Friday October 2, 2015

4th Rutgers Applied Probability Conference

Analytic Methods in Health Care and in Clinical Trials

Rutgers Business School – Newark and New Brunswick
Rutgers Robert Wood Johnson Medical School

In Honor and Memory of Lycourgos (Lee) Papayanopoulos

Sponsors:

CVI: The Cardiovascular Institute of New Jersey

RUTCOR: Rutgers Center for Operations Research

CDDA: Center for Dynamic Data Analytics

I-DSLA: Rutgers Institute for Data Science, Learning, and Applications

Management Science & Information Systems Department

APDA: Applied Probability and Data Analytics Laboratory

BREAKFAST 8:30-9:00 AM Room **1144**

OPENING REMARKS 9:00 - 9:15 AM, Room **5085**
Lei Lei, **Dean,** *Rutgers Business School - Newark and New Brunswick*

SESSION 1. 9:15 - 10:45 AM, Chair Michael N. Katehakis, Rutgers University Room **5085**

Condition-based maintenance and spare parts supply.

Geert-Jan van Houtum, Eindhoven University of Technology (**TU/e**), the Netherlands.

Abstract: We consider advanced capital goods such as medical equipment, lithography machines, printing systems, and baggage handling systems. Downtimes of these systems have severe consequences for their users and therefore it is beneficial to prevent or reduce these downtimes based on remote monitoring of critical components. Remote monitoring information may consist of direct information on parameters of degradation processes and indirect information, and is used to generate (imperfect) failure predictions. In this talk, we first consider the use of these failure predictions for the maintenance optimization of systems with many components and high setup costs for maintenance. Next, we consider the use of imperfect predictions for spare parts supply. Imperfect predictions may not be good enough to justify predictive replacements of critical components, but they can be used for an improved spare parts supply by ensuring that a spare part is available at the time of a potential failure. We will show that also quite imperfect failure predictions may lead to significant reductions of downtimes and costs.

Smart maintenance for healthcare systems.

Stella Kapodistria, **TU/e**, the Netherlands.

Abstract: We are interested in maintenance optimization concepts for high-tech medical imaging systems such as the IXRs (interventional cardiovascular X-ray systems). For reasons of simplicity and illustration purposes, in this presentation, we will choose a single component of the IXR system and show the steps of how to go from the available condition data to the derivation of the optimal maintenance planning. The path of such an analysis also covers issues related to the collection of the data, the use of statistical analysis for the data, the usage of SPC (Statistical Process Control) techniques, and the usage of MDPs (Markov decision process). Moreover, this talk will try to bridge the data driven models and the stochastic models, two areas that within the field of maintenance have mainly developed independent , through the presentation of a case study for a particular component of a high-tech medical equipment. This is joint work with Szilard Kalosi, Jacques Resing, and Laura Restrepo

Integrating Statistical Process Control into Condition Based Maintenance.

Alessandro Di Bucchianico, TU/e, **Stella Kapodistria, TU/e**, the Netherlands.

Abstract: In order to provide patients appropriate medical care and at the same time control costs, high-tech medical equipment like MRI scanners must have a high availability and maintenance should not disturb tight patient schedules. Manufacturers of such devices are thus facing challenges in defining and executing maintenance strategies. A promising way to tackle these challenges is to make use of the data captured by device sensors. This approach is known as CBM (Condition Based Monitoring). Since CBM is based on monitoring the state of the device at hand, it seems to be advantageous to make use of concepts and techniques from SPC (Statistical Process Control). We will explore this relatively unexplored idea and show how to extend the ideas from a seminal paper by Panagiotidou and Taragas. We will also briefly touch upon practical issues arising within a project with a manufacturer of high-tech medical equipment.

Break.

SESSION 2.A 11:00 - 1:00 PM, Chair Junya Honda, University of Tokyo, Japan Room **5085**

An approach to the multi-armed bandit.

Eric V. Denardo, Yale University.

Abstract: A classic approach to the multi-armed bandit is based on stopping times. Described in this talk is an alternative approach that is based on pairwise comparison. This approach facilitates a somewhat more general analysis in the case of a linear utility function, it encompasses risk aversion, it leads to efficient computation, and it facilitates constrained optimization in the case of linear utility. This approach was developed by Uriel G. Rothblum and the speaker, with significant contributions by Eugene Feinberg, Haechurl Park and Ludo van der Heyden.

