RESEARCH

Inside IISE Journals

This month we highlight two articles from *IISE Transactions*. The first article studies the most appropriate routes for hazardous materials transportation. It develops a flexible mathematical model and algorithm risk mitigation methods by using spectral risk measures to balance between the shortest route and the safest route. The developed method is tested in real transportation planning cases. The second paper develops a comprehensive network flow-based evacuation planning approach to traffic congestion triggered by mass evacuation that can provide tighter bounds for evacuation clearance time. These articles will appear in the June 2019 issue of *IISE Transactions* (Volume 51, No. 6).

How to find the best route to transport hazardous materials

Hazardous materials (hazmat) are defined as chemical hazards and toxic substances that pose a wide range of health hazards, such as irritation, sensitization and carcinogenicity and physical hazards such as flammability, corrosion and explosibility. Hazmat accidents exhibit the characteristics of the low-probability, high-consequence events.

Most current hazmat routing methods rely on the average risk level of routes and are vulnerable to the catastrophic consequences of accidents. When hazmat is transported, the shortest route usually is taken by carriers. However, the shortest routes often traverse highly populated areas, which increases the risk of accidents. On the other hand, the safest route to transport hazmat is usually a long, detoured route to avoid residential and commercial areas.

Doctoral student Liu Su and professor Changhyun Kwon of the University of South Florida with OR analyst Longsheng Sun of United Airlines and professor Mark Karwan of the University at Buffalo have worked to advance routing methods in hazmat transportation. Their article, "Spectral Risk Measure Minimization in Hazardous Materials Transportation," presents a flexible mathematical model and algorithm risk mitigation methods that can balance between the shortest route and the safest route. In particular, spectral risk measures (SRM) are used to consider both the average risk level and the worst risk level.

The authors demonstrate that relying on a simple risk measure can lead to catastrophic hazmat accidents and suggest carriers need to consider various spectrums of risk to choose a route. SRM provides a flexible risk modeling with capability to consider various spectrums within a single modeling framework.

The authors first propose a step spectrum function that is simple enough to be useful in practice as well as flexible enough to capture various spectrums. They also consider a general spectrum function, either continuous or discontinuous, which provides the most comprehensive hazmat routing tool and develop efficient computational methods.

Case studies in the paper confirm the validity and effectiveness of the proposed SRM and computational methods. SRM minimization for hazmat routing is applied and tested in four road networks: Ravenna, Italy; Albany, New York; Buffalo, New York; and Barcelona, Spain. With proper parameter settings, the authors find that SRM minimization can identify most appropriate routes for hazmat transportation.

Authors Liu Su (left) and Changhyun Kwon are seen in front of their research poster.

CONTACT: Changhyun Kwon; chkwon@usf.edu; (813) 974-5588; Industrial and Management Systems Engineering, University of South Florida, Tampa, FL 33620

Having a reliable evacuation plan is key in disasters

Disasters such as hurricanes Katrina (2005) and Harvey (2017) have caused loss of lives, billions of dollars in property damage, massive traffic congestion from the simultaneous evacuations of several million residents and significant shortages of fuel and other necessities.

Large-scale evacuations are rare and limited data regarding them are available. When an evacuation is called for, not all residents agree to evacuate, for various reasons. Hence, evacuation demand estimates are usually based on expert judgment, which can lead to difficulties

Ph.D. candidate Ayda Darvishan (left) and industrial engineering chair and professor Gino Lim of the University of Houston developed a paper addressing traffic evacuation during a disaster.

in forming a reliable estimate of the associated demand distribution, creating inconsistencies in the estimation.

In some contexts, limited historical data may suffice to roughly estimate the mean demand, which allows us to formulate and solve the so-called expected-value problem in which the uncertain parameters take their mean values. However, in the context of evacuation planning, when some unplanned event occurs, an expected-value plan may seriously impair the effectiveness of such an evacuation plan.

Gino Lim, a professor and chair of industrial engineering at University of Houston, Mukesh Rungta at Air Liquide and Ayda Darvishan, a Ph.D. candidate at University of Houston, have been working with engineers in the city of Houston and the Texas Transportation Institute to better understand traffic congestion triggered by mass evacuation in the greater Houston area.

In their paper, "A Robust Chance Constraint Programming Approach for Evacuation Planning Under Uncertain Demand Distribution," they developed a comprehensive network flow-based evacuation planning approach to address demand uncertainty, not only for the case that mean and variance of demand distribution are known, but also for the case that additional information such as the demand uncertainty with symmetry and/or support information are available.

Using this additional information, the authors prove that tighter bounds can be achieved on evacuation clearance time while providing optimal evacuation plans: route selection, time to evacuate and how many cars should each evacuation path accommodate at each time interval during the course of evacuation.

CONTACT: Gino Lim; ginolim@uh.edu; (713) 743-4194; Department of Industrial Engineering, E206, Engineering Bldg. 2, Houston, TX 77204

This month we highlight two articles from *IISE Transactions on Healthcare Systems Engineering* (Volume 9, No. 1). The first article weighs the benefits of having nations screen patients for Alzheimer's disease studies by using data analysis and Markov Decision Processes to model disease progression. The second article combines data analysis and root-cause analysis with discrete-event simulation to reduce patient wait times in cancer clinics.

Researchers study whether to screen or not for Alzheimer's

About 50 million people suffer from dementia worldwide, a figure that is expected to double by 2030. The cost of dementia is estimated at about $818 billion and is predicted to reach 1 trillion U.S. dollars in the next two years. Alzheimer's disease is the estimated diagnosis in 50 percent to 75 percent of all dementia cases. This has led to vigorous debates on screening for the disease.

Disease screening programs have the goal of catching a health condition early, sometimes even before any symptoms occur. Mammography for breast cancer and PSA tests for prostate cancer are well-known examples. Screening programs are established by policymakers after a team of experts study the problem extensively and develop guidelines that balance benefits and costs by taking disease facts into consideration.

Currently, no country has adopted a screening program for Alzheimer's. This is mainly due to lack of a cure. Medications are prescribed to control Alzheimer's symptoms and possibly slow down the disease's progression.

In "Optimal Population Screening Policies for Alzheimer's Disease," Zehra Önen, a postdoctoral fellow at Koç University, Serpil Sayın, a Koç professor at and Hakan Gürvit, a professor of neurology at the Istanbul University School of Medicine, collaborated to provide an operations research perspective on Alzheimer's screening. They model disease progression using a tool known as Markov Decision Processes, by representing different disease stages as model states and by incorporating a screening question. The screening test in the model is the Mini Mental State Examination (MMSE), a cognitive test widely used in clinical practice. The objective function combines quality-adjusted life years (QALYs) and costs.

Using data from Alzheimer's Disease Neuroimaging Initiative for disease progression and from existing literature for costs and QALYs, they find it best not to employ a population wide screening program for the time being. They then employ sensitivity analysis and identify levels of incremental cognitive ability stabilization or cognitive improvement required in treatment plans that would shift the balance in favor of screening. The authors suggest policymakers should assess effectiveness of emerging treatment alternatives periodically and consider initiating population screening programs when the time is right.

CONTACT: Serpil Sayın; ssayin@ku.edu.tr; +90 212 3381428; Koç University, College of Administrative Sciences and Economics, Rumelifener Yolu, Sarıyer 34450 Istanbul Turkey

Reducing wait times in cancer treatment centers

Wait times for cancer treatments can have consequences on the risk of recurrence of the cancer and on the quality of patients' lives. With a growing demand for chemotherapy, cancer care providers must use resources efficiently to ensure

Professor Serpil Sayın (left) and post-doctoral fellow Zehra Önen (right) at Koç University in Istanbul, Turkey, along with Hakan Gürvit (not pictured), a professor of neurology at the Istanbul University School of Medicine, collaborated on an operations research paper addressing screening for Alzheimer's disease.

Researchers Emma Liu, Claire (Xiang) Ma, Antoine Sauré and Leah Weber joined with (not pictured) Martin L. Puterman and Dr. Scott Tyldesley on an operations research simulation model to help ease long wait times in chemotherapy clinics.

A snapshot of the simulated chemotherapy clinic

The 3D animation model devised by an operations research team combined data analysis and root-cause analysis with discrete-event simulation modeling.

patients receive timely access to care in a cost-effective manner. Operations research methods can help them make informed decisions regarding care delivery process configuration, capacity planning and patient scheduling decisions.

In "Improving Access to Chemotherapy through Enhanced Capacity Planning and Patient Scheduling," members of the Operations Research for Improved Cancer Care Team at the British Columbia Cancer Agency (BCCA) – including Emma Liu, Claire (Xiang) Ma, professor Antoine Sauré, Leah Weber, professor Martin L. Puterman and Dr. Scott Tyldesley, conducted a process analysis and a simulation study at a regional chemotherapy clinic in BC. They investigated the impact of simultaneous changes in demand level, nurse and pharmacy staffing levels and appointment scheduling practice on clinic overtime and patient in-clinic wait times.

Combining data analysis and root-cause analysis with discrete-event simulation modeling, the proposed methodology provides a systemