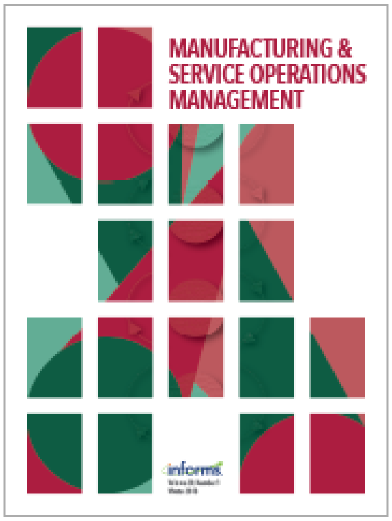

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Commentaries to "The Vital Role of Operations Analysis in Improving Healthcare Delivery"

This series of discussions presents commentaries on where the field of healthcare operations management is now and possible future research directions, expanding upon the key points raised by Green [Green LV (2012) The vital role of operations analysis in improving healthcare delivery. *Manufacturing Service Oper. Management* 14(4):488–494].

Key words: healthcare; information technology; data analysis; capacity planning; flexibility; coordination; practice variation
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The State of Healthcare in OR/OM

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Linda Green has been providing us with scholarly research applying operations research (OR) principles to healthcare delivery for decades. Now that this is a "hot" topic in operations management (OM), it is most appropriate to hear from her about how we can make the greatest contributions to this important field of study. Her work touches on several principles of operations management and how they may be applied to our healthcare systems to improve health outcomes and enhance the efficiency of care delivery. In her paper, Green (2012) discusses several key challenges facing the healthcare industry and some of the opportunities for operations to help address them. Our goal is to capitalize on our own experiences and amplify her overall theme of the vital role that we, as a profession, can play in advancing the ability of the healthcare industry to serve the needs of its patients in the most cost-effective manner. We will present some specific examples relating to the themes described in her paper and suggest some other important areas for us to consider as we embark on research in the field of healthcare delivery.

Medical vs. Operational Decision Making

Green gives examples of opportunities for operations research to improve care. These examples fall into two categories: medical decision making and operational decision making. Medical decision making relates to those decisions that directly affect a patient's clinical outcomes. Some examples are diagnostic and evaluative protocols, treatment options, and care regimens, to name a few. In contrast, operational decision making includes those decisions that determine how the organization makes itself available to serve patients, such as resource and capacity allocation as well as the scheduling of patients, facilities, and providers.

If we are to maximize the benefit of operations thinking in healthcare settings, it is vitally important to recognize when medical decisions have operational implications and vice versa. The line separating these domains is blurry at best in many situations. Consider the question of the number of intensive care unit beds that should be staffed, as mentioned by Green. Too many is prohibitively expensive; too few and operating rooms get blocked, among other consequences. In another example, when deciding which emergency department (ED) patients should get complete blood count (CBC) tests, the answer may affect the ED's backlog, extend waiting, and possibly increase the number of patients who leave without being seen, which can cause further harm.

This intersection is hard to expose and ameliorate because very few operations researchers have significant medical knowledge and very few medical professionals have operations training. We need more physicians and nurses with exposure to operations or systems thinking and more OR/OM students (and others) to work in healthcare settings. We are already starting to see more of this happening, as medical providers are increasingly attending academic professional meetings and our students are more frequently working on projects and internships in health delivery organizations.

As more and more OR/OM researchers contribute to operational decision making in the healthcare field, we will see more *direct* benefits. These are typically observed in terms of reduced patient waiting, better access, improved utilization, and cost savings. Achieving these benefits may involve resolving trade-offs between competing goals: providing care to different types of patients (e.g., within an ED), balancing the benefits between patients and providers (e.g., patient waiting and provider idle time or overtime), and achieving a mix of cost savings and increased access.

The *indirect* benefits of increased operational focus on healthcare may indeed include improved patient outcomes, such as those typically associated with medical decision making. For example, improving capacity management may reduce waiting, which may lower complications and the need for repeat visits. The best care choice for an individual patient could have negative consequences for other patients, resulting in lower quality of care. These trade-offs may not be easy to identify, let alone quantify, but their pursuit should be one of our goals.

Centralization and Flexibility

Care of a patient can involve a huge number of different decisions and decision makers. Green posits that one of the issues preventing more rapid and widespread improvement in the healthcare industry is that there is little or no communication or coordination among the various providers typically involved in caring for a patient. Some may then conclude that improving operational effectiveness would require increased centralization, at least for some types of decisions. Centralization can aid in decreasing waste. For example, redundant and unnecessary replication of tests and consultations may be avoided if the knowledge of a patient's medical history is centralized. Centralization can also improve the consistency of decision making. An increasing emphasis on adherence to standards of care, and the use of care pathways (standardized protocols for treating specific diseases and conditions), suggests that consistency is valuable in many cases.

Related to centralization is the issue of flexibility, as the benefits of flexibility can be difficult to realize without some centralized oversight. Determining how much and what kind of flexibility will require centralized decision making, or at least agreement among, and oversight by, the various entities that interact with the policy. Specialization, or the tendency for a resource to focus more and more on an increasingly narrow set of goods or services, may increase in the absence of such oversight. This can lead to an imbalance in the larger care delivery system and cause a situation where some fields may not have sufficient capacity. A lack of primary care physicians in the United States is but one immediate example of such a shortage (Steinbrook 2009). But, as we discuss later, centralizing decision making, such as is common in standardization efforts, may have its own risks.

Flexibility often is expensive, but it has been shown that even a very small amount of flexibility may lead to almost all of the benefits associated with completely flexible resources. In ongoing research with colleagues, initial results suggest that making even a few operating rooms flexible (available for both emergency patients and scheduled cases) yields nearly 100% of the performance improvements achieved by making all operating rooms flexible, yet causes far less disruption to existing schedules. Like the findings of Jordan and Graves (1995), this contributes to the body of evidence suggesting that operational flexibility can be an extremely powerful tool when attempting to expand access without raising costs.

Dealing with Change

Uncertainty around events is common in the complex world of hospitals and clinics. Decision making in this environment is very difficult. Some analytic approaches may take this uncertainty into account, but the likelihood that the future will unfold as expected is slim, and the hospital is faced with altering decisions or coping with possibly less-than-optimal solutions and getting unexpected results. We need ways of dealing with these uncertain environments, through models and solution approaches that handle stochastic elements more thoughtfully and completely.

One way of dealing with this uncertainty is to build extra resources into the system. This slack accounts for the possibility that demand will be higher than expected. Obviously, this "safe" system may be easy to model and solve, at least, conceptually, but is least desirable in terms of cost (Baker and Trietsch 2009). This approach may need only basic information about system demand and may not require sophisticated monitoring of process realizations.

A second, more thoughtful, approach is to divide the demand into components—such as, separating out the low-uncertainty demand from the high-uncertainty demand—and then build parallel, strategically aligned systems. An efficient system should handle the low-uncertainty demand (e.g., scheduled outpatient visits), and a responsive system should handle the high-uncertainty demand (e.g., emergency departments). In fact, many EDs are adding a "fast track" system to accommodate the low-acuity stream of patients that should probably be seen in an acute-care clinic, but who come to the ED because of lack of insurance, convenience, or other reasons. The processing of these patients has less uncertainty than the higher-acuity patients. Taking the low-acuity patients out of the main ED flow improves responsiveness to patients who need immediate attention. This separate-systems approach is consistent with Fisher's well-known supply chain paper (Fisher 1997) and echoes part of the discussion on flexibility above.

A third approach is to employ sophisticated modeling techniques, such as stochastic optimization, to determine the best operating policy or plan for a given system. However, because of the size and/or complexity of many healthcare systems in practice, stochastic optimization techniques alone are rarely able to provide detailed recommendations for specific healthcare environments. To address that, these methods are being combined with simulation, which combines the analytical power of optimization with simulation's capacity for considering massive amounts of variability that may not always follow well-defined or mathematically convenient distributions. One example of this is the scheduling of complex outpatient clinics (Froehle and Magazine 2012). We have used integer programming to schedule the many resources for a given set of patients. Almost surely, we will not be able to follow the schedule as planned; patients will arrive late or not at all, providers will take much longer than expected to do a task, or a particular resource is not needed when scheduled. One can attempt to use a robust measure in building the schedule, but we have not successfully identified one that can deal with all of the contingencies possible. Ideally, we would like to continuously change the schedule as new information reveals itself. This requires a decision-making capability that has not been addressed with current technologies.

The Increasing Importance of Information Technologies

Green discusses the investments in healthcare information technology (HIT) and suggests that we need a similar investment in operations management. We believe that investing in one without the other is likely wasteful. Some current HIT can tell us what is happening (descriptive), but, without commensurate investments in operational modeling, HIT's ability to tell us what *will* happen (predictive) or what operational actions are likely best (prescriptive) is extremely limited. Similarly, investing in operations analysis without improving HIT capabilities provides no long-term sustainable improvement. The organization may get a very good peek into what it is doing, or even *should* do right now, via operations modeling, but, as the state of the system changes, those policies may no longer be optimal. Without the supporting organizational data being regularly refreshed, the methods are unable to integrate that change and provide current best approaches.

Unfortunately, most off-the-shelf electronic health records (EHR) systems do not, as of yet, pay much attention to operational data gathering. EHRs primarily focus on clinical/patient data and care "transactions" (for billing purposes). Unfortunately, making up for this inadequacy is not yet second nature to most healthcare organizations. It is often not obvious to administrative units what operational data they should be collecting. For instance, we might have an indication when a patient arrives and leaves the clinic. In a complex environment with many providers and many visits by the physician, this inability to resolve beyond "length of stay" is inadequate for precise decision making. In hospital EDs, we often see when a physician first sees a patient and when the physician decides on the final disposition of the patient. But, because of multiple visits by the physician and many tests and waiting by the patient, we do not get a fruitful understanding of the physician's actual service time. And, without that detail, the potential benefit of specific interventions cannot be adequately estimated.

One recent study we were involved in focused on resolving the hand-offs between the emergency department and radiology. To gain even a basic level of data-driven insight into how the process was performing, we required records from four different hospital information systems. While the findings from this investigation were ultimately useful in improving the hand-off between the two departments, the delay between data being recorded and the same data being available to be analyzed and made useful for system improvement was measured in weeks. Although this might be acceptable for gradual system improvement over time, it is wholly incompatible with helping any particular patient receive timely and efficient care.

HIT that are more operationally sensitive, such as real-time locating technologies like RFID, are needed to get the most appropriate event timestamps to build useful system models. We have been involved in several efforts to improve patient flow that relied on manual data collection. One approach uses nurses and support personnel to collect the data, whereas a different approach asks the providers themselves to interact with a tracking mechanism (e.g., entering timestamps when they begin and end interactions with patients). The first approach is very expensive, and the second approach rarely yields data with the consistency and accuracy we require. Without pervasive technologies collecting operational data automatically in the background, we are very limited in our ability to assist operational decision making in real time and with high confidence in our recommendations.

Integrating these operationally savvy HIT is yet another aspect of improvement that many OR/OM academics have precious little experience. Whereas there are unique challenges associated with working with healthcare professionals, as we discuss next, there are also challenges associated with working with the HIT professionals that develop and implement these technologies in hospitals, clinics, and other delivery environments. Much has been written on the operational challenges associated with enterprise resource planning (ERP) system design and implementation (Finney and Corbett 2007), and the introduction of large-scale healthcare technologies like EHR seems to be following a similar trajectory.

Working with Physicians—Implementation Issues

Many of our operations colleagues say they would like to get involved in healthcare delivery operational issues. They do not feel as if they have the contacts, and entry is a barrier. We have been fortunate to find administrators, physicians, and other decision makers to provide this entry. Nevertheless, sustaining our recommendations is a very difficult problem and barrier for implementation. Whereas some operational analysis opportunities are one-off strategic decisions, such as where to locate a new hospital, or how many operating rooms to include in a new wing, many involve day-to-day tactical decisions that need to be reanalyzed regularly. In these cases, we need to enable practitioners to reanalyze their operations regularly so that the improvements are unlikely to be sustainable. This will require inserting solution methods in a framework that makes them more accessible. Otherwise, traditional methods of organizational guidance, such as management by anecdote, and greasing particularly squeaky wheels first, will return to dominate decision making.

Involving a team of academics each time one of these tactical decisions has to be made is inadequately scalable. We need to partner with our IS colleagues and work with healthcare IT vendors, not just the practitioners, to get our methods embedded into the systems that hospitals and clinics are adopting already. We were asked to develop a new workforce schedule (Ferrand et al. 2011) for a local hospital. Because we embedded the decision-making logic contained in our model into their own scheduling system, the system should remain usable despite future changes in personnel, rules, or preferences.

Also, when starting to work in healthcare, operations researchers need to begin to understand the unique culture of that industry. We will not belabor the point, as there has been much written on it, but suffice to say that one cannot walk into a hospital with the same mentality as one might approach a manufacturing facility or even a traditional service organization. Learning how healthcare professionals think about quality, for example, is eye-opening because the concept of "acceptable defects" often simply does not exist in that context.

One particular challenge that operations researchers may face when working with healthcare practitioners, directly stems from the push toward centralization and standardization that has benefitted many other industries, not the least of which is manufacturing. As medicine has traditionally been taught as a combination of science and art—dependent upon both intellect and creativity—practitioners tend to be wary of efforts that may curtail their autonomy. The thought of reducing their ability to make decisions on their own raises at least two concerns in some providers. First, inappropriate standardization may threaten the quality of care they provide or perceive to their patients (Bohmer 2005). Second, a reduction in autonomy can be unappealing, if not insulting, to many highly trained practitioners in knowledge-intensive professions, medicine being no exception. For at least these reasons, standardization cannot, and should not, be used as a blunt instrument.

When collaborating with physicians on a research project, they will often want to evaluate the effects of operational intervention on patient outcomes. This is important to do, but is also extremely difficult. Because of the indirect nature of the effects, its impact can be small, thereby requiring a lot of data and/or highly precise methods to identify significant changes. Also, because medical environments rarely go very long without something changing, eliminating potential confounds can also be difficult. For example, accounting for changes in patient census, tracking staffing levels, or adjusting for institutional, state, or federal policy changes can be imperative if the effect of an operational intervention is to be evaluated in practice.

Summing Up

When Green (2012, p. 493) says that these "are but a few of the many challenges that exist and will arise as health delivery systems...evolve," we could not agree more. We have only touched on a few of the applications of operations management to healthcare in general, and to the delivery of healthcare in particular. Each time we go to a clinic, talk with a medical provider, or visit the emergency room (hopefully not as a patient), we will encounter new problems that will be ripe for analysis. We invite our colleagues to join us in this important and rewarding venture.

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Driving New Science of Healthcare Delivery: What Does It Take to Make an Impact?

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Introduction

In her paper, Green (2012) discusses the vital role of "operations analysis" in "fixing" the national healthcare delivery system in the United States and highlights several important directions, in which operations research and operations management approaches could be applied to obtain more coordinated and cost-effective processes and systems. Indeed, the continuous rise of healthcare costs in the United States (over 17.6% of the national gross domestic product; equal to over 2.9 trillion dollars last year) (Martin et al. 2011), as well as the aging population and the striking increase in the incidence of obesity, diabetes, and other chronic illnesses (Centers for Disease Control and Prevention 2010), threaten the financial stability of the United States. Moreover, in spite of excessive spending, the U.S. healthcare delivery system has serious quality and access problems (Kohn et al. 2000, Leape and Berwick 2005, New England Healthcare Institute 2007), and falls behind other developed countries with respect to many comparative quality indicators (OECD 2011).

Complementary to Green (2012), the premise of this commentary is to challenge the operations management (OM) community and suggests that it has a unique opportunity to play a major role in developing a *new science of healthcare delivery* that will enable the design of new, more cost-effective healthcare delivery approaches, methods, and organizations. In particular, we would like to discuss "How can the OM community make an impact?" Impact here refers to tangible and sustainable large-scale implementations and changes in the operations of healthcare delivery systems (HDSs), as well as policy changes directly driven by work done in the OM community. In spite of an increasing number of papers, and without underestimating several very impressive success stories, it is fair to say that the OM community has not yet achieved significant impact on healthcare policy makers or clinicians and administrators within large HDSs. Increasing the impact of the OM community on the healthcare industry will not be accomplished merely by marginally tweaking the existing toolkit of methods and models, but will require developing new models and domains of knowledge, as well as collaborating with new communities in new ways.

The public debate around healthcare delivery in the United States has been impacted over the years primarily by traditional economists and public health experts, who, for the most part, view the core problem as a *market incentive problem*. Inherent in this approach is the perspective that the core problem is misaligned incentives, and that the primary way to fix this is by changing the *payment scheme* (Ma 1994, Epstein et al. 2004, Porter 2010). Policy makers have emphasized these issues for many reasons, one of which is that the payment scheme can be regulated through legislation. However, past attempts to change the payment schemes were not successful in ultimately controlling cost increases, nor they were successful in increasing the quality of care. Another approach that has evolved over recent years is focused on *process improvement and reengineering* through a variety of methods borrowed from other industries (e.g., *lean approach*) (Bohmer 2010). This approach aims to engage front-line clinicians in efforts of process improvement with the primary goal of increasing efficiency and reducing medical errors. Whereas several academics in the OM community are involved in efforts of the latter type, the majority of these efforts are led internally within hospitals or by external consulting firms.

Although these approaches have merit, they alone do not seem to be sufficient to drive and sustain the changes that are needed. There are at least two major issues that do not receive sufficient attention. First, the realization that healthcare is delivered by *complex* *organizations* (Glouberman and Mintzberg 2001a, b) that are largely defined by their history and cultures (Starr 1982) and driven by a potentially contradicting set of objectives and complex dynamics. Second, the understanding that sustainable solutions to the national challenge of healthcare delivery in the United States require a fundamental change in the core operational and organizational capabilities of most of the existing HDSs. However, if one accepts this perspective, the implication is that to make a tangible impact, the OM community will not be able to merely take its existing toolkits and simply apply them to healthcare management problems. Rather, the OM community will have to develop new *knowledge domains* by engaging and closely collaborating with clinicians and administrators in HDSs and other players in the industry, such as payers, pharmaceutical, and biomedical companies. Specifically, it will require spending time and effort studying and understanding not only clinical aspects of healthcare, but equally important aspects related to the respective organizational and cultural complexities. Only the integration of operations research approaches with other related disciplines (e.g., economics, marketing, finance, psychology, behavioral organization) will allow the creation of this much needed new science of how to provide systematic and sustainable cost-effective healthcare.

In what follows, we discuss, in more detail, several related examples and issues that highlight some of the organizational complexities in healthcare environments, as well as suggest some potential interesting future directions of work for the OM community. We then proceed to describe a model of collaboration between academics with OM background, and large academic medical centers (AMCs) that has been proven to be very successful.

Academic Medical Centers—Threefold Mission Organizations

The public discussion around healthcare has focused almost entirely on issues of cost, access, and quality related to the delivery of *healthcare services*. AMCs receive special attention, because they serve as the backbone of the national healthcare delivery system, take care of the sickest patients, and incur the highest costs. There are currently 1,100 teaching hospitals in the United States, out of which about 375 are larger centers that form the backbone of the healthcare system in the United States. (More than 40% of the healthcare expenditures in the United States are related to hospitals (Herzlinger and Grahling 2008).)

Unlike other hospitals and nonacademic HDSs that focus entirely on delivering clinical care, AMCs have at least two additional important missions: education and research. AMCs train future physicians and other clinicians, as well as conduct research that contributes to the development of new drugs, medical equipment, and clinical treatments. The balance of these missions is organization-specific. AMCs do not usually consist of one integrated unit, but rather comprise three major entities: (i) the hospital, (ii) the medical school, and (iii) the physician organization and their practices. The relationship between these entities varies depending on the specific medical center; in fact, almost any configuration of relationship exists (e.g., all separated entities, fully integrated entities, hospitals and physicians integrated but separated from the medical school, etc.). Naturally, each one of these entities views the various missions in different priority order. For example, the chief executive officer of the hospital usually focuses mostly on clinical services, whereas the dean of the medical school cares mostly about teaching and research. Thus, the structure of the relationships between the three entities significantly affects the culture and priorities of the respective organization. Ignoring the educational and research missions could have very negative long-term implications. For example, as Green (2012) mentions, it is well known that one of the major barriers to providing cost-effective and appropriate access to care in the United States is the lack of sufficient number of healthcare providers, especially, primary care physicians (PCPs). The shortage of PCPs could undermine many of the proposed changes in the healthcare industry in the United States and, in particular, the recently approved national healthcare reform legislation (Bohmer and Knoop 2007). Training physicians is currently a very long and expensive process that will be hard to change quickly. One of the major bottlenecks in training more physicians is the requirement to expose them to certain types and numbers of respective clinical conditions. This has become an even bigger challenge because of recent regulations that restrict the number of daily and weekly hours residents can work. Whether there exist better ways to design residents training and expedite it is still an open question. To demonstrate the tension between competing objectives in the day-to-day operations and systems design of AMCs, we next discuss a concrete representative example.

Anesthesia Staffing

Unlike private practices, where anesthesiologists administer anesthesia and usually work independently in the operating room, in AMCs there is typically a two-level coverage model. In most cases, each operating room is staffed by either a resident or a certified registered nurse anesthetist (CRNA) that administers the anesthesia to the patient. The anesthesiologists (senior doctors or "attending" physicians) can each supervise up to four operating rooms that are all staffed with CRNAs. However, even if one operating room is staffed with a resident, the attending can supervise at most two rooms. Financially, it is usually most beneficial to use many CRNAs, and maximize the utilization of the most expensive resource, i.e., the anesthesiologist. However, the training requirements of residents often drive their assignment to specific cases. Furthermore, CRNAs do not usually maintain a research or professional academic agenda, which can be a major cultural consideration in restricting the number of CRNAs in an academic anesthesia department. Attendings that maintain a focused research agenda in a certain area of anesthesia might seek to practice only in that specific area, which limits flexibility and challenges "efficient" capacity utilization. The decision on the right mix of attendings, residents and CRNAs, as well as the professional profile (level of specialization) of the attendings, has to balance multiple contradicting objectives and financial considerations.

The previous discussion and example described above demonstrate the need for models that do not simply optimize with respect to a single objective, but rather quantify the *trade-offs* between different (competing) objectives and present solutions on the efficiency frontier. In addition, practical models must incorporate the cultural and organizational aspects of the specific AMC being studied. The need for richer quantitative models represents a major opportunity for the OM community. The modeling of cultural and organizational aspects will require the adaptation of traditional models and approaches in ways that could benefit the entire research in the OM field and increase its impact on many areas beyond the healthcare arena. To capture these aspects, new types of multiobjective, potentially noncentralized models will have to be developed and new constraints will have to be incorporated. The discipline of *behavioral and organizational operations* will have to be further developed.

What Does Cost-Effective Mean?

In this section, we discuss the issue of *cost-effectiveness* in the context of HDSs and AMCs and, particularly, the challenges to define and reliably estimate cost-effectiveness. Measuring cost within HDSs and AMCs is surprisingly very challenging. There are several methodologies that hospitals use to measure their cost (e.g., see High-Value Health Care Project 2011). Most, if not all, of the approaches assign costs to each activity (or an episode), both directly based on the resources that this activity consumes and indirectly through the allocation of some fraction of the total overhead costs (Kaplan and Porter 2011). These approaches usually lack a sound operational perspective, and have several potential flaws. First, they can easily lead to confusion between different types of costs (e.g., fixed, variable, marginal), which in turn can lead to flawed and even adverse decisions (Lexa et al. 2005). In addition, there is usually no explicit quantification of the cost of providing *access*. In particular, hospitals are currently paid only for activities directly related to providing care to patients, and not for providing access, such as 24/7 access to the emergency room. Another major concept that is missing from current cost accounting methodologies used by hospitals is the notion of *opportunity cost*, i.e., the cost of performing one activity at the expense of not doing another activity that competes on overlapping resources. Finally, reliable measurements of cost in healthcare environments is challenging because of the lack of relevant operational data that is typically not being collected, at least not in a way that makes it easily accessible.

The notion of efficiency in HDSs/AMCs is also quite challenging because of multiple contradicting objectives. There is often lack of a clear definition of what the performance targets of the *system* should be. Many of the operational performance measures currently in use are "local" in nature, and it is difficult to demonstrate why they necessarily reflect a higher level of system efficiency. Locally defined performance targets can potentially lead to unintended adverse effect on the overall performance of the system. For example, many hospitals place significant attention and effort to reduce the turnaround time between surgical cases performed consecutively at the same operating room. However, it is not clear how improving this performance measure (i.e., reducing the turnaround time) translates necessarily to better overall system performance.

The discussion around cost-effectiveness is also related to the notions of *value and quality* in healthcare environments. This is yet another challenging aspect in creating common methodologies to measure cost-effectiveness. There are recent efforts to establish quality measurements that allow comparisons between different HDSs/AMCs and the creations of targets of "best" practices (see Green 2012). However, it is fair to say that thus far, most of the quality measures being used are *process-compliance based* (Porter 2010). That is, they measure how clinicians and HDSs/AMCs comply with specified processes, but are not necessarily tied to outcomes. In particular, in some cases these performance measures may alter the behavior of clinicians, sometimes in unintended directions that do not necessarily lead to better quality of care. The challenge stems from many factors, two of which are the lack of sufficiently sound methods to account for variability in the health status of different patient populations (also known as *risk adjustment*) and its impact on outcomes, as well as the fact that healthcare outcomes often need to be measured over long periods of time, sometimes over many years.

Reducing variability in HDSs/AMCs is generally considered an effective way to increase system efficiency. HDSs tend to have many sources of variability, some of which are driven by the inherent variability of patients and the environment, and some others are the result of how the system is organized and operates and how clinicians practice (see Green 2012). The latter type of variability is *artificial* in the sense that it is not inherent to the environment. This is the type of variability that should ideally be eliminated or at least be minimized. However, most HDSs/AMCs do not have reliable tools to understand the overall sources of variability in the system, let alone predict in advance how the system will evolve.

Another issue that complicates the discussion around cost-effectiveness in healthcare environments is the notion of *fairness*. In many settings in healthcare, the most "efficient" solution will be not acceptable from a social or patient fairness perspective. The notion of fairness is central to many emotionally and politically charged issues, such as *end of life* care and the minimum level of care that every citizen is entitled to.

The OM community could play a major role in creating systematic ways to measure cost-effectiveness and quality within HDSs. Many cost concepts from operations, supply chain management, and revenue management could potentially be adapted to create new data-driven models that make explicit connections between cost and efficiency with respect to specified system performance targets. There is a major need to use state-of-the-art tools from statistical, machine learning together with operational methodologies to develop new predictive models for the operational dynamics of HDSs, as well as the characteristics of patient populations that potentially affect clinical outcomes. Finally, OM models have a tremendous potential of incorporating the notion of fairness at the policy level, as well as assisting with more operational and tactical level decisions (Bertsimas et al. 2011).

A Model of Collaboration

This section is based on the common experience of the authors in leading and shaping a long-term strategic collaborative relationship between the Sloan School of Management at the Massachusetts Institute of Technology (MIT) and the Massachusetts General Hospital (MGH) in Boston. As part of this collaboration, we have created a large team of MIT faculty, postdoctoral fellows, and graduate students, as well as clinicians and administrators from MGH that have been working together for several years on a systematic effort to redesign the perioperative care system, which is responsible to care for surgical patients within the hospital.

MGH is one of the largest and oldest premier hospitals in the United States, with over 900 beds, 56 operating rooms, and over 35,000 surgeries annually. It is also the largest nongovernmental employer in the state of Massachusetts, with over 23,000 employees. MGH delivers a broad range of healthcare services (from very simple to the most complex) in multiple locations, maintains extensive teaching and research programs, and is involved in various community service activities.

The collaborative relationship between Sloan and MGH has already yielded several large-scale implementations, including a recent major change in the scheduling processes of elective and nonelective surgeries. As part of this change, 40% of over 230 surgeons changed their day of surgery, and other related significant policy changes were implemented. Initial results are very promising. The collaboration has also yielded several academic publications in various stages (Schoenmyer et al. 2009; Segev et al. 2012; Ghassemi et al. 2011; Johnson et al. 2012; Carnes et al. 2011a, b; Christensen et al. 2012a, b) and case studies that are used in the classroom (McCarty et al. 2012).

Instead of diving into a detailed discussion of the specifics of any single project, we use the limited space of this commentary to briefly describe some of the core principles underlying the collaborative relationship described above. We believe that this is a very powerful model of collaboration, which could leverage the 'know-how' expertise of the OM community into tangible long-term strategic impact on AMCs (and HDSs) and the healthcare industry in general:

- **Work on top priority system issues.** We made sure to work only on top-priority central issues to the *organization* and aimed to identify end-to-end system goals, rather than "local" ones.
- **Learn the mutual cultures and organizational dynamics.** The working team meets regularly (several times every week) to discuss the various aspects of the projects with great emphasis on the respective stakeholders. There has been a mutual effort to learn the respective cultures and ways of thinking and willingness to adapt and create productive synergies.
- **Adapting traditional models.** The team was open to adapting traditional models as needed. For example, in traditional queuing models the processing time of a job is not affected by the time it waits in the queue. However, empirical data suggests that in HDSs, patients that are delayed in getting access to the appropriate level of care tend to ultimately consume more resources (Carnes et al. 2011a, Chan and Farias 2011). In addition, when appropriate, the team incorporated experts' opinions into the

quantitative models, i.e., the operational intuitions and clinical expertise of the clinicians and administrators in the hospital. The goal was usually not to find the "optimal" solution with respect to one objective, but to obtain conceptually simple models and solutions that highlight the respective trade-offs between several objectives.

- **Champions.** The existence of champions on both sides has been crucial. Specifically, the executive medical director of perioperative services at MGH, Peter Dunn (an accomplished clinician), and Retsef Levi have been jointly leading the project and developed the vision and the agenda of the collaboration.
- **Hospital senior leadership support.** The collaboration has been sponsored by the senior leadership of the hospital, specifically, Ann Prestipino and the president of the hospital. They were willing to commit extensive funding to support MIT as well as MGH resources. Senior leadership played a central role in the implementation of the recommendations of the project team; this included, among others, the president of the hospital, the surgeon-in-chief, the chief executive officer of the physician organization, and Ann Prestipino.
- **From planning to execution.** The project team not only formed recommendations and solution approaches based on data-driven analysis and analytical operational models, but also developed decision support tools and supported the implementation phase. In particular, many of the initial solutions had to be modified to accommodate various organizational and other constraints. The tools that have been developed played a major role in guiding and informing the management of the organizational change. After the implementation, the team developed methodologies to analyze the outcomes and monitor the changes and trends in the performance of the system.
- **Academic publications and teaching.** The project has had a clear goal of transforming the work done as part of the project into academic publications and teaching material that can used in the classroom.

Based on this successful model of collaboration, the Sloan School of Management has developed similar relationships with additional AMCs and healthcare organizations and companies in the Boston area and beyond. We believe that this model of collaboration is potentially a key to accomplish major system level changes in complex HDSs.

Conclusions

The premise of this commentary is to suggest that the OM community has a unique opportunity to play a major role in developing a new science of healthcare delivery that will enable the design of new more cost-effective healthcare delivery approaches, methods, and organizations. Indeed, this is a unique opportunity to make a long-lasting impact on one of the most important national challenges that the United States is currently facing. Green (2012) as well as the corresponding commentaries outline just a few examples of central issues that should be addressed.

However, this will not be accomplished merely by tweaking the existing toolkit and writing about marginally new variants of known models. It will require the study and development of new models and tools that explicitly incorporate organizational and cultural aspects of complex organizations. Moreover, it will require institute-level collaborations with HDSs and other players in the healthcare industry, as well as the willingness to study and understand their unique cultural and organizational complexities.

The OM community could lead this process by developing a range of analytical data-driven tools that will equip HDSs with new and much needed operational and organizational capabilities. However, only the integration of analytics and the development of a deep understanding of these complex organizations, as well as individual behaviors of patients and providers, will ultimately lead to tangible impact on the respective organizations.

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Can OR/MS Be a Change Agent in Healthcare?

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Green (2012) has done an excellent job summarizing the main deficiencies in the healthcare delivery system, in particular, focusing on how "current systems are highly fragmented and suffer from a lack of coordination and communication" (p. 488). The result is failure to "achieve cost-effective and timely access to appropriate care" (p. 488). She also explores how operations research and management science (OR/MS) can play an important role in improving the healthcare systems, and she identifies the kinds of problems she believes are well suited to OR/MS analyses. Green correctly puts capacity setting and allocation decisions at the heart of the OR/MS role. These are the kind of decisions that our field traditionally addresses and is adept at. These are also decisions that are challenging in the healthcare setting, and any change to the healthcare system will impact these decisions significantly, as Green describes. Although I agree with Green's assessment, in this comment I build on her analysis by advocating for a more ambitious agenda that puts OR/MS in the role of change catalyst as well as broadens the range of problems we study.

Breaking the Cost Model

Most OR/MS research on healthcare takes the particular portfolio of healthcare services as given and attempts to reduce its costs often by better matching capacity to demand to increase resource utilization without reducing access. Efforts to model outpatient appointment scheduling and surgical scheduling are all based on the desire to increase access to service given a fixed capacity. Some approaches like advanced access will only work if the capacity of a provider is set correctly (Dobson et al. 2011, Green and Savin 2008). Although of value, all of these analyses tend to be restricted to the existing cost framework of existing delivery systems.

The OR/MS community should do more to challenge the existing cost structure of the health delivery system and use its tools to analyze the benefits of fundamental changes that are just over the horizon and therefore accelerate their adoption. For example, it is currently the standard that a doctor's office is located in a dedicated medical office park with its own parking lot and buildings. Inside each practice there is a dedicated waiting room and at least one receptionist, several nurses, several exam rooms, and an office manager and/or billing person, in addition to the doctors and perhaps nurse practitioners and lower-level nursing staff. Work is strictly divided. Only the receptionist will answer the phone and schedule appointments; however, he or she may request input from the providers. Only the office manager handles billing, only a nurse or medical technician greets the patient in the waiting room, takes them to an exam room and takes vitals, etc. In recent years there have been attempts to break this system and replace it with one that has many fewer support staff and a doctor heavily supported by information technology. Operations analysts know that handoffs are detrimental to efficiency; we know that specialization advantages are probably meager with many of the low-level tasks done by medical support staff. We know that many of these tasks can be managed by technology, e.g., online appointment booking. Finally, we also know that patients crave more time with their physicians. Yet there has been little rigorous study of the application of lean practices to the operations of outpatient medical offices.

We can take this a step further and ask why should providers be isolated in their office-park fortresses? Why not place small doctors' offices in leased space within an adjoining supermarket? This has already begun to happen with Walmart, CVS, and others establishing clinics in their retail spaces. This means shared parking space and utilities; a waiting room that is the shopping area, making it useful for the consumers/patients; and revenue generating. Such medical stations are probably not appropriate for outpatient surgery but are good for immunization, urgent care, and collection of health data for maintenance of chronic conditions and other services that work well in a walk-up access setting. This will reduce the need to see a regular physician except for physicals and more serious consultations. One could argue that such an approach would reduce the continuity of care, but it should also be realized that many people do not go to the doctor frequently anyway, and when they have urgent care needs go to whatever doctor is available in their practice or covering after hours. Furthermore, many typically lower-economic-class patients go to clinics staffed with many residents who turnover frequently. On the positive side, this alternative care distribution network can be utilized to provide PCPs with more data on their patients. For example an HMO can give patients small incentives to get their vitals checked monthly at these supermarket outposts. These data would be delivered electronically to the PCPs medical records and so, at the next physical or other appointment with a PCP, there is a richer time series of health data to look at. An electronic medical record could also alert a PCP to those patient's changes in health status if it detects anomalies. Currently, it is not convenient or cost-effective for a patient to make a trip to their PCP to collect health data. The design of these alternative healthcare distribution networks is a perfect problem for OR/MS analysts to address. There are issues of cost structure, accessibility and timeliness of care, division of labor, and the types of care delivered among others that all must be integrated in the analyses. The important point here is that instead of waiting for others to propose changes to the healthcare delivery system and then determining the resulting capacity needs, OR/MS researchers should be drawing on our own expertise in system design to propose the changes to the delivery system ourselves.