Multi-Armed Bandit with Global Constraints.

David Simchi-Levi, Massachusetts Institute of Technology.

Abstract: In many real-life applications such as online ad placement, retail pricing, crowdsourcing or clinical trials, one needs to analyze exploration versus exploitation trade-offs. These problems are typically modeled as multi-armed bandit problem. We present a variation of the classical Thompson Sampling algorithm that takes into account various resource constraints such as limited inventory. We show that our algorithm has both strong theoretical performance guarantees as well as promising numerical performance results when compared to other algorithms developed for the same setting.

Asymptotically Optimal Policies for Multiparameter and Nonparametric Bandits.

Junya Honda, University of Tokyo, Japan.

Abstract: We consider a problem of sequential allocation known as a multiarmed bandit problem. In this problem a player chooses an action at each time and receives an i.i.d. random reward according to an unknown distribution associated with each action. It has been known that there exists an asymptotic lower bound on the cumulative regret but optimal policies achieving this bound have been known only for models of reward distributions where the parameter space is one-dimensional or compact. In this talk we introduce some frameworks to achieve the bound and give new optimal policies for the model of normal distributions with unknown means and variances and the model of nonparametric distributions where only the upper bound of the reward is known.

Asymptotically Optimal Policies for Non-Parametric MAB Models Under Generalized Ranking.

Wesley Cowan, Rutgers University, and **Michael N. Katehakis,** Rutgers University.

Abstract: We consider the problem of sequential activation with the goal of activating the "best" bandit as frequently as possible, with "best" being left to the discretion of the controller. A non-parametric framework is presented. We provide conditions under which asymptotically optimal policies, in the sense of Lai-Robbins (1985) and Burnetas and Katehakis (1996), exist. The main results are illustrated through the use of parametric examples.

SESSION 2.B 11:00-1:00 PM, Chair Apostolos N. Burnetas, National and Kapodistrian Univ., Greece Room **5117**

Designing Health-Services Appointment Offering Under Patient Choices.

Peter van de Ven, CWI Amsterdam, the Netherlands, **Nan Liu,** Columbia University, **Bo Zhang,** IBM Reserach.

Abstract: With population aging, the imbalance between health service capacity and patient demand is becoming a global problem. However, a significant amount of provider time is wasted due to the inefficiency of appointment scheduling systems currently in use; this is particularly reflected in the fluctuating, and relatively low, fill rate (the ratio between number of patients scheduled and number of available slots). A recent development in patient scheduling is the emergence of online appointment scheduling, which offer more flexibility in patient choices and give patients an Amazon-like "shopping" experience of accessing care. Although online scheduling makes it possible to better accommodate patient preferences, it is not likely to eliminate the problem of low fill rates if not managed well. In this work we investigate how to design

traditional online scheduling to achieve high fill rates.

We develop models that account for heterogeneous patient preferences in appointment choice offering: there are different types of patients who accept different (sets of) appointment slot types. We observe that by only offering a strict subset of all available slots to patients, we can direct patients into appointment slots that are beneficial for achieving a high fill rate. We first obtain the optimal "blocking" policies of such for certain instances using MDPs. We then derive heuristics for the general cases, based on insights from revenue management.

Managing Customer Arrivals in Outpatient/Diagnostic Clinics with Multiple Servers.

Christos Zacharias, University of Miami, **Michael Pinedo**, New York University Stern School of Business.

Abstract: We analyze a discrete multi-server model for scheduling patient arrivals under no-shows. This study demonstrates that an informed strategy for appointment overbooking can improve the operational performance of a service system, while customers experience short waiting times and better access to care. A discrete time stochastic scheduling model captures the random evolution of the system's workload, based on which we derive recursive expressions for the performance measures of interest. The task of finding an optimal schedule is modeled as an integer stochastic program which is analytically intractable and computationally expensive. A tight upper-bound (a solution to a convex program) restricts our search for an optimal schedule on a contained solution space. Our theoretical and experimental analysis reveals properties and patterns that appear in the optimal scheduling strategy, and informs the development of two highly efficient heuristic solutions. Our analysis demonstrates the benefits of resource-pooling in containing operational costs and increasing customer throughput.

Analysis of admission, routing and early discharge decisions in a hospital setting.

Lerzan Örmeci, Koç University, Turkey.

Abstract: We consider the problem of bed management in a hospital. The patients stay at the hospital for a random length of time to recover after a surgery. Hence, the operation schedule has a long-term effect on the occupancy levels. Moreover, these levels significantly affect the quality of care for the patients. To control the occupancy levels in each department, hospital management has a number of options: (1) New patients may be rejected at high levels of occupancy, (2) Patients operated by a certain department may stay in the ward of another department, (3) Patient(s) staying at the hospital may be discharged early.

To analyze the effects of these decisions on the hospital performance, we develop a Markov decision model with two types of patients (severe and mild). The recovery time of a severe patient is represented by a two-stage hypo-exponential distribution whereas that of a mild patient follows an exponential distribution. Severe patients can stay only in the main ward, while the mild patients can stay both in the main ward and in the so-called overflow ward. We investigate certain monotonicity properties of optimal policies, and derive sufficient conditions for a patient type to be "preferred" or "strongly preferred." We illustrate our findings through the data obtained from a Turkish private hospital.

This is a joint work with Nermin Kurt.

Strategic balking behavior in a queueing system with delayed congestion information.

Apostolos N. Burnetas, University of Athens, Greece, **Antonis Economou**, University of Athens, Greece, and **George Vassiliadis**, University of Athens, Greece.

Abstract: We consider the single server Markovian queue with infinite waiting space and strategic customers. We assume that there exists a certain reward-cost structure that reflects the customers' desire for service and their dislike for waiting. Arriving customers decide whether to join the system or balk. Regarding the information structure, we assume that customers make their decisions without knowing the queue length upon arrival. However, the administrator provides them with periodic announcements of their current positions, so that they may renege after reevaluating their expected net benefit. This situation is modeled as a game among the potential customers and we determine the corresponding symmetric equilibrium strategies. The associated problems of the overall social benefit optimization and the profit maximization for the administrator of the system are also discussed.

Lunch Break.

SESSION 3.A 2:15 - 4:15 PM, Chair Jian Yang, Rutgers University Room **5085**

Balance Optimization Subset Selection (BOSS): An Alternative Approach for Causal Inference with Observational Data.

Sheldon H. Jacobson, University of Illinois.

Abstract: Researchers in medicine and the social sciences attempt to identify and document causal relationships. Those not fortunate enough to be able to design and implement randomized control trials must resort to observational studies. To preserve the ability to make causal inferences outside the experimental realm, researchers attempt to post-process observational data to draw meaningful insights and conclusions. Finding the subset of data that most closely resembles

experimental data is a challenging, complex problem. However, the rise in computational power and discrete optimization algorithmic advances suggests an operations research solution as an alternative to methods currently being employed.

Innovation in Healthcare Data Analytics.

Eva Lee, Georgia Institute of Technology.

Abstract: Risk and decision models and predictive analytics have long been cornerstones for advancement of business analytics in industrial, government, and military applications. In particular, multi-source data system modeling and big data analytics and technologies play an increasingly important role in modern business enterprise. Many problems arising in these domains can be formulated into mathematical models and can be analyzed using sophisticated optimization, decision analysis, and computational techniques. In this talk, we will share some of our successes in healthcare, defense, and service sector applications through innovation in predictive and big data analytics.

A brief glimpse of Dr. Lee's healthcare work can be found in the following: link.

Determination of an Appropriate Pilot Sample Size in Estimation of Treatment Mean Response.

Nitis Mukhopadhyay, University of Connecticut.

Abstract: A multistage sampling strategy for estimating treatment mean response requires that a practitioner uses some initial data with a pilot size m, an appropriately chosen number. Under purely sequential sampling, a choice of m may not be very difficult to come up with as long as m is reasonably small. It is so because one goes forward step-by-step adaptively under purely sequential sampling. However, in multistage sampling (especially under two-stage sampling), the choice of an appropriate pilot size happens to be crucial. In such situations, understandably m should not be too large or too small, but what choice of m qualifies as not "too large" or "too small" when the "optimal fixed sample size" remains unknown? We shall explore some concrete ideas based on (i) large-sample approximations, (ii) Fisher information, and then contrast them. Illustrations will follow.

Modeling Risk and Ambiguity-on-Nature in Normal-form Games.

Jian Yang, Rutgers University.

Abstract: We propose multi-player frameworks that mitigate decision-theoretical difficulties with the traditional normal-form game, where players are concerned with expected utility functions of their payoffs. We react to Allais's (1953) paradox by concerning players with potentially nonlinear functionals of the payoff distributions they encounter. To counter Ellsberg's (1961) paradox, we let players optimize on vectors of payoff distributions in which every component is a payoff distribution corresponding to one particular nature action. In the preference game we introduce, players merely express preferences over payoff-distribution vectors. Depending on ways in which players' mixed strategies are verified, there will emerge two equilibrium concepts, namely, the ex post and ex ante types. Conditions for equilibrium existence are identified; also, the unification of the two concepts at the traditional game is explained. When the preference relations lead to real-valued satisfaction functions, we have a satisfaction game. Two notable special cases are one coping with Gilboa and Schmeidler's (1989) ambiguity-averse worst-prior setup and another involving Artzner et-al (1999) coherent-risk measure with risk-averse tendencies. For both, searching for ex post equilibria boils down to solving sequences of simple nonlinear programs (NLPs).

SESSION 3.B 2:15 - 4:15 PM, Chair Mor Armony, New York University — Room **5117**

Critical Care in Hospitals: When to Introduce a Step Down Unit?.

Mor Armony, New York University, **Carri W. Chan,** Columbia University, **Bo Zhu,** New York University.

Abstract: Step Down Units (SDUs) provide an intermediate level of care between the Intensive Care Units (ICUs) and the general medical-surgical wards. Because SDUs are less richly staffed than ICUs, they are less costly to operate; however, they also are unable to provide the level of care required by the sickest patients. There is an ongoing debate in the medical community as to whether and how SDUs should be used. On one hand, an SDU alleviates ICU congestion by providing a safe environment for post-ICU patients before they are stable enough to be transferred to the general wards. On the other hand, an SDU can take capacity away from the already over-congested ICU. In this work, we propose a queueing model to capture the dynamics of patient flows through the ICU and SDU in order to determine how to size the ICU and SDU. We account for the fact that patients may abandon if they have to wait too long for a bed, while others may get bumped out of a bed if a new patient is more critical. Using fluid and diffusion analysis, we examine the tradeoff between reserving capacity in the ICU for the most critical patients versus gaining additional capacity achieved by allocating nurses to the SDUs due to the lower staffing requirement. Despite the complex patient flow dynamics, we leverage a state-space collapse result in our diffusion analysis to establish the optimal allocation of nurses to units. We find that under some circumstances the optimal size of the SDU is zero, while in other cases, having a sizable SDU may be beneficial. The insights from our work provide justification for the variation in SDU use seen in practice.

Queues with Time-Varying Arrivals and Inspections with Applications to Hospital Discharge Policies.

Carri W. Chan, Columbia University, **Jing Dong**, Northwestern University, **Linda V. Green**, Columbia University.

Abstract: In order for a patient to be discharged from a hospital unit, a physician must first perform a physical examination and review the pertinent medical information to determine that the patient is stable enough to be transferred to a lower level of care or be discharged home. Requiring an inspection of a patient's 'readiness for discharge' introduces an interesting dynamic where patients may occupy a bed longer than medically necessary. Motivated by this phenomenon, we introduce a queueing system with time-varying arrival rates in which servers who have completed service cannot be released until an inspection occurs. We examine how such a dynamic impacts common system measures such as stability, expected number of customers in the system, probability of waiting and expected waiting time. Leveraging insights from an infinite-server model, we're able to optimize the timing of inspections and find via theoretical and numerical analysis that 1) optimizing a single inspection time could lead to significant improvements in system performance when the amplitude of the arrival rate function is large, 2) the amount of time between subsequent inspections should be uniform throughout a day, and 3) the marginal improvements of adding additional inspection times is decreasing.

Designing hospital and patient incentives for reducing readmissions when care is co-produced.

Chris Tang, UCLA Anderson School of Management, **Dimitrios Andritsos**, HEC Paris, France.

