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KLUWER ACADEMIC PUBLISHERS
NEW YORK, BOSTON, DORDRECHT, LONDON, MOSCOW

eBook ISBN: 1-4020-8066-2
Print ISBN: 1-4020-7629-0

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PUBLIC POLICY AND ECONOMIC ANALYSIS

1 HEALTH CARE DELIVERY: CURRENT PROBLEMS AND FUTURE CHALLENGES

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SUMMARY

In both rich and poor nations, public resources for health care are inadequate to meet demand. Policy makers and health care providers must determine how to provide the most effective health care to citizens using the limited resources that are available. This chapter describes current and future challenges in the delivery of health care, and outlines the role that operations research (OR) models can play in helping to solve those problems. The chapter concludes with an overview of this book – its intended audience, the areas covered, and a description of the subsequent chapters.

KEY WORDS

Health care delivery, Health care planning

1.1 WORLDWIDE HEALTH: THE PAST 50 YEARS

Human health has improved significantly in the last 50 years. In 1950, global life expectancy was 46 years [1]. That figure rose to 61 years by 1980 and to 67 years by 1998 [2]. Much of these gains occurred in low- and middle-income countries, and were due in large part to improved nutrition and sanitation, medical innovations, and improvements in public health infrastructure.

However, not all countries have experienced an increase in life expectancy in recent years. In countries of the former Soviet Union, life expectancy dropped from 70 years in 1986 to 64 years in 1994, with an even more marked drop among men [3]. Factors contributing to this decline include economic and social instability, high rates of tobacco and alcohol consumption, poor nutrition, depression, and deterioration of the health care system [4]. In many African nations, life expectancy has been significantly diminished by HIV/AIDS. In seven African countries life expectancy is now less than 40 years and falling [5].

Worldwide, infectious diseases kill 13 million people per year [6]. In 1999, 2.8 million people died from AIDS alone [7]. Infectious diseases once confined to specific geographic regions have spread across country borders as a result of increasing global travel. New infectious diseases continue to emerge [8]. Noncommunicable diseases such as heart disease, cerebrovascular disease (stroke), cancer, and diabetes are the primary cause of death in high-income countries. Such diseases currently account for less than half of all deaths in low-income countries, but in the next 20 years are expected to account for 70% of deaths [9]. In low-income countries, malnutrition remains a serious health problem, whereas in high-income countries, obesity is increasingly becoming a health problem. Tobacco, alcohol, and drug use have led to significant health problems worldwide. Tobacco use currently accounts for almost 5 million premature deaths per year. This figure is projected to rise to more than 8 million deaths per year by 2020, with many of these in low- and middle-income countries [10]. Food and water contamination cause at least 2 million premature deaths per year, primarily in low- and middle-income countries. Environmental agents (e.g., arsenic, lead, silica) also pose significant health risks in some areas. In addition, manmade chemical and biological weapons are a potential threat to public health.

1.2 HEALTH CARE DELIVERY CHALLENGES

Governments and health care providers face a variety of challenges in the delivery of health care. Below we describe current and future health care challenges. Because low- and middle-income countries face significantly different challenges in health provision than do high-income countries, we describe their current health care challenges separately. We then describe the future challenges in health care delivery that are common to all countries.

1.2.1 Current health care delivery challenges in low-income and middle-income countries

In low- and middle-income countries, where 80% of the world's population lives, malnutrition and infectious diseases account for significant numbers of premature deaths. Half of young child deaths in low-income countries are caused by malnutrition [11]. Although vaccines are available for a number of infectious diseases that cause childhood deaths, 25% of the world's children have not received these vaccines [12]. Many people in low- and middle-income countries do not receive even basic health care. Health facilities are often located in urban areas, far from rural areas and frequently difficult to access by public transportation. The care that is provided can be costly and substandard. In recent years, low- and middle-income countries have seen a significant shift in population from rural to urban areas, but have had no commensurate increase in urban health services. Inadequate infrastructure (e.g., inadequate roads, storage and distribution systems, electricity, clean water) and poorly functioning public health systems also impede the provision of health care.

Resources for health care in low-income countries are quite limited. Among the world's 60 poorest nations, annual per capita health spending in the year 2000 was less than $15 [13], and approximately one third of this funding came from international aid. Such an amount is insufficient to provide even the most basic health services. In contrast, annual per capita health spending in the industrialized world was on the order of $2,000, and was $4,500 in the United States [13]. Even if low-income countries were to devote more of their scarce public funds to health care, as recently recommended by the World Health Organization [13], per capita spending would still be at levels far below that in the industrialized world.

The lack of health care funding in low- and middle-income countries is exacerbated by rising health care needs and costs. Countries severely affected by HIV/AIDS are facing far greater demands for health care than they can meet. In other low- and middle-income countries, aging populations have increased overall demand for health care. Health care costs have risen as a result of new health care technologies and procedures. Moreover, many medicines that are routinely used in high-income countries (so-called "essential medicines") are not affordable in low-income countries. In some cases, even basic vaccines are too expensive.

1.2.2 Current health care delivery challenges in high-income countries

In high-income countries, resources for health care are orders of magnitude greater than in low-income countries. However, high-income countries face their own health care challenges. Although such countries spend much more on health than low-income countries, performance of health care systems varies markedly among high-income countries. For example, the United States spends almost twice as much per capita on annual health care as many other high-income nations, without achieving any greater life expectancy or any lower "burden of disease" (measured in terms of life years lived, adjusted for health disabilities) [14]. A recent report by the World Health Organization ranked the U.S. 37th in overall health systems performance among 191 Member States [14]. France, which spends half as much as the U.S. on per capita annual health care, was ranked first in overall health systems performance [14]. (Health systems performance as measured in the report included not only measures of health, but also measures of health system fairness and responsiveness.)

Inequities in health care provision exist within high-income countries. In countries with no national health system, such as the U.S., a significant fraction of individuals have no health insurance coverage and thus have only limited access to health care. Poor people and those in rural areas also often have only limited access to health care. In some high-income countries, including the U.S., the gap in life expectancy between rich and poor people is as great as the gap in life expectancy between high- and low-income countries [15].

Like low-income countries, high-income countries have experienced significant increases in demand for and cost of health care. Aging populations are making disproportionately heavy demands on health systems in high-income countries. Chronic conditions have become more prevalent. While new health care technologies and procedures have improved health, they have also increased costs. Patients are not only consuming more health services, but are consuming more intensive health services. Prescription drugs have also become increasingly expensive. In many high-income countries, health care spending has significantly outpaced economic growth. In the U.S., for example, health care spending accounted for 5% the Gross Domestic Product (GDP) in 1960 (or $143 per person); by 2001, health care spending accounted for 14.1% of the GDP (or $5,035 per person) [16]. As a result of these increases in demand for and cost of health care in high-income countries, national health systems, insurers, and health care providers are all under strain.

1.2.3 Future health care delivery challenges

As we begin the 21st century, many of the health care challenges described above will continue. Preventable diseases will persist. Inequities in access to health care within and across countries will persist. Health care costs will continue to increase, as will demands for health care. Advances in medical knowledge will continue, along with costly new technologies and medicines. Aging populations will consume increasing amounts of health care services. Patients will have increasing expectations for cures and treatments of more health problems. New means of delivering health care (e.g., telemedicine) will continue to emerge, creating a need for improved communication and information management systems.

In both rich and poor nations, public resources for health care will remain inadequate to meet the demand. Policy makers and health care providers must determine how to provide the most effective health care to citizens using the limited resources that are available. Governments and health care providers must strive to meet basic health needs for all their citizens. Moreover, they must work to improve health and health-related quality of life for citizens in all stages of their lengthening life span. They must set health care priorities (e.g., between disease prevention and treatment or between alternate means of health care delivery) and develop health care systems that can deliver the needed health care in the most effective and efficient manner possible. Worldwide health improved dramatically during the 20th century. The challenge of the 21st century will be to continue this improvement.

1.3 PROVIDING EFFECTIVE AND EFFICIENT HEALTH CARE

To provide the best health care given the limited resources that are available, policy makers need effective methods for planning, prioritization, and decision making, as well as effective methods for management and improvement of health care systems. The planning and management decisions facing policy makers and planners can be grouped into two broad areas: health care planning and organizing, and health care delivery.

1.3.1 Health care planning and organizing

Health care planning and organizing involves relatively high-level policy decisions about the economics of health care systems (e.g., health care resources, pricing, and financing), the structure of health care systems, and other aspects of public policy regarding health care.

<u>Economics of health care systems</u> At the highest level of planning, governments and other health care providers must determine the level of resources they will devote to health care, and how much they will spend on individual patients. Governments must decide which goods and services are to be paid for through public funding and who will receive those goods and services. Because funds are not available to meet all health care needs, governments must set priorities and determine how they will ration the health services they pay for. Health care providers must determine the cost of services and set prices. Government agencies and other large insurers must negotiate prices for drugs and vaccines. Insurers, including governments, must determine who will receive health insurance coverage and what that coverage will consist of. They must develop affordable, workable payment schemes for physicians and other health care providers, and must determine what fees patients must pay for health care services. Such financing schemes must provide proper incentives for health system efficiency.

<u>Structure of health care systems</u> Another set of high-level decisions concerns the structure and organization of health care delivery systems. Health care providers must determine which goods and services they will provide and how to allocate resources among them. Governments must decide to whom the goods and services will be provided. Resources must be allocated among different levels of the health service – for example, among primary care and public health programs versus hospital services. Resources must be allocated between capital development and operating costs, and between salary and nonsalary expenditures. Resources must be allocated among geographic areas – for example, different regions of a country, or urban versus rural areas. Resources must be allocated among specific programs – for example, programs for control of specific diseases, immunization programs, or reproductive health programs. Resources must also be allocated among specific health care goods and services – for example, doctor visits, procedures, or medications.

<u>Other public policy issues</u> In addition to economic and structural issues, decision makers face a variety of other policy decisions that have a broad effect on the delivery of health care. Policy makers must develop strategic plans for national and regional health improvement. These include identifying risks to public health (e.g., environmental contaminants, infectious disease epidemics, or unhealthy lifestyles) and developing plans for mitigating such risks. Such plans may include, for example, national or

regional disease screening and prevention programs, health promotion programs, mass vaccination programs, programs to control biological pests (e.g., spraying against malaria-transmitting mosquitoes), programs for the control of illicit drugs, or programs for response to potential bioterrorist attacks. Policy makers must develop plans for the provision of health care that address the availability of and access to health care among those whom the health care system serves, with consideration given to the impact of insurance and regulatory policies on such access. Other population-level policy issues include policies for the allocation of transplant organs among potential recipients, for managing national blood supplies, and for managing national vaccine and pharmaceutical stockpiles.

1.3.2 Health care delivery

Planning and managing health care delivery involves decisions about the management of health care operations and about clinical practice.

Operations management for health care delivery Operations management problems that arise in the delivery of health care are similar in many ways to traditional problems in operations management. These include strategic planning problems such as design of services (e.g., inclusion of neonatal intensive care units in some hospitals, or provision of free-standing urgent care clinics or rural health workers), design of the health care supply chain (e.g., design of a network of hospitals, outpatient clinics, and laboratory services), facility planning and design (e.g., location and layout of hospitals and outpatient clinics, or design of material handling systems), equipment evaluation and selection, process selection, and capacity planning. Other planning problems include demand and capacity forecasting, capacity management, scheduling and workforce planning, job design, and management of the health care supply chain. Managers of health care systems must manage inventory (e.g., drugs, supplies, or blood), measure and manage system performance and quality, and assess the performance of health care technologies. Decision support systems must be designed and implemented to support all of these activities.

Clinical Practice Clinicians face a number of important planning and management problems in the delivery of health care. These include assessing health risks and diagnosing diseases and conditions of individual patients. Clinicians must design and plan treatment for their patients. For example, they must assess how disease is likely to progress in a patient and then they must select appropriate drugs and dosages and design other aspects of a treatment regimen (e.g., surgery, radiation, rehabilitation). Clinicians must determine appropriate disease prevention strategies for individual patients (e.g., vaccination, disease screening, drug treatment, lifestyle changes). The goal of these clinical activities is to provide the highest quality care given the resources that are available. Doing so requires ongoing assessment of clinical quality and well as assessment of the cost and effectiveness of different health care interventions. A recent innovation in clinical practice has been the development of broad-based practice guidelines that specify the recommended standard of care for various diseases and conditions. Such guidelines are developed based on cost-effectiveness analysis of alternative interventions, and vary according to the population and setting (e.g., guidelines for treating a disease in a low-income country will differ from guidelines for treating the same disease in a high-income country). Finally, given the explosion of new medical knowledge, information management and decision support systems can play a crucial role in supporting effective and efficient clinical practice.