Broadening Our Goals

In recent years there has been increasing attention given to finding evidence that particular medical treatments and diagnostic procedures are truly effective. For example, mammography (Kolata 2009, Stein 2009) and prostate-specific antigen tests (Harris 2011) are under increasing scrutiny that questions whether they actually save lives and suggests that they lead to many unnecessary expensive and damaging treatments. The typical approach to studying medical treatments is to compare the health of populations that receive a treatment with those that have not, at different points in time after treatment. They control for risk factors and demographics, and the gold standard is a double-blind randomized study in which neither the investigators nor the subjects are aware of whether or not they receive the treatment. A limitation of even the best of these studies is that they are very narrow in scope and ignore the reality that medical treatment is an optimal control problem. Patients are receiving treatments and undergoing tests over time and in each period incur costs from these medical procedures as well as experience quality of life based on their health status. Similarly, there are societal costs from the medical procedures and gains from increased quality of life and life expectancy. Truly evaluating the "efficacy" of a treatment requires an analysis within this broader and richer framework. The OR/MS community has much to offer in this regard, and one area in which this has been demonstrated has been in modeling the spread and control of infectious diseases. See, for example, the work of Kaplan and O'Keefe (1993), Zaric and Brandeau (2001), and Long et al. (2008). This work does not only evaluate medical care procedures but it also enables the optimization of this care. The study of optimal organ transplant rules (Zenios et al. 2000, Kong et al. 2010) and, for example, optimization of dialysis treatment (Lee et al. 2008), are examples of cases where OR/MS techniques have been used to find ways to make treatment more effective.

We are still far from reaching the full potential of optimizing the healthcare that is delivered. One important trend here is the increased customization or personalization of healthcare. There are two sides to this: customization of treatment to the specific characteristics of an individual patient and patient differences in terms of what they are seeking to achieve with medical treatment, e.g., tolerance for risk and side effects etc. This means that we need to move away from the model of optimizing healthcare at the population level toward solving the individual level optimal control problem. In the language of Markov decision processes, both the value functions and the action spaces differ from patient to patient. There is an opportunity here to develop tools that can guide a patient through the healthcare system, including information on treatment and diagnostic pathways, as well as financial ramifications given one's insurance. Currently, the user interface for our healthcare system is a conversation with a physician. Looking ahead, using our knowledge of optimization, decision analysis, risk modeling, artificial intelligence, and information systems, the OR/MS community could be developing a future user interface for the healthcare system that can provide a customized health analysis that informs and empowers the patient to make usage choices that will lead to the best outcomes for them.

Behavior

In her discussion of medical homes and accountable care organizations, Green has noted the important implications of shifts in incentives for care providers for how resources are used in the healthcare delivery system. I elaborate on some of these issues here, because, unfortunately, often a weak point in OR/MS work has been a tendency to ignore the response of actors in a system to proposed changes. In healthcare, this is particularly important because it is very difficult to monitor the interactions of providers and patients, and in the case of the decentralized U.S. healthcare system, even more pronounced. The patient typically lacks the medical expertise to evaluate the care they receive, and the measurement of quality of care is an underdeveloped science with often long lags until success can be assessed. As a result, assessment of quality of care must often rely on intermediate measures, such as compliance with certain protocols that are indirect indicators of ultimate patient well being and quality of care.

In the U.S. healthcare system, the provider plays a central role in determining the consumption of resources and must balance the sometimes conflicting objectives of the entire system. Ethically, they must serve and advocate for the best interests of their patients but also have responsibility to the institution that employs them and the broader healthcare system. Finally, they have their own selfish professional and financial incentives. For example, some physicians may face pressure from their patients to prescribe them antibiotics even in situations that do not really call for them. Over prescription of antibiotics leads to more rapid obsolescence because resistant strains of bacteria develop, thus hurting society at large. A physician may order tests that have a low probability of influencing decisions or treatment, to play it safe and protect himself from malpractice lawsuits, knowing that the patient will not bear the financial costs of the tests. Physicians also resist giving access to patients via email and phone if they are not compensated for this service. There are also cultural and professional biases that stem from the training and previous experience of the providers. For example, a surgeon may be more likely to recommend surgery than a medical specialist. Taking the independence of these actors into account will be critical to the success of any proposed improvements.

Fortunately, in recent year there has been increased inclusion of principal-agent issues in OR/MS modeling. Some of these efforts have also appeared in healthcare applications. For example, using gatekeepers successfully to do triaging to determine whether a patient should be referred to an expert or specialist relies on the gatekeeper (a nurse or primary care physician) making the right choices of who to refer. Shumsky and Pinker (2003) show how incentive contracts for the gatekeepers can lead to system optimal gatekeeper behavior. Fuliora and Zenios (2001) look at principal-agent issues in dialysis treatment. The follow-up work by Lee and Zenios (2011) takes this further to empirically demonstrate how dialysis clinics respond to incentives and show how using risk-adjusted performance outcomes in setting payments can potentially reduce hospital admissions.

Keeney (2008) demonstrated that many deaths and medical conditions are caused by poor decision making. Even if our health delivery system is perfect, if people engage in behaviors that lead to obesity and its concomitant diabetes, heart disease, etc., costs will still be unacceptably high. Rather, we need to view the poor behaviors as symptoms of a disease that must be studied and controlled in similar ways to which we have addressed diseases like HIV. This can be viewed as combating a social epidemic. The example of obesity and its connection to diabetes highlights an important health trend, which is the explosion of chronic diseases. The Centers for Disease Control and Prevention (CDC 2011) estimates that the direct treatment cost of diabetes in 2007 was $174 billion. There are examples of good OR/MS work, which I have mentioned above, that have sought to optimize the use of treatment resources to serve patients with chronic diseases cost-effectively and to optimize the treatments themselves. We must ask: Are these efforts merely addressing the fringes of the core problem? The core problem is that people are engaged in behaviors that cause obesity and lead to diabetes and other diseases. Is there a research program for OR/MS to find the best ways to decrease the onset of diabetes and increase the adherence of patients to behavioral choices that reduce its symptoms? This is not a problem that necessarily fits the paradigm of OR/MS, but ours is a field that has shown great adaptability in the past, so I do not rule it out.

The recent work by Bradley et al. (2011) perhaps presents a way forward. They show evidence that there is a link between societal health outcomes and spending on social services. This linkage suggests that researchers need to look more broadly at the question of how to improve healthcare. Changing the socioeconomic state of the users of the healthcare system may do more to improve its cost-effectiveness then changing the system itself. If there are significant differences in behavior across socioeconomic classes in terms of risk taking, diet and prevention activities, etc., then social services could lead to significant indirect benefits in healthcare. This type of systems perspective is well suited to operations researchers. Chronic diseases and societal behavior trends require projections of the resource needs into the future, a natural role for OR/MS, as Green (2012) has written. Such projections make sure policy makers understand the scope of the problems we face and can be a spur to action.

Conclusion

Often OR/MS research in healthcare has focused on optimizing the workings of the existing system. In this paper, I have attempted to encourage researchers to be less timid in their goals. One of the great strengths of both analytical and simulation modeling comes from their ability to make predictions about what could happen if we make changes to a system before making these changes in practice. This suggests that OR/MS can be a change agent by giving a rigorous foundation for proposals to make wholesale structural changes to our healthcare system. Pursuing such goals, though, will require an even greater attention to behavioral issues because the success or failure of any proposal may depend strongly on the individual responses of the participants. There is no doubt that there is a role for OR/MS in improving healthcare systems, but we need to be aware of the major societal health trends if we want to have as a significant role as possible.

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Leaving a Mark on Healthcare Delivery with Operations Analysis

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Introduction

In the Dutch context, we see similar problems as outlined in Green's (2012) commentary and also an increased interest by healthcare providers to use operations analysis to confront them. In this commentary, we provide our take on the same problems to extend the discussion and to highlight additional areas for consideration. Furthermore, we discuss recent projects to provide further examples of how operations analysis can be applied within these problem areas. Through this discussion, we aim to emphasize *how* operations analysis can be applied in a scientific, practical, and relevant way in the healthcare domain. Given that many review papers question whether the promised contribution of applying operations analysis is being achieved in healthcare (Lagergren 1998) and because reporting implementation results is rarely done in journal articles (Katsaliaki and Mustafee 2011), we feel there is a need for such a discussion.

As with the U.S. healthcare system, as described by Green, the Netherlands also has an issue of "poor quality and wasteful expenditures." This came to a head in 2006, when the country passed the Healthcare Insurance Act. The Act completely reformed the structure of healthcare delivery with the intent to use competition to breed efficiencies and improve value-for-money. To ensure that all Dutch citizens have the same basic level of health insurance regardless of ability to pay, a number of regulatory elements were introduced. However, significant competition was created at the same time and at two different levels. Competition exists between health insurance companies, which vie for enrollees, and healthcare providers (new and existing), which vie for contracts with health insurance companies. Insurance companies compete mainly by offering extended coverage packages (e.g., additional dentistry, eye-wear, cosmetic surgery, alternative medicine) at lower prices. Healthcare providers compete mainly on the remuneration amounts per diagnosis related group (paid by insurers to providers) and quality of care (e.g., access times, treatment options).

The crucial underpinning of this system is to use competitive markets and insurance companies to force a higher performing and a more cost-effective healthcare system. The extent to which this is working can be debated; however, the concept is generally lauded (Seddon 2008). As is more directly related to this commentary, it has been our experience that this new competition has applied significant pressure on healthcare providers, which has, as a result, significantly increased the use of (and demand for) quantitative analysis.

In the following sections, we discuss specific projects that have addressed problems related to the three "big problem areas" outlined by Green. Whereas Green reports on "what should be done," the focus of this paper is on "what is being done" in the Netherlands, with particular attention paid to its impact on hospital operations. For each problem area, we provide our interpretation and use recent projects as examples to further illustrate how operations analysis can be applied. In the final section, we "sum up" our thoughts and provide summary insights.

Identifying Capacity Needs

Because the financial funds and thus the capacity of healthcare is finite, policy makers have to ration care and make choices on how to distribute physical, human, and monetary resources. An added challenge is that hospitals are designed such that "managers make resource allocation decisions, but doctors decide what the hospital does with those resources" (Carter 2002, p. 29). On an ad hoc basis these decisions are difficult and often plagued with ethical considerations related to who needs it more and how "need" is defined. Capacity planning on a longer horizon requires similar ethical considerations but faces a greater degree of uncertainty. Despite these challenges, advanced capacity planning is important to achieve seamless patient transitions and efficient and manageable resource use systemwide. As such, we agree with Green's (2012) statements that accurately identifying capacity needs is "critical to controlling costs and achieving better clinical outcomes" (p. 489).

As with the intensive care and obstetrics unit examples described by Green, the operating theatre and inpatient wards face similar complexity and uncertainty. This includes multiple patient types, variable service times (and lengths of stay), and uncertain demand. This has led to a significant number of studies of this hospital area, although with reportedly limited evidence of implementation (Cardoen et al. 2010).

Identifying the capacity needs of the ward as a function of the operating theatre schedule can lead to improved patient flow and better resource utilization (Vanberkel et al. 2010a).

Predicting how their redesigned master surgical schedule (MSS) would affect the capacity of the wards was a recent challenge faced by the Netherlands Cancer Institute. Using operations analysis, a model was developed to make the predictions and also to provide insights into the characteristics of good MSSs (Vanberkel et al. 2011). Based on projected periods of over- and underutilization, staff from the wards and the operating theatres reached a consensus on the design of the new MSS. Modeling and analysis gave the hospital the ability to quantify the concerns of multiple departments, thereby providing a platform from which a new MSS could be negotiated. To support future redesigns of the MSS, the hospital worked with their business intelligence developer to implement the model in their system.

Another area where identifying capacity is essential for seamless and sustainable patient care is in clinical practices and, in particular, those with planned follow-up appointments. The appropriate size of these clinics is often referred to as the clinic's panel size. A physician's panel size is defined as the number of patients that he or she can effectively be accountable for. Typically, this is studied in general practice settings where general practitioners want to know how "big" their practice can be (i.e., how many patients they can be accountable for) before the waiting times for appointments becomes too long or overtime too frequent. By identifying the capacity needed for a given panel size, physicians can manage their clinics so as to guarantee certain performance levels. Panel sizes in hospital environments have been studied less, although there are similar concerns. The characteristics of a hospital that distinguish it from a general practice include turnover rates of patients and multiple patient and appointment types (Vanberkel 2011). This is made more complex when treating chronic diseases, because these patients tend to require care and treatment for many years (World Health Organization 2011).

A further factor to consider when identifying capacity needs is the reliability of the source providing the information. Consider an MRI scanning facility, with limited capacity and several medical departments that compete for that capacity. The fairness of the capacity allocation by the radiology department depends on the quality of the information provided by the medical departments. When the departments over- or underestimate the demand, it can occur that the actual demand is less than the allocated capacity (i.e., the scanner sits idle) or the actual demand is larger than the allocated capacity. Perhaps surprising, both situations can arise simultaneously. To have a fair allocation, where all available capacity gets used, the radiology department should motivate medical departments to provide an honest forecast of their demand. As illustrated in a project at the Leiden University Medical (LUMC) center, by using a Bayesian game approach that stimulates the disclosure of true demand (truth-telling), capacity needs can be identified in a fair manner (Zonderland and Timmer 2011).

Dedicated or Flexible Resources

In limiting the range of services offered, specialized departments (or hospitals) use dedicated resources to reduce complexity and allow the department to concentrate on doing fewer things more efficiently. This in turn can lead to decreased service times. This philosophy has been the basis for modern manufacturing plants (i.e., focused factories; Skinner 1985), where focus, simplicity, and repetition aims to breed competence. This is the strategy used at the much lauded Shouldice Hernia Centre (Heskett 1983). It has been argued that focused factories in healthcare can be a "solution to our current efficiency and productivity crisis" (Leung 2000, p. 943).

In contrast to focused factories are the more common functional departments, which pool resources based on their function and not on the type of demand. In pooled departments, resources are flexible, instead of focused, and serve all demand, instead of specific (or specialized) demand. This setup benefits from economies of scale and complies with the adage that pooling resources is an easy way to gain efficiencies (Cattani and Schmidt 2005).

The decision of whether and to what extent to pool resources is complicated and depends on numerous clinic attributes, such as appointment length, clinic load, number of resources, and patient demand. Furthermore, many of these attributes are interrelated, meaning that identifying one attribute's influence in isolation from the others is extremely difficult. In general, we have shown that clinic load, patient mix, and variability are the most important factors. In particular, we know that pooling highly utilized resources from (specialized) clinics will result in little efficiency gains due to economies of scale (Vanberkel et al. 2012). Although general guidelines and rules of thumb can help focus the pooling discussion on particular hospital areas, implementing a change of strategy (whether breaking a pooled clinic into multiple specialized clinics or vice versa) often requires a more detailed study reflecting actual clinic characteristics.

In an effort to improve patient satisfaction, the Netherlands Cancer Institute is considering the use of specialized clinics to treat patients with similar cancer diagnoses. This setup is preferred by patients; however, hospital managers want to know whether service-time improvements (if any) in the unpooled setting are sufficient to compensate for any economy of scale losses caused by unpooling the functional departments. To support this decision making, an operations analysis decision support tool (described in Vanberkel et al. 2010b) is used to compute the economy of scale losses that result from changing a pooled department into a focused factory style department. The tool further calculates the service-time improvements necessary to compensate for economy of scale losses. Managers can then discuss if such service-time improvements are possible in the new specialized environment. A specific application found that splitting the pooled chemotherapy department into two separate departments would not result in service-time improvements and an increase in capacity of 5% would be required to maintain existing service levels.

Designing and Managing Patient-Centered Processes of Care

In designing patient-centered processes of care, the aim should be to optimize a patient's entire clinical course. This broad scope is used in an effort to discourage situations where clinicians advance the patient-at-hand, unknowingly at the expense of other patients. For example, a physician may admit a patient to a bed to reduce access time for diagnostics (inpatients are typically given priority access to diagnostic services) and thereby advance their patient ahead of other patients. Of course, this "gaming" of the system leads to many undesirable effects, and results in patient-centeredness that is not equitably distributed. Achieving patient-centered processes of care for all patients often means considering and improving how multiple departments treating the same patients can do so in a seamless manner and also changing the mindset of physicians from patient to process centric.

Numerous literature reviews (e.g., Fletcher and Worthington 2009, Vanberkel et al. 2010a) have found that managers often consider hospital departments in isolation when designing processes and making decisions. This is often reflected in the models used by academics to support decision making, although this is changing (Vanberkel 2011). Typical examples include designing surgical schedules that consider the capacity of the surgical ward or understanding how emergency department congestion is caused by an inability to admit patients to an overcrowded medical ward.

It is not surprising that the flow of inpatients is often studied, because their costs are high and easily measured using patient length-of-stay data. Outpatient processes are studied less, presumably because these costs are often hidden (i.e., patients waiting at home and outside the hospital do not directly affect a hospital's bottom line, whereas the patient in the hospital does). There is also a trend to perform an increasing number of procedures in outpatient clinics (Cayirli and Veral 2003). As such, there should be renewed attention paid to the operations of outpatient clinics and, in particular, how these clinics function together to provide seamless patient-centered care.

The preanesthesia evaluation process at LUMC was recently studied. Prior to surgery, patients often visit a preanesthesia evaluation clinic where patients consult several medical professionals and the risks of, and requirements for, anesthesia are determined. The goal of the study was to determine whether a reorganization could decrease the time required to approve (or not approve) patients for surgery. Using operations analysis and a queuing theory model, the initial setup of the clinic and alternative designs related to the walk-in appointment policies were examined. The chosen intervention was implemented and resulted in shorter turnaround times for approving patients for surgery. Patient arrivals increased sharply over one year by more than 16%; however, patient length of stay at the clinic remained essentially unchanged. If the initial setup of the clinic would have been maintained, the patient length of stay would have increased dramatically (Zonderland et al. 2009).

Another approach to patient-centered care is to use clinical pathways for similar patient types. Given the vast number of hospital facilities that a patient has to visit, hospitals aim to optimize the flow of patients following clinical pathways. This is often achieved by prioritizing them in the appointment planning process or by reserving specific resources for them. As a result, regular patients who are not following a clinical care pathway may experience a decrease in service. To measure the trade-off between accessibility for patients on the care pathway and the accessibility of regular patients, a queuing theory based approach was developed in conjunction with LUMC (Zonderland et al. 2011). The methodology is used as the basis of a capacity planning tool, allowing managers to study the trade-off between the delay for walk-in patients and the probability that the number of slots reserved for the care pathway patients is not sufficient.

The examples above are but a few of the many projects ongoing in the Netherlands and in the world. Given the receptiveness of healthcare providers in the Netherlands to employ operations analysis, we have seen great strides in terms of discerning scientifically novel research questions and implementing results.

Summing Up

Identifying capacity needs is not only a strategic exercise for health policy makers. As discussed, there is also a need to understand how operational and tactical decisions influence capacity requirements over the short term, especially in adjacent departments. Successful applications of operations analysis to predict capacity needs based on operation and tactical decisions can lead to better utilization of existing capacity and hence an overall decrease in capacity needs. At the same time, understanding the long-term capacity needs of new patients (as in the panel size project) is crucial for designing services that are sustainable over time. From every new patient that arrives, there is at least some indication about his or her future capacity needs; using this information can improve planning and lead to more informed capacity-allocation decisions.

Dedicated or flexible resources represent competing philosophies on the orientation of resources and whether they should be *dedicated* to a service or *flexible* and available to all services. As discussed, both have merits worth considering; however, before committing to one or the other, policy makers must understand that, typically, the former provides economies of scale while the latter typically offers shorter service times through focus and simplicity. Furthermore, a philosophy that is best for one department may not be the best for another. Operations analysis can provide general insight to support informed discussion; however, decision should be made on a case-by-case basis with analysis that takes into account the specific intricacies of the department under study.

Patient centeredness may involve eliminating wastes and/or employing clever scheduling procedures; however, it often involves complex trade-offs resulting in one patient type having priority over another. With clinical pathways, we have seen care processes streamlined and patient care put before red tape. This can be great for patients on the clinical pathway, however it may come at the expense of patients not on a pathway, because pathway patients often have dedicated resources and hence higher priority. Evaluating and understanding these trade-offs prospectively is crucial for ensuring that new patient-centeredness policies do not incidentally hinder the care of other patients.

The 2006 financial reforms of the Dutch healthcare system are just one of the many efforts by developed nations to eliminate poor quality and wasteful expenditures in healthcare. Perhaps not surprising, given that value-for-money was a guiding mandate in the reforms, they have acted as a catalyst for making operations analysis commonplace in many Dutch hospitals. This has led to an enormous increase in research questions motivated by healthcare providers. Research results are influencing national healthcare policies and changing the way healthcare is delivered across the country. Although the financial reforms are unique to the Netherlands, the operations analysis research it has incentivized has broader appeal and can support improvement efforts at healthcare providers around the world.

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