Abstract: To reduce preventable readmissions, many healthcare systems are transitioning from Fee-for-Service (FFS) to reimbursement schemes such as Pay-for-Performance (P4P) or Bundled Payment (BP), which allow the funder of a healthcare system to transfer to the hospital some of the financial risks associated with a patient's re-hospitalization. To examine the effectiveness of different schemes (FFS, P4P, and BP), we develop a "health co-production" model in which the patient's readmissions can be "jointly controlled" by the efforts exerted by the hospital and the patient. Our analysis of the equilibrium outcomes reveals that FFS cannot entice the hospital and the patient to exert readmission-reduction efforts. Relative to BP, we find that P4P is more "robust" in that it can induce readmission reduction effort over a wider range of parameter values. However, BP can induce greater efforts than P4P. More importantly, we characterize the conditions under which BP (or P4P) is the dominant scheme from the funder's perspective. Finally, we find that patient cost-sharing can generate two benefits: (a) it provides incentive for patients to exert efforts; and (b) it reduces the financial obligations of the funder.

Stabilizing Patient Flows: from admissions to Discharge.

Rene Bekker, Vrije Universiteit Amsterdam, the Netherlands.

Abstract: In hospital operations, peaks in demand lead to bed block, excessive access times for hospital procedures, poor quality of care, high costs and mortalities. The central theme of this presentation is to show the merits of stabilizing patient flows. At the day-of-week time scale, we propose an admission scheduling approach to stabilize the usage of inpatient beds, which is based on time-dependent analysis of infinite-server queues. At the time-of-day time scale, we see a mismatch between arrivals and discharges over the day typically leading to a mid-day spike. We model the time-of-day census process and discharge timing and investigate how this affects hospitals bed capacity. Finally, if time permits, we investigate the impact of flexibility and overbooking for an access time model.

PANEL DISCUSSION 2:15 - 4:15 PM, Chair **Eugene Schneller,** *Arizona State University* Room **5073**

Can Health Care Influence Supply Chain? & Can Supply Chain Influence Healthcare?

Eugene Schneller, *Arizona State University*
Dr. Anand Joshi, *Director of Clinical Procurement at New York - Presbyterian Hospital*
Phillip Mears, *Senior Vice President of Supply Chain at Mount Sinai Hospital*
Christopher J. O'Connor, *Executive Vice President of Greater New York Hospital Association (GNYHA) Ventures, Inc.*
Benjamin Melamed, *Rutgers University*

Break.

SESSION 3.A 4:30 - 6:30 PM, Chair Xiaodong Lin, Rutgers University Room **5085**

Learning and Adapting to Non-stationary Environments in Multi-armed-bandit Problems.

Omar Besbes, Columbia University, **Yonatan Gur**, Stanford University, **Assaf Zeevi**, Columbia University.

Abstract: A prototypical model for sequential the the multi-armed bandit (MAB) problem, in which a decision-maker needs to choose at each round of play one of K arms, each characterized by an unknown reward distribution. Reward realizations are only observed when an arm is selected, and the decision-maker's objective is to maximize cumulative expected earnings over some decision horizon T. This problem has been studied extensively when the reward distributions do not change over time; an assumption that supports a sharp characterization of performance through regret bounds, yet is often violated in practical settings. In this paper, we focus on a MAB formulation which allows for a broad range of temporal uncertainties in the rewards, controlled by a budget of "variation" while still maintaining mathematical tractability.

We fully characterize the (regret) complexity of this class of MAB problems by establishing a direct link between the extent of allowable reward "variation" and the minimal achievable regret relative to the dynamic oracle (sequence of ex ante best actions). We further characterize the "price of universality": the additional regret incurred due to not knowing the budget of variation.

Near Optimal Bandit Strategies Evaluated in the Context of Clinical Trials in Rare Diseases.

Sofia Villar, MRC Biostatistics Unit, Cambridge University UK.

Abstract: In a rare disease setting the number of patients in the trial is a high proportion of all patients with the condition (if not all of them) and this number is not enough to guarantee the required statistical power to detect a treatment effect of a meaningful size. In such a context, the idea of prioritizing patient benefit over hypothesis testing as the goal of the trial can lead to a trial design that produces useful information to guide treatment, even if it does not do so with the standard levels of statistical confidence. The idealized model to consider such an optimal design of a clinical trial is known as a classic multi-armed bandit problem with a finite horizon and a patient benefit objective function. Such a design maximizes patient benefit by balancing the learning and earning goals as data accumulates. On the other hand, optimally solving such a model has a very high computational cost (many times prohibitive) and furthermore, a cumbersome implementation, even for populations as small as a hundred patients. In this talk we present a novel heuristic rule to solve it based on the reformulation of the problem as a Restless bandit problem and the derivation of its corresponding Whittle index rule. Such rule was recently proposed in the context of a clinical trial in Villar et al (2015). We performed extensive computational studies to compare through both exact value calculations and simulated values the performance of this rule and other simpler heuristics previously proposed in the literature. Our results suggest that for the two-armed case and a patient horizon less or equal than a hundred patients, all rules are a priori practically identical in terms of the expected proportion of success attained. However, we find that a posteriori the index policies outperform the simpler rules in every instance and specially so in the case of many arms and a larger, though still relatively small, total number of patients with the diseases. The extremely good performance of these bandit rules in terms of patient benefit (i.e. expected number of successes and mean number of patients allocated to the best arm, if it exists) makes these rule very attractive and appropriate to be used in context of drug development for rare diseases.

References:

Villar, S., Bowden, J. and Wason, J. (2015) Multi-armed Bandit Models for the Optimal Design of Clinical Trials: Benefits and Challenges. Statistical Science Vol. 30, No. 2, 199215.

An Optimally Confident Bandit Algorithm.

Tor Lattimore, University of Alberta, Canada.

Abstract: The multi-armed bandit problem is the simplest example of reinforcement learning and has many applications. Surprisingly there are still numerous open problems, even in the most classical formulations. I will present some recent work describing the first algorithm that is simultaneously optimal in terms of the worst-case regret and the distribution-dependent regret. The new algorithm is based on the famous Upper Confidence Bound (UCB) algorithm, but uses a carefully chosen confidence parameter that optimally balances the cost of excessive optimism against the risk of failing confidence intervals. Empirical results indicate that the algorithm outperforms both UCB and Thompson sampling with the flat Gaussian prior.

Bayesian Bandit Models for the Optimal Design of Clinical Trials.

Peter Jacko, Thomas Jaki, Faye Williamson, Lancaster University, UK, **Sofia Villar,** Cambridge University UK.

Abstract: Development of treatments for rare diseases is particularly challenging. Learning about treatment effectiveness with a view to treat patients in the larger outside population, as in the traditional fixed randomized design, is less important. Now, the priority is to treat the patients within the trial as effectively as possible whilst still identifying the superior treatment. This problem is a natural application area for bandit models which seek to balance the underlying exploration versus exploitation trade-off inherent in clinical trial design. We formulate this model as a finite-horizon Markov decision problem and use dynamic programming (DP) to obtain an optimal adaptive treatment allocation sequence which maximizes the total expected reward over the planning horizon. However, this optimal design is deterministic, which is undesirable from a practical point of view, so we modify it by forcing actions to be randomized. Further concerns with this design are that it is very underpowered and there is the possibility that all patients will be allocated to only one of the treatments. To resolve these issues, we propose a constrained version of the randomized DP design in which we add a constraint to ensure that we always obtain at least n/10 observations from each treatment arm (where n denotes the sample size). We evaluate several performance measures of these designs through extensive simulation studies. For simplicity, we consider a two-armed trial with binary endpoints and assume immediate responses. Simulation results for this constrained variant show that (i) the percentage of patients allocated to the superior arm is much higher than in the traditional fixed randomized design and (ii) relative to the optimal DP design, the power is largely improved upon. Furthermore, this design exhibits only a small

bias of the treatment effect estimator, and has the desirable property that changing the degree of randomization does not impact the results significantly.

SESSION 3.B 4:30 - 6:00 PM, Room **5117**

Chairs David D. Dobrzykowski, Yao Zhao, Rutgers University

Using Data Analytics and Systems Modeling to Inform Hospital Obstetrics Capacity Planning.

Nan Liu, Mailman School of Public Health, Columbia University, **Linda V. Green,** Columbia University.

Abstract: As a result of recent cuts from Medicare and increased pressure from private payers to control costs, many hospitals are trying to downsize. While cutting excess beds increases efficiency and eliminates waste, cutting too many threatens patient care and ultimately increases costs due to poor quality of care. Traditional hospital capacity planning guidelines followed by healthcare managers, however, are based on simple target bed utilization levels, and can often lead to inappropriate capacity investment suggestions. Using a recent large data set that contains all hospital obstetrics units (n=40) in NYC, we demonstrate and validate the use of data analytics and systems modeling for planning hospital bed capacity. We estimate capacity needs based on the probability of delay experienced by patients in getting a bed. Our analysis reveals significant variation in obstetrics capacity utilization in NYC, and shows that NYC can save $26.5M a year with appropriate reallocation of obstetrics capacity.