1.4 OVERVIEW OF THIS BOOK

Operations research techniques, tools, and theories have long been applied to a wide range of issues and problems in health care. However, to date, no single handbook has synthesized the wide applicability of such techniques and presented future challenges and avenues for research. In fact, practitioners, students, and researchers in this field have had difficulty finding a comprehensive reference that can help them improve their ability to apply such techniques, learn new techniques, explore new issues and challenges, and pursue new research avenues. This handbook aims to fill that need.

This book covers applications of operations research in health care, with particular emphasis on health care delivery. The book is geared toward a multidisciplinary audience that includes OR practitioners, students, scientists and researchers with interest in health care (either new interest or existing expertise), as well as health practitioners (such as clinicians, administrators, and managers), students, scientists, and researchers in health sciences, health administration, public health, health care delivery, and health policy.

Three main areas are covered: (1) health care operations management, (2) public policy and economic analysis, and (3) clinical applications. Within each area, a broad range of topics is addressed. Each chapter details a problem area, a state-of-the-art application, the methodology employed, and research issues raised. Each topic is structured and addressed in such a way that a wide audience – with varying levels of knowledge of the subject area or the methodology employed – will be able to access and use the material presented.

This book covers topics as diverse as hospital capacity planning and management, supply chain management for blood banking, evaluation of hospital efficiency, vaccine pricing policies, national drug control policy, decision making for bioterror preparedness, breast cancer diagnosis, optimal design of radiation treatments, and analysis of asthma treatments. Although they cover diverse topics, all of the chapters show how operations research can be applied to help make health care delivery more effective and efficient.

1.4.1 Health care operations management

The first main section of the book comprises chapters describing the application of OR models to problems in health care operations management. In Chapter 2, Linda Green describes how OR models have been and can be used for hospital capacity planning. In Chapter 3, Mark Daskin and Latoya Dean review the application of facility location models in health care. They also present a novel application of the classical set covering model to the analysis of cytological samples. In Chapter 4, Shane Henderson and Andrew Mason discuss the application of a customized simulation model to assist in decision making by a New Zealand ambulance service. In Chapter 5, William Pierskalla discusses the management of blood bank supply chains. In Chapter 6, Liam O'Neill and Franklin Dexter present a method to identify best practices among hospitals' perioperative services using data envelopment analysis (DEA). In Chapter 7, Yasar Ozcan, Elizabeth Merwin, Kwangsoo Lee, and Joseph Morrissey describe the application of DEA to develop a methodology for analyzing organizational performance of community mental health centers. They also present measures of efficiency that can be used as a basis for improving productivity in behavioral health care. In Chapter 8, Michael Carter and John Blake describe four case studies of simulation applied to problems in hospital operations management. They describe the obstacles encountered in these applications, and the lessons learned.

1.4.2 Public policy and economic analysis

The second main section of the book comprises chapters that illustrate the application of OR to problems of health care policy and economic analysis. In Chapter 9, Rose Baker describes applications of conditional likelihood methods for estimating risks to public health. In Chapter 10, Thitima Kongnakorn and François Sainfort describe how medical outcomes can be modeled in order to facilitate economic analysis of health care policy problems. In Chapter 11, Anke Richter presents three case studies of the application of OR techniques to evaluate the economic consequences and health benefits of new medications and treatments. In Chapter 12, Jonathan

Caulkins provides an overview of the ways in which OR models have been applied to evaluate policies for the control of illicit drugs. In Chapter 13, Gregory Zaric reviews recent OR advances in modeling maintenance treatment programs for opiate addicts. In Chapter 14, Harold Pollack describes how OR models have been used to evaluate syringe exchange programs and substance abuse treatment programs for injection drug users, and how such models can assist policy makers. In Chapter 15, Douglas Owens, Donna Edwards, John Cavallaro, and Ross Shachter apply a simulation model and economic analysis to evaluate the cost effectiveness of potential vaccines against HIV, the virus that causes AIDS. In Chapter 16, Sheldon Jacobson and Edward Sewell review the application of linear programming models to address a variety of economic issues surrounding pediatric vaccine formulary design and pricing. In Chapter 17, Margaret Brandeau reviews OR models that have been developed to assist in the allocation of resources to control infectious diseases. In Chapter 18, Stephen Chick, Sada Soorapanth, and James Koopman evaluate the public health benefits of two interventions for controlling infectious microbes in the water supply – improvements to centralized water treatment facilities, and localized point-of-use treatments in the homes of particularly susceptible individuals. In Chapter 19, Ruth Davies and Sally Brailsford present a model that evaluates policies for public health screening to detect diabetic retinopathy (which is early indications of eye disease caused by diabetes). In Chapter 20, Edward Kaplan and Lawrence Wein review the recent smallpox vaccination policy debate in the U.S., and describe the successful use of OR methods to influence policy in this arena. In Chapter 21, Stefanos Zenios reviews OR models that have been used to evaluate policies for allocating donor kidneys to transplant recipients. In Chapter 22, Mike Cushman and Jonathan Rosenhead describe the application of a model-based approach to the redesign of children's health services in inner London.

1.4.3 Clinical applications

The third main section of the book comprises chapters that describe the application of OR techniques to clinical problems. In Chapter 23, Andrew Schaefer, Matthew Bailey, Steven Shechter, and Mark Roberts review the application of Markov decision process models to guide medical treatment decisions. In Chapter 24, Gordon Hazen describes how dynamic influence diagrams can be applied to model clinical decision problems. In Chapter 25, Elisabeth Paté-Cornell describes the application of risk analysis to evaluate policies for reducing risk during anesthesia procedures. In Chapter 26, David Paltiel, Karen Kuntz, Scott Weiss, and Anne Fuhlbrigge present a model that simulates health and economic outcomes among patients with asthma, and they illustrate the application of the model to assess the cost effectiveness of inhaled corticosterioids among certain adult patients. In

Chapter 27, Daniel Rubin, Elizabeth Burnside, and Ross Shachter present a Bayesian network model that can help radiologists interpret mammograms and determine appropriate followup. In Chapter 28, Eva Lee and Marco Zaider describe an optimization model and decision support system to help plan radiation treatment for patients with cancer. In Chapter 29, Allen Holder describes linear optimization models that can be used to help design radiation treatments. In Chapter 30, Michael Ferris, Jinho Lim, and David Shepard describe the application of Matlab for radiation treatment planning. In Chapter 31, James Koopman, Ximin Lin, Stephen Chick, and Janet Gilsdorf present a transmission model of a common bacteria that colonizes the human nose and throat, and they show how the model can be used to evaluate the relative effectiveness of different vaccines (in particular, vaccines that reduce transmission of the bacteria versus vaccines that prevent disease once a person's throat has been colonized). Finally, in Chapter 32, David Craft, Lawrence Wein, and Dennis Selkoe present a model of the accumulation of amyloid, β-protein (Aβ) in the brain during the course of treatment for Alzheimer's disease, and show how the model can be used to determine appropriate treatments.

1.4.4 Conclusion

In a recent report [6], the World Health Organization stated that, "One of the most important roles of the World Health Organization is to assist countries in making optimum use of scarce health resources." This, too, is a role for operations researchers, as this book demonstrates.

Acknowledgments

M.L.B. was supported by the National Institute on Drug Abuse (Grant Number R-01-DA-15612).

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2 CAPACITY PLANNING AND MANAGEMENT IN HOSPITALS

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SUMMARY

Faced with diminishing government subsidies, competition, and the increasing influence of managed care, hospitals are under enormous pressure to cut costs. In response to these pressures, many hospitals have made drastic changes including downsizing beds, cutting staff, and merging with other hospitals. These critical capacity decisions generally have been made without the help of OR model-based analyses, routinely used in other service industries, to determine their impact. Not surprisingly, this has often resulted in diminished patient access without any significant reductions in costs. Moreover, payers and patients are increasingly demanding improved clinical outcomes and service quality. These factors, combined with their complex dynamics, make hospitals an important and rich area for the development and use of OR/MS tools and frameworks to help identify capacity needs and ways to use existing capacity more efficiently and effectively. In this chapter we describe the general background and issues involved in hospital capacity planning, provide examples of how OR models can be used to provide important insights into operational strategies and practices, and identify opportunities and challenges for future research.

KEY WORDS

Hospitals, Capacity management, Queueing theory

2.1 INTRODUCTION

2.1.1 Background

Hospitals are the locus of acute episodes of care for most serious illnesses and form the backbone of the emergency medical care system. Over the years, hospitals have been successful in using medical and technical innovations to deliver more effective clinical treatments while reducing patients' time spent in the hospital. However, hospitals are typically rife with inefficiencies and delays. Patients spend hours and sometimes days in emergency rooms and recovery rooms waiting for beds. Procedures and surgeries have to be cancelled and rescheduled. Inpatients are placed in inappropriate beds and transferred multiple times from one unit to another. Nurses and other staff are often in short supply to handle peak loads.

These inefficiencies have their roots in the regulatory and financing environment in which most hospitals existed until recently. Until the mid-1980's, U.S. hospitals were paid by insurers on a "fee for service" basis and capacity expansions were subsidized by state governments. With the increased prevalence of managed care and reduced government subsidies, hospital managers have been under increasing pressure to cut costs and have undertaken large-scale changes to do so. Hospitals have been merged, downsized, and in many cases, closed. Beds have been reorganized, units closed, and patients discharged earlier to increase utilization and throughput. Emergency rooms are getting more crowded and there are increasing reports of ambulance diversions due to a lack of beds. Yet, most hospitals struggle to operate in the black.

In this environment, it is more important than ever for hospital managers to identify ways to "right-size" their facilities and deploy their resources more effectively. Yet, hospitals do not generally use the kind of OR/MS methodologies used in many other service industries to help with capacity planning and management.

2.1.2 Capacity planning in hospitals: overview

The most fundamental measure of hospital capacity is the number of inpatient beds. Hospital bed capacity decisions have traditionally been made based on target occupancy levels – the average percentage of occupied beds. Historically, the most commonly used occupancy target has been 85%. Certain nursing units in the hospital, such as intensive care units (ICUs) are often run at much higher utilization levels because of their high costs.

Until recently, the number of hospital beds was regulated in most states under the Certificate of Need (CON) process, under which hospitals could not be built or expanded without state review and approval. (In the last few years, most of these states have either relaxed or totally eliminated CON bed requirements.) Target occupancy levels were the major basis for these approvals. Though there has been fairly extensive literature on the use of queueing, simulation, and optimization models to support hospital planning [1-6], occupancy targets have been and continue to be the primary measure for determining bed requirements at the individual hospital and even hospital unit level. Faced with increased pressure to be more cost efficient, some hospitals are now setting target levels that exceed 90% without understanding and addressing the issues of bottlenecks and congestion in what is usually a highly stochastic, interdependent system.

The other major component of capacity is personnel, particularly nurses. Nurses are the chief caregivers as well as managers of the clinical units. In recent studies, nursing has been found to have a significant impact on clinical outcomes [7]. In addition, nursing costs comprise a very substantial fraction of hospital budgets. In most hospitals, the number of nurses assigned to a unit is determined by a specified ratio of patients to nurses. The norm for most types of clinical units has been 8:1, while for intensive care units it could be as little as 1:1. Though most hospitals subscribe to these standards, cost pressures and a national nursing shortage have resulted in these ratios being exceeded in many cases. Sometimes, however, this is the result of a failure to adequately plan for the daily, weekly and sometimes seasonal variations in hospital census that are common in most clinical units of virtually every hospital. Though there have been many articles on the use of optimization models to determine nurse staffing (see references in [3, 8, 9]), hospitals often lack basic data, such as patient census by time of day, that would be needed to use such models [10].

Another significant component of capacity is operating rooms. Surgical procedures are usually a critical source of revenues for hospitals. The efficient use of operating rooms, which are often bottlenecks, can be central to the smooth functioning of the hospital as a whole. Substantial work on scheduling operating rooms has appeared in the OR literature (see references in [3, 11, 12]), though there is evidence that this resource is still a source of operational problems.

Major diagnostic equipment, such as magnetic resonance imaging devices (MRIs), comprise another important category of capacity. These machines are extremely expensive, so operating policies are usually oriented toward achieving 100% utilization. In order to avoid "excess" capacity and "unnecessary" usage, these purchases are regulated by the states under a certificate of need (CON) process. Hospital policies governing the use of MRIs are very varied. For example, in some hospitals, outpatients are scheduled on a dedicated facility while in others, inpatients, outpatients and emergency patients all use the same machine. Policies and priority rules are constructed and implemented without any OR analysis and often result in long lead times for outpatient appointments as well as on-site delays. See [13] for a dynamic programming approach to the allocation of capacity for a shared facility.

