only from U.S., but also from Australia, Singapore, Japan, Italy, and Spain have contributed to this book. Despite different models of care delivery in these countries, the international contributors demonstrate the power of healthcare management engineering and its use as a means of improving efficiency of care delivery and cost containment. These issues are not unique to U.S. healthcare, and highlighting international experience and approach is instructive.

Prospective audience for this book includes healthcare and clinic administrators, managers, directors, vice-presidents for improvement and chief operating officers, i.e. those stakeholders who have the power to make managerial decisions. Another perspective segment of readers are graduate students pursuing a Master of Business Administration (MBA) or Master of Public Health (MPH) programs. These students are on the forefront in developing and providing economically viable processes of healthcare delivery.

This book is organized in 5 sections.

Section 1, Efficient Managerial Decision-Making and Management of Operations, includes 9 chapters.

Chapter 1, Efficient Managerial Decision-Making in Healthcare Settings: Examples and Fundamental Principles, provides an overview of the overall domain of healthcare management engineering. Management engineering domain includes capacity management, staffing, scheduling, patient flow, probabilistic resource allocation, patient volume forecasting, techniques for reduction of the number of variables for large patient data bases, as well as optimization of the geographic location of facilities and facilities layout, engineering (design) of the facility optimized workflow, defining and measuring productivity, supply chain and inventory management, quality control techniques, advanced multivariate statistical data analysis for marketing and budgeting purposes.

Four types of problems are illustrated in particular in this chapter: (i) dynamic supply and demand balance using discrete event simulation, (ii) the probabilistic resource optimization, (iii) variables reduction technique for identifying a few significant contributing variables (factors), and (iv) the recursive forecasting of a time series. Traditional managerial decision-making and management engineering methodology are applied side by side to analyze the same problems in order to illustrate and explain their differences. Some fundamental management engineering principles are summarized in conclusion.

Chapter 2, Dynamic Capacity Management (DCAMM™) in a Hospital Setting, illustrates that hospitals are dynamic systems and must be analyzed and managed as such. Therefore, it is needed dynamic analytical tools and thinking to fix hospitals’ most pressing issues. Concepts such as “Dynamic Standardization” and “Outlier Management” can augment the existing, static process improvement methods such as Lean and Six Sigma. This chapter provides an overview of the concepts and structures necessary to profoundly change the way our hospitals, and health systems, are managed.

Chapter 3, Simulation Modeling of Healthcare Delivery, points out that healthcare has delivered incredible improvements in diagnosis and treatment of diseases but faces challenges to improve the delivery of services. This chapter reviews the current challenges and methods including the use of simulation modeling. Analysis of emergency patient flows through a major hospital shows the capability of simulation modeling to enable improvement of the healthcare delivery system. This chapter enables healthcare managers to understand the power simulation modeling brings to the improvement of healthcare delivery.
Chapter 4, *Simulation Applications in a Healthcare Setting*, will broaden the engineer’s perception in regards to the gamut of simulation implements. This ranges from paper-and-pencil and board-game reproductions of situations to complex computer-aided interactive systems. Some of the problem-solving models discussed include labor and delivery room utilization, neonatal intensive care unit expansion, emergency department staffing and process improvement, radiology process improvement, patient transport, operating room elective case surgery optimization, partial pediatric unit conversion to Intermediate Medical Care unit, family practice, and women’s health clinics.

Chapter 5, *Modeling Clinical Engineering Activities to Support Healthcare Technology Management*, discusses that in order to assure patient safety medical devices must be correctly managed and used, and that the quality of healthcare delivery is related to the suitability of the available technology. The activities that guarantee a proper management are carried on by the people working on a Clinical Engineering (CE) Department.

The chapter describes a model to estimate the number of clinical engineers and biomedical equipment technicians (BMET) that will constitute the clinical engineering department staff. It was used by managers of Regione Piemonte (Italy) to start a regional network of clinical engineering departments.

Chapter 6, *Intensive Care Unit Operational Modeling and Analysis*, illustrates that the outcome of critical illness depends not only on life threatening disturbances, but also on several complex “system” dimensions. Systems engineering tools offers a novel approach which can enable the emergence of a “systems understanding” of patient-environment interactions facilitating advances in the science of healthcare delivery. Patient variation and uncertainties present an additional challenge to investigators wishing to model and improve healthcare delivery processes. A system engineering approach is presented to modeling critical care delivery using sepsis resuscitation as an example.

Chapter 7, *Human-Centered Systems Engineering: Managing Stakeholder Dissonance in Healthcare Delivery*, discusses that deploying new tools and technologies often results in creating new problems while solving existing problems. A root cause is the interaction between tool design and organizational deployment. One undesirable result is the creation of stakeholder dissonance (SD). SD is a term for the conflict between the needs, wants, and desires (NWDs) of different stakeholders. In healthcare delivery systems, it is evidenced by errors, workarounds, and threats to patient safety and organizational profitability. Human-Centered Systems Engineering (HCSE) is the foundational paradigm for managing SD. HCSE emphasizes the criticality of the interfaces between humans, their tools, and their organizations, offering methods to recognize, measure, and control SD. It is complimentary to Lean, Six Sigma, Balanced Scorecard, and Quality Function Deployment approaches.

Chapter 8, *Enabling Real-Time Management and Visibility with RFID*, indicates that Radio frequency identification (RFID) and Real Time Location Systems (RTLS) provide a wireless means to identify, locate, monitor, and track assets and people. RFID technology can be used for resource and patient location, to reduce costs, improve inventory accuracy, and improve patient safety. A number of pilot deployments of RFID and RTLS technology have yielded promising results, reduced costs and improved patient care. However, there are three major issues facing RFID and RTLS systems: privacy, security, and location accuracy. As described in this chapter, the privacy and security issues can be easily addressed by employing standard security measures. Location accuracy issues are physics-related and new advances continue to improve this accuracy. However, in hospital applications accuracy to the room level is sufficient.

Chapter 9, *Healthcare Delivery as a Service System: Barriers to Co-Production and Implications of Healthcare Reform*, discusses issues of healthcare delivery as a system. The authors borrow from
systems engineering and business management to present the concept of service co-production as a new paradigm for healthcare delivery. Using the foresight afforded by this model the authors systematically identify the barriers to healthcare delivery functioning as a service system. The service co-production model requires for patient, provider, insurer, administrator and all the related healthcare individuals to collaborate at all stages – prevention, triage, diagnosis, treatment, and follow-up – of the healthcare delivery system in order to produce optimal health outcomes. Analysis presented in this chapter reveals that the barriers to co-production – the misalignment of financial and legal incentives, limited incorporation of collaborative point of care systems, and poor access to care – also serve as the source of many of the systemic failings of the U.S. healthcare system. The Patient Protection and Affordable Care Act takes steps to reduce these barriers, but leaves work to be done. The authors assess the state of service co-production in the U.S. healthcare system, and propose solutions for improvement.

Section 2, Outpatient Clinic Management and Scheduling, includes 5 chapters.

In Chapter 10, Using Simulation to Design and Improve an Outpatient Procedure Center, the authors discuss the use of simulation to improve patient flow at an outpatient procedure center (OPC) at Mayo Clinic. The OPC addressed is the Pain Clinic, which was faced with high patient volumes in a new, untested facility. Simulation was particularly useful due to the uncertain patient procedure and recovery times. The authors discuss the simulation process and show how it helped reduce patient waiting time while ensuring the clinic could meet its target patient volumes.