Impact of Health Sector Context on Trust and Purchasing.

Eugene Schneller, Arizona State University.

Abstract: The paper examines the barriers to achieving supply chain integration in the health sector. Specifically, the paper aims to identify the tensions that block the development of trusting relationships between healthcare providers and their suppliers. Two methodologies are used to derive the results of this paper. First, case interviews are conducted, sampling six healthcare providers and five suppliers. The second method applies an exploratory factor analysis method to analyze survey data from 321 healthcare providers and suppliers. Four barriers to trust in the healthcare context are identified: (1) misalignment of incentives between physicians, hospitals, and suppliers; (2) lack of information and knowledge sharing; (3) tension from pricing and provisioning of value-added services; and, (4) environmental uncertainties. Research limitations/implications This work establishes a research agenda to further scrutinize barriers of trust and to consider mechanisms to mitigate them.

Probabilistic Operational Decision Making in Healthcare: case of predicting daily surgical case volumes.

Vikram Tiwari, Vanderbilt University Hospital.

Abstract: Variability in daily surgical volume leads to mismatch between the labor capacity planned for the day and the actual labor-hours needed. We developed a technique to predict the case volume from the developing elective schedule up to 30 days in advance, and with sufficient confidence to be able to flex nurse and anesthesia staffing. The same methodology has been expanded to predict future daily surgical inpatient bed needs. Developing the OR methods further, using computer simulation model and Bayesian analysis, the prediction of daily case volume at individual surgeon and service as far out as 42 days has been tested. These applied OR implementations impact areas of operations across the medical center.

SESSION 3.C 4:30 - 6:00 PM, Chair Alessandro Di Bucchianico, **TU/e** Room **5073**

Risk-Averse Optimal Learning for Clinical Trial Dose Escalation.

Curtis McGinity, Rutgers University.

Abstract: Novel pharmaceutical agents have unknown toxicity as a function of dosage, which must be safely assessed/ ascertained/learned. Cytotoxic agents increase the safety concerns in the trial, while the nature of their use endeavors to achieve effective treatment for each patient. This is a manifestation of the classical exploitation vs. experimentation dilemma. We formulate the problem of determining an optimal dose escalation policy as an optimal learning problem. We introduce risk-aversion, develop dynamic programming equations, and present a novel risk-averse lookahead policy. We then formulate an approximation architecture and present solutions to the associated ADP equations.

A Comparative Analysis of the Successive Lumping and the Lattice Path Counting Algorithms.

Laurens C. Smit, University of Leiden, the Netherlands, **Michael N. Katehakis,** Rutgers University, **Floske Spieksma,** University of Leiden, the Netherlands.

Abstract: In this talk a successive lumping (SL) based algorithm and a lattice path counting based algorithm (LPCA) are compared both in terms of applicability requirements and numerical complexity. Both type of algorithms make use of rate matrices, and are part of matrix analytic models. To make the comparison between the procedures, we analyze their performance for certain classical queueing and inventory models. We will show that the structure required to use any of the two algorithms is very similar. When both methods are applicable the SL based algorithms outperforms the LPCA one in speed. We will go in detail how the matrices arising in SL algorithms can be inverted fast and show various properties of these matrices. There are classes of problems (e.g., models with (level) non-homogenous rates or with finite state spaces)

for which the SL methodology is applicable and for which the LPCA cannot be used. There are also some structures for which LPCA can compute rate matrices, while the SL algorithm cannot.

Analytic Models for Dynamic Health Workforce Management.

Junmin (Jim) Shi, New Jersey Institute of Technology, We develop and analyze workforce capacity models for health institutions. The new models incorporate workforce demand over a finite horizon and personnel attrition patterns. The objective is to optimize measures of expected operation costs subject to maintaining service level targets.

DINNER 6:45 - 9:15 PM

Organized by: Michael N. Katehakis (Chair), John B. Kostis, Dimitris N. Metaxas

Program Committee: David Dobrzykowski, Kemal Gursoy, Stella Kapodistria, Spiros Papadimitriou, Andrzej Ruszczyński, Flora Spieksma, Yao Zhao

Conference Coordinator: Ms. Luz Kosar kosar@andromeda.rutgers.edu