2.2 AN ILLUSTRATION OF THE ISSUES: EMERGENCY ROOM DELAYS

2.2.1 Understanding the problem

Newspapers, magazines and television have recently reported on severe overcrowding of emergency departments (EDs) and increases in the amount of time that ambulances are being turned away from hospitals [14-16]. Though troubling even on the surface, these reports are even more ominous given the current environment of terrorist threats. So what needs to be done to improve hospitals' ability to respond to emergencies?

Before looking for solutions, it is critical to first understand the nature of the problem. This should begin with the question: "How long should patients wait?" Reports of excessive delays and overcrowding can be very misleading unless there is an understanding of what performance standards should be applied. This, in turn, necessitates an understanding of the potential medical consequences of specific delays for each category of patients. Many patients who arrive to an ED are "non-urgent" and would not be harmed by significant delays in seeing a physician. Most, however, are either "emergent" (requiring "immediate" care) or "urgent" (requiring care within a "short" period of time). Within each of these broad categories, however, there is considerable variety in the exact nature of the illness or injury and extremely little clinical evidence supporting specific delay standards. Unlike, say, telephone call centers, there are no industry-wide standards for what constitutes excessive delays in an ED. Nor are there generally accepted standards for how long a patient requiring admission from the ED should wait for a bed. It is this latter delay that directors of EDs generally cite as most responsible for ED overcrowding and ambulance diversions.

2.2.2 Complexities of capacity planning

Even without specific standards, there is clearly a problem when patients wait for the better part of the day for a bed, when filled stretchers block walkways and hallways, or when a hospital must routinely turn ambulances away. What causes these problems? Though one likely cause (and the one most widely cited in the media) is the reduction of inpatient beds over the last ten years, many other factors must be considered. From a capacity planning perspective, the entire process from patient arrival in the ED to placement in a bed must be examined. Considering only the major steps, the process begins with the triage nurse, who determines the acuity of the patent's condition, and registration which is usually a clerical function. Next, the patient is seen by an ED physician. Often this results in a request for diagnostic testing such as blood analysis and x-rays. Laboratory specimens are generally collected by technicians or nurses and sent to a central testing facility of the hospital. If the patient needs to be taken to another location in the hospital for a diagnostic test, transport personnel are needed. When all tests are completed, the physician reviews them and determines whether the patient requires admission to the hospital. If so, a bed is requested in the appropriate nursing unit (e.g., medical, surgical, intensive care). The availability of a bed is affected not only by the capacity of the relevant unit, but also by the admission and scheduling policies of elective patients, particularly surgical patients who compete for the same beds as many emergency patients [17], and by transfer and discharge policies and procedures. Even if a suitable bed is vacant, it must be located and identified as empty, and then cleaned, if necessary. In addition, a floor nurse must be available to admit the patient. When everything is ready, a request is made for transport and when it is available, the patient is finally moved to the assigned bed. Clearly, there is the potential for a mismatch between the demand and availability of capacity in each step of the process.

This description of the ED admission process illustrates the complexities of hospital capacity planning and management. First, it demonstrates the interdependencies of the various parts of the hospital and the need to identify bottlenecks. These bottlenecks may change from hour to hour, shift to shift, daily, weekly and seasonally. Second, it shows the variety of both fixed capacity (e.g., inpatient beds, ED beds, diagnostic equipment) and variable capacity (e.g., nurses, physicians, technicians, housekeepers, transport staff) that must be managed. Third, much of the capacity required for ED admissions – such as inpatient beds, labs, diagnostic equipment and transport staff – is shared by other patients in the hospital, and thus policies and procedures are required to allocate these resources among the various patient groupings. Fourth, ED admissions are generally time-dependent with distinct time-of-day and day-of-week patterns as well as some seasonality. Therefore, it is imperative that managers develop appropriately flexible staffing policies as well as strategies for using fixed capacity to handle peak loads efficiently and effectively. Finally, in order to create a true emergency response system, capacity needs must be considered on a regional basis and ambulance dispatch and diversion policies developed to assure timely access to care for the most urgent patients. Given that hospitals within the same geographic area are likely to experience many of the same peaks in demand, this means that enough regional capacity should be available so that the probability of all hospitals within a given area being on ambulance diversion simultaneously is extremely small. This is well illustrated by the case of New York City which experienced a severe and protracted citywide shortage of inpatient hospital beds in 1987/1988 [18]. During this period, ambulances were routinely turned away from full hospitals and urgently sick patients experienced delays of days waiting for an open bed.

2.3 HOW MANY HOSPITAL BEDS?

2.3.1 The problem with occupancy levels

As mentioned previously, hospitals often rely on target occupancy levels to plan and evaluate bed capacity. Until recent reports on ED overcrowding and increased ambulance diversion started surfacing, the widespread perception among policymakers and hospital managers was that there were too many hospital beds in the U.S. This belief was primarily supported by the discrepancy between what has usually been considered the "optimal" occupancy figure of 85% (see, e.g., [19], p.55) and the actual average occupancy rate for nonprofit hospitals which has recently been about 64% [20]. This and other related target occupancy levels were originally developed at the federal government level in the 1970's as a response to accelerating health care costs and the perception that more hospital beds resulted in greater demand for hospital care (which was shown to occur under fee for service reimbursement). These occupancy targets were the result of analytical modeling for "typical" hospitals in various size categories and were based on estimates of "acceptable" delays [21].

What is wrong with using occupancy levels to manage capacity? First, reported occupancy levels are generally based on the average "midnight census". This refers to the time when hospitals count patients for billing purposes. However, the midnight census usually measures the lowest occupancy level of the day. One reason is the phenomenon known as the "23-hour patient" who is admitted in the morning and discharged in the evening. Managed care companies have encouraged this practice as a way of allowing evaluation of a patient while avoiding unnecessary hospitalization. More generally, most patients are admitted in the morning or early afternoon and are not discharged until after attending physicians have conducted examinations, so that the peak census is in the middle of the day and can easily be 20% higher than at midnight [22]. In addition, the utilization of hospital facilities is far from uniform across the week or across the year. Very few procedures are scheduled for weekends, so elective patients are not usually admitted on weekends when the average daily census is considerably lower. Summer and holiday periods are also slower [23] and other seasonal effects have been observed in specific hospitals and/or for specific units. Reported occupancy levels are yearly averages and hence do not reflect significantly higher levels that may exist for extensive periods of time. For all of these reasons, reported occupancy levels are not reliable measures of general bed utilization.

More importantly, bed occupancy levels do not measure or even indicate patients' delays for beds. Yet, hospitals do not typically measure bed delays nor do they use queueing or simulation models to estimate the delays that would result from changes in demand or the number or organization of beds.

2.3.2 Target occupancy levels, bed delays and size

Evaluating bed capacity based on a target probability of bed availability or other measure of delay can lead to very different conclusions than would be reached from the use of a target occupancy level. This can be illustrated in considering obstetrics units. Obstetrics is generally operated independently of other services, so its capacity needs can be determined without regard to other parts of the hospital. It is also one for which the use of a standard M/M/s queueing model is quite good. Most obstetrics patients are unscheduled and the assumption of Poisson arrivals has been shown to be a good one in studies of unscheduled hospital admissions [24]. In addition, the coefficient of variation (CV) of length of stay (LOS), which is defined as the ratio of the standard deviation to the mean, is typically very close to 1.0 [6] satisfying the service time assumption of the M/M/s model.

Since obstetrics patients are considered emergent, the American College of Obstetrics and Gynecology (ACOG) recommends that occupancy levels of obstetrics units not exceed 75% [25]. Many hospitals have obstetrics units operating below this level. For example, based on the 1997 Institutional Cost Reports (ICRs), 117 of the 148 or 79% of New York State hospitals had average occupancy levels below this standard. Some have eliminated beds to reduce "excess" capacity and costs [26]. Conversely, fewer than 20% of these hospitals had obstetrics units that would be considered over-utilized by this standard.

But evaluation of capacity based on a delay target leads to a very different conclusion. Though there is no standard delay target, Schneider [27] suggested that the probability of delay for an obstetrics bed should not exceed 1%. Applying this criterion and using the ICR data in an M/M/s model results in 40% of the hospitals having insufficient capacity by this standard. The major reason for this is size. From queueing theory, we know that larger service systems can operate at higher utilization levels than smaller ones while attaining the same level of delays [28]. While obstetrics units are usually not the smallest units in the hospital, there are many small