Chapter 11, Reducing Consultation Waiting Time and Overtime in Outpatient Clinic: Challenges and Solutions, analyzes the situation for an outpatient clinics that face increasing pressure to handle more appointment requests due to aging and growing population. The increase in workload impacts two critical performance indicators: consultation waiting time and clinic overtime. Consultation waiting time is the physical waiting time a patient spends in the waiting area of the clinic, and clinic overtime is the amount of time the clinic is open beyond its normal opening hours. This chapter analyzes the complexity of an outpatient clinic in a Singapore public hospital, and factors causing long consultation waiting time and clinic overtime. Discrete event simulation and design of experiments are applied to quantify the effects of the factors on consultation waiting time/clinic overtime. Implementation results show significant improvement once those factors are well addressed.

Chapter 12, Reducing Patient Waiting Time at an Ambulatory Surgical Center, describes a methodology to reduce patient waiting time in a for-profit ambulatory surgical center. Patients in this facility are scheduled in advance for the various operations, and yet operations start late and last longer than expected, creating undesired delays. Although this facility is limited to ambulatory surgery, it provides a large number of different surgeries, which are scheduled using “block” scheduling approach. The methodology presented generates a more accurate schedule by creating better time estimates for the operations and with lower variability. The effect of sequencing the surgeries, such that the ones with lower variability are performed earlier in the day, is also discussed.

Chapter 13, Scheduling Healthcare Systems: Theory and Applications, offers a series of scheduling techniques and their applications in healthcare settings. Healthcare administrators, physicians, and other professionals can use such techniques to achieve their operational goals when resources are limited. The chapter covers a wide spectrum of scheduling models, from single server and deterministic models to the more difficult ones, those which consider several servers and stochastic variables. A strong emphasis is placed on the practical aspects of scheduling techniques in healthcare.

Chapter 14, Appointment Order Outpatient Scheduling System with Consideration of Ancillary Services and Overbooking Policy to Improve Outpatient Experience, points out that patient wait time and access
to care have long been a recognized problem in modern outpatient healthcare delivery systems. In spite of all the efforts to develop appointment rules and policies, the problem of long patient waits persists. Despite the reasons, the fact remains that there are few implemented models for effective scheduling that consider patient wait times, physician idle time, overtime, ancillary service time, as well as individual no-show rate, and are generalized sufficiently to accommodate a variety of outpatient clinic settings.

The goal of this chapter is demonstrating how it is possible to improve the quality and efficiency of healthcare delivery by developing a physician schedule that meets the clinical policies without overbooking using an innovative ‘wait ratio’ concept, a patient arrival schedule from the physician schedule accounting for ancillary services, an evidence-based predictive model of no-show probability for individual patient, and a model-supported dynamic overbooking policy to reduce the negative impact of no-shows.

Section 3, Electronic Health Records, includes three chapters.

Chapter 15, Electronic Health Record: Adoption, Considerations and Future Direction, points out that over the last two decades there has been considerable deliberation, experience, and research in the arena of Health Information Technology (HIT), Electronic Medical Records (EMR), Electronic Health Records (EHR) and more recently Electronic Personal Health Records (EPHR).

This chapter attempts to synthesize the vast amount of information, experience, and implementation perspectives related to Electronic Health Records with the intent of assisting healthcare institutions and key stakeholders in making informed choices as they embark on designing, developing, and implementing an EHR. EHR considerations, challenges, opportunities, and future directions are also addressed. The chapter highlights the power of management engineering to facilitate planning, implementation, and sustainability of the EHR, a critical asset for a healthcare organization and the overall healthcare industry.

Chapter 16, Electronic Medical Records (EMR): Issues and Implementation Perspectives, presents the views and experience of the practicing physician. The author indicates that for many years the electronic medical record has been the holy grail of hospital system integration. Hundreds of millions of dollars have been spent in attempts to develop effective electronic medical records (EMR) to provide clinical care for patients. The advantages of an EMR are listed as reducing error, streamlining care, and allowing multiple people to provide simultaneous care. Unfortunately, most current EMR implementations are developed without completely understanding the processes that are being automated. In some implementations, there is an effort to first outline the process, and then try to create software that will facilitate the existing process, but this effort is not typically done systematically and with the discipline of an engineer. We will discuss the areas of the EMR that management systems engineers can facilitate to design and implement, reducing the errors in the current processes and preparing the healthcare system for further improvements.

