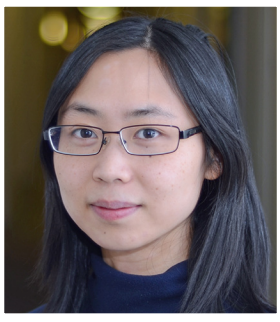
RESEARCH

Inside IISE Journals

This month, we highlight two articles from the May issue of *IISE Transactions* (Volume 57, No. 5), showcasing how industrial and systems engineering methods can enhance healthcare decision-making. The first article examines how to quantitatively assess the benefits and costs of increasing decision frequency in sequential healthcare settings with regular decision epochs. More frequent decision-making reduces uncertainty, allowing for closer monitoring and personalized treatment. However, it often comes with higher costs. The authors developed a novel evaluation method based on the Markov Decision Process (MDP). They applied this approach to analyze how increased decision frequency impacts healthcare benefits under various conditions. Their insights provide practical clinical guidance, helping healthcare providers and policymakers optimize decision frequency while balancing costs and quality of care. The second article focuses on evaluating the service level of emergency departments (EDs) to support hospital operational decisions by managing unpredictable patient arrivals and prioritizing treatment based on severity. A key challenge is ensuring timely care while handling fluctuating demand. However, accurately measuring service levels in such a complex, time-varying system is challenging. The authors apply queueing system modeling to develop a quantitative method for assessing service levels in priority-based, time-varying systems. They propose closed-form approximations for practical implementation to help balance resource constraints while ensuring timely care.

Cynthia Gong



Sze-Chuan Suen

Vinay Sundaram

Suyanpeng Zhang

When more medical decisions mean better healthcare

In healthcare, the frequency at which decisions can be made or changed is usually constrained by resources, such as a doctor's availability, the patient's budget or available organ offers. Generally, increasing the frequency of decision-making allows caregivers to monitor a patient's disease progression more closely and deliver more customized treatments.

However, this often comes with higher costs. For example, a patient awaiting a liver transplant can be listed at multiple hospitals to receive offers more frequently, which boosts the chances of finding a highly compatible organ. At the same time, it may also lead to added expenses, including fees for multiple listings and long-distance travel for medical appointments.

Quantifying the benefits of increasing the frequency of decision-making allows for a better evaluation of whether the benefits justify the potential costs of creating these additional decision-making opportunities and improving the quality of care.

In their work, "Quantifying the Benefits of Increasing Decision-Making Frequency for Health Applications with Regular Decision Epochs," Suyanpeng Zhang, Ph.D., Sze-Chuan Suen, Ph.D. and Cynthia Gong, Ph.D., from the University of Southern California and Vinay Sundaram, M.D., from Cedars-Sinai Medical Center (who sadly passed away in 2022) show how to address this problem using a Markov

Decision Process framework. Their work demonstrates the benefits of more frequent decision changes under varying conditions.

The authors show that the benefits of more frequent decision-making increase monotonically over time and with disease severity, provided that the increased frequency does not change the optimal recommended actions. Conversely, these benefits decrease monotonically over time and with disease severity if a higher decision-making frequency leads to changes in the optimal actions.

The authors illustrated their findings through two numerical examples: One focused on liver transplantation and the other on chronic kidney disease (CKD) management. In the first example, they identified a cost threshold at which multiple listing becomes beneficial for a group of patients with acute-on-chronic liver failure. In the second, they demonstrated that early initiation of treatment is both necessary and beneficial for patients in the early stages of CKD. Both examples show how the authors' analysis leads to practical clinical implications.

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Measuring service levels to assist emergency physician staffing decisions

The emergency department (ED) is the front line of hospital medical services and differs significantly from outpatient and other medical departments. One key task of EDs is to classify emergency patients into different levels based on the severity of their conditions and other factors, creating priority orders.

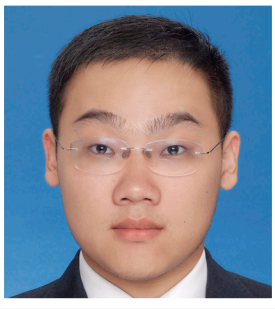
Another distinguishing characteristic of EDs is the time-varying arrival rates of patients and service capacities. Waiting time, a crucial factor for emergency patients, varies by the severity level of patients, with each level requiring treatment within specific time thresholds to ensure timely care. The probability of meeting these wait time thresholds is often used as a measure of the ED service levels.

While maintaining high service levels is a priority for EDs, how to precisely measure and calculate service level in such a complex system remains an open question. Moreover, it remains unclear whether service level constraints should be incorporated into the planning and scheduling of emergency resources. For example, in the critical task of physician scheduling in the ED, how can service level considerations be integrated to create a more efficient scheduling plan? These are urgent challenges faced by ED managers.

In their paper, "Service-level Computation in Time-Varying Queueing Systems with Priorities: Application to Physician Staffing in the Emergency Department," Associate

Ran Liu

Huiyin Ouyang



Chengkai Wang

Xiaolan Xie

Professor Ran Liu and doctoral student Chengkai Wang from Shanghai Jiao Tong University, Assistant Professor Huiyin Ouyang from the University of Hong Kong and Professor Xiaolan Xie from Mines Saint-Étienne present effective methods for calculating service levels in time-varying systems with priority queues.

The authors also propose closed-form approximations for these service levels to make them implementable. Furthermore, they demonstrate how these computational techniques can be applied to assist real-world physician staffing decisions in the ED, where service levels for each class of patients are treated as constraints. Numerical results indicate that their proposed staffing solutions outperform the hospital's current staffing decisions, leading to improved service levels for patients and reduced physicians' working hours.

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This month we highlight an article from *The Engineering Economist* (Volume 69, No. 4). The author explores why financial executives often are reluctant to use a real options approach for investment opportunities. He factors the tracking costs into a real option model that corresponds to updating a company's cash-flow estimates and strategic plans. The article shows that the impact of tracking costs on investment timing is far from negligible and justifies why some real options are optimally discarded.

The impact of tracking costs in real options investments

The real-options approach (ROA) represents a well-settled paradigm to value investment opportunities, which overcomes the limitations of the naïve net present value (NPV) criterion. When properly managed, real options are a source of value creation. However, chief financial officers frequently ignore real-option techniques in their analyses.

The documented scarcity of ROA in capital budgeting can be attributed to several factors: lack of top management support, the existence of other proven methods, the complexity of the approach or the fact that it encourages excessive risk-taking. Furthermore, some conclusions drawn from real options models can be odd; for example, the optimal investment thresholds typically imply extremely high expected times until investment, which is unrealistic.

The research in the article "The Impact of Tracking Costs in Real Options" by Óscar Gutiérrez, professor of the department of Business Economics at the Universitat Autònoma de Barcelona, provides a justification to why CFOs seem to be reluctant to use real options models. The paper incorporates to a real option model the tracking costs that the investment opportunities actually entail. These costs correspond to updating the cash-flow estimates and strategic plans of the firm, deploying financial and marketing resources, acquiring operational licenses, etc.

The article shows that the impact of tracking costs on investment timing is far from negligible, leading to an intermediate solution between the standard ROA solution and the NPV criterion. The numerical simulations show that, for typical parameter configurations, moderate tracking costs lead to significant corrections to the standard solution obtained from the ROA, around 20% to 50% lower. The impact is higher as the level of volatility decreases.

Óscar Gutiérrez

In some cases, the optimal investment rule is close to the NPV criterion. The model also justifies why some real options are optimally discarded – due to the existence of tracking costs, it is optimal to ignore the investment opportunity if the project value falls about 5% to 50% below the lump sum cost required to invest.

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