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Introduction to the Special Issue on Advancing Health Services

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1. Overview and Motivation

In 2016, INFORMS' *Service Science* embarked on an expansion and reorganization of its editorial board. As part of this restructuring, four areas were formed, one of which is healthcare applications. The mission of the healthcare applications area is to publish and promote scientific research focused on achieving excellence and understanding in healthcare services. The area encourages submissions from a broad range of research methodologies and disciplines, with an underlying goal of being a premiere outlet for scientific researchers working in the area of health services research within the INFORMS community and beyond.

The impetus for the creation of the healthcare applications area of *Service Science* is the need for science-based research efforts in healthcare services. Healthcare costs continue to rise at an alarming rate at the same time that a large portion of the population is aging and that new technological and biological challenges are emerging. Multidisciplinary approaches that integrate computing, informatics, and engineering methodologies with the biobehavioral medical research community are required to produce the innovations necessary to improve the health of the country (National Science Foundation 2017). Thus, there exists a need for a significant transformation in medical, public health, and healthcare delivery approaches that the healthcare applications area aims to bolster. We recognize that healthcare applications within the operations research/management science (OR/MS) field are varied and include medical decision making, healthcare operations management, precision medicine, and supply chain optimization, among others. As such, there are many OR/MS journals that also publish healthcare applications related work. At *Service Science*, we are particularly interested in health applications that either directly deal with healthcare services delivery or work that can impact quality (such as access, cost, and timeliness) of healthcare services.

In support of both the newly established healthcare applications area of *Service Science* and the multitude of economic and operational challenges faced by today's healthcare delivery systems, the call for this special issue of *Service Science* on Advancing Health Services was issued in December 2016. The goal was to attract quantitative papers that included innovative applications of science, management, and engineering that contribute to the current knowledge base on healthcare services and processes. Specific emphasis was placed on rigorous, interdisciplinary, data-driven approaches that demonstrate an improvement in accessibility, delivery, and quality of healthcare services.

The result is a nicely balanced body of work that highlights state-of-the-art research on the design, analysis, and operations of existing and emerging healthcare systems. The special issue's inherent balance arises from its inclusion of both (1) scheduling applications in a variety of health services settings and (2) medical decision-making applications for a variety of patient and intervention types.

Challenges associated with appointment scheduling in healthcare have been well documented (Gupta and Denton 2008). These challenges include the stochastic nature of arrivals and service times in, for example, primary care, specialty care, and other health services, which are usually highly resource-constrained environments. Furthermore, medical appointment scheduling involves highly context-specific considerations (e.g., patient and provider preferences and utilization targets), as well as considerations for how to implement model-generated schedules (e.g., dealing with no-shows and the availability of information technology).

Similarly, the clinical science of medical decision making continues to be an important area of study as researchers increasingly attempt to capture the realities associated with patient behavior and choice while using clinical data to drive decision-making. Medical decision making is challenging because for any medical problem there are interactions of influences at various levels (e.g., the individual, community, and society), and there are

multiple interacting mechanisms involved (e.g., biological, behavioral, and environmental). (The NIMHD Research Framework (<https://www.nimhd.nih.gov/about/overview/research-framework.html>) presents the multitude of determinants of health across levels and domains.) The inclusion of health determinants, such as patient behavior, and increased use of data analytics in healthcare models allows for the design of more personalized interventions that lead to improved outcomes.

Within these two categories of papers in the special issue, we see additional balance. More specifically, two papers focus on the scheduling of healthcare providers (physicians and ambulatory services), and two papers focus on the scheduling of patient appointments across a broad range of types of care (from primary care to telemedicine). The medical decision-making efforts examine interventions ranging from disease prevention, to the treatment of acute patients, to chronic disease management and clinical trial design. Details of the content of the papers are provided in Section 2 below.

Just as the content of the special issue is balanced in terms of application areas, we also see a broad range of methodologies used. Many operations research methods have been employed, sometimes in conjunction, including: dynamic programming, game theory, stochastic programming, integer programming, and nonlinear optimization. Statistical methods are also employed in several papers, and simulation is applied to test the impact of suggested results in practice.

Another strength of the special issue is the consistent use of real-world data or data derived from clinical studies. These data include electronic health records, recorded encounters, and time studies. The populations generating the data are also quite diverse, ranging from a German hospital, to a Canadian clinic, to a South Korean cohort, to rural clinics in the United States, and from women in labor to patients awaiting a liver transplant.

2. Contents of the Special Issue

2.1. Scheduling Applications

Schoenfelder and Pfefferlen (2018) develop a mixed-integer programming formulation to generate a physician schedule, which abides by rules and regulations, for an anesthesiology department of a hospital in Berlin, Germany. This schedule is embedded in an Excel environment to ensure ease of use, maximum flexibility, and a visual output representation for practitioners.

Eagen et al. (2018) design a new schedule for the outpatient clinics offered by a hospital in Toronto, Canada. They developed an integer programming model to optimize the assignment of clinics to timeslots and locations, with the goal of minimizing changes from the historical schedule. The authors highlight the value that their work has created for the hospital and present the lessons learned in development of the model and through their collaboration with the hospital team.

Alvarez-Oh et al. (2018) investigate the problem of scheduling primary care teams comprised of flexible nurses and dedicated providers. Because of the uncertainty in visit durations, a two-stage stochastic integer programming model is developed to determine patient appointment times, so as to minimize a weighted combination of patient wait and provider idle times for the team practice. A lower bounding technique is used to deal with issues related to computational complexity.

Erdogan et al. (2018) study the problem of scheduling telemedicine patients; telemedicine services are increasingly being used to provide medical care to patients in rural areas. The authors present a two-stage stochastic linear program to inform the optimal schedule while considering cleaning of procedure devices and patient no-show behavior. A case study for scheduling rural patients to a telemedicine clinic to receive a cystoscopy for bladder cancer surveillance is presented.

Gul (2018) investigates the number and availability of turnover teams, which may significantly affect the performance of a surgery schedule. This paper considers the limited availability of turnover teams and uncertainty in the durations of surgical operation and turnover. The objective is to minimize the competing criteria of expected patient waiting time and operating room idle time. A two-stage stochastic integer programming formulation is proposed along with a heuristic approach to generate near-optimal surgery schedules is provided.

2.2. Medical Decision-Making Applications

Lee et al. (2018) devise an implementation strategy for interventions intended to prevent hypertension in a diverse population. The strategy is driven by individual health record data and consists of first, identifying individuals at risk, and second, selecting an intervention for each individual based on a ranked list of choices.

Zhang et al. (2018) also focus on chronic disease management. They model the patient-physician decision-making process using a multiperiod stochastic game formulation in which patients determine the frequency with which they visit their physician as well as their lifestyle choices, and physicians determine the degree of effort to allocate when the patient visits.

Batun et al. (2018) consider a more acute setting, namely that of a single patient/physician making organ accept/decline decisions over time while awaiting liver transplantation. They focus on the impact of risk sensitivity on the optimal health and organ quality thresholds that dictate when a patient should choose to accept and transplant.

Hicklin et al. (2018) also consider an adaptive acute-care decision-making problem, in particular that of whether to allow a woman in labor to continue or to initiate a Cesarean delivery as a function of cervical dilation and time in labor.

Like Batun et al. (2018) and Hicklin et al. (2018), Rojas-Cordova et al. (2018) also consider an optimal stopping problem, but in the context of a clinical trial. They examine how the option to terminate the trial early, at one or more points in time for either benefit or futility, impacts drug misclassification rates (i.e., false negatives and false positives).

3. Final Thoughts and Future Directions

In this special issue, the authors tackle real and difficult problems observed in healthcare services and processes. All the papers kept sight of their underlying healthcare service question and that the methods and approach taken were chosen so as to provide a solution that incorporated the salient features and context specific aspects of the problem at hand. Common assumptions made in previous literature have been relaxed in several of the papers and the models are formulated with practical implementation in mind. By doing this, all papers were able to demonstrate an improvement to healthcare services. Most also provide insights for researchers in terms of how to approach modeling of real-world healthcare applications, suggestions for collaborating with practitioners, and recommendations for implementation. They also provide insights to practitioners about lessons learned and the impact that different levers have on outcomes of interest.

The papers in this special issue suggest multiple directions for future work. Even as the use of data to inform models becomes more prevalent, there are many potential areas for improvement. When taking a systems approach, it is often the case that data are not available for all model components, or data are sparse or incomplete. In such cases, assumptions must be made or we rely on expert opinion. Thus, it is suggested that future work could focus on improving data estimation and collection techniques, including, for example, econometric studies. With implementation in mind, researchers must be careful to consider the trade-offs between practical and context-specific models, and generalizability and impact. Thus, it may be the case that future healthcare applications modeling efforts include multiple phases, early phases in which the theoretical and methodological foundations are established, and later phases that use the work presented to develop decision support tools that can be used in practice.

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