In Chapter 17, Health Information Exchange for Improving the Efficiency and Quality of Healthcare Delivery, it is pointed out that in healthcare industry providers, patients and all other stakeholders must have the right information at the right time for achieving efficient and cost effective services. Exchange of information between the heterogeneous system entities plays a critical role. Health information exchange (HIE) is not only a process of transmitting data, but also a platform for streamlining operations to improve healthcare delivery in a secure manner. In this chapter, the authors present a comprehensive view of electronic health record (EHR) systems and HIE by presenting their architecture, benefits, challenges, and other related issues. While providing information on the current state of EHR/HIE applications, the authors also discuss advanced issues and secondary uses of HIE implementations, and shed some light on the future research in this area by highlighting the challenges and potential.
Section 4, **Patient Flow**, includes 2 chapters.

Chapter 18, *Evaluating Patient Flow Based on Waiting Time and Travel Distance for Outpatient Clinic Visits*, discusses how and why patient flow greatly affects the quality of service delivered to the patients. Among the various performance measures identified for patient flow, the chapter focuses on the analytical modeling of two key measures, namely, patient waiting time and travel distance. Waiting time is analyzed by a simple analytical tool – queuing theory. Three queuing models, including single station, multiple serial stations, and network systems are presented. Meanwhile, patient travel distance is investigated by an analytical model to evaluate the patient flow. For both measures, the applicability of models is illustrated with numerical examples.

Chapter 19, *Using Patient Flow to Examine Hospital Operations*, points out that adopting an admission-to-discharge patient flow perspective has the potential to improve hospital operations. Flow paths provide insight regarding patient care needs, support resource allocation and capacity planning decisions, and improve the operational performance of the hospitals. Studying patient flow using systems engineering tools and applications can help decision makers assess and improve care delivery. This chapter presents current research and techniques used to describe, measure, and model inpatient flow. The authors formally define patient flow from an operational standpoint and discuss why it is crucial for operational decisions. Systems engineering techniques that describe and analyze inpatient flow are introduced. However, these techniques present certain modeling challenges, which the authors address. The chapter concludes with a discussion of emerging approaches to capture patient flow.

The last section 5, **Cost Management**, includes chapter 20, *A New Cost Accounting Model and New Indicators for Hospital Management Based on Personnel Cost*. This chapter discusses that specified hospital accounting systems are necessary for a manager to determine the proper management strategy. A new cost accounting model based on new allocation rules of personnel cost is presented in this chapter. The model offers a manager useful tool to calculate the medical cost not only for an individual patient and for each clinical department, but also each DRG system for a specific period.

New financial indicators were developed based on personnel costs which were calculated using this new cost accounting system. Indicator 1: The ratio of the marginal profit after personnel cost per personnel cost (RMP). Indicator 2: The ratio of investment (=indirect cost) per personnel cost (RIP). Operation profit per one dollar of personnel cost (OPP) was demonstrated to be the difference between the RMP and RIP. The break-even point (BEP) and break-even ratio (BER) could be determined by combining the indicators. RMP demonstrates not only the medical efficiency, but also the medical productivity in the case of DPC/DRG groups. OPP can be utilized to compare the medical efficiency of each department in either one hospital or multiple hospitals. It also makes it possible to evaluate the management efficiency of multiple hospitals.

In conclusion, this book illustrates the power of management engineering for quantitative managerial decision-making in healthcare settings. Management engineering helps in understanding responses of processes and systems to different inputs with random and non-random variability. This understanding makes it possible, in turn, to predict performance and/or real resource requirements, allowing decision-makers to be truly proactive rather than reactive.

This book illustrates to healthcare administrators the importance of understanding quantitative decision-making techniques offered by management engineering. The editors hope that this book will help to reduce barriers between healthcare practitioners and engineering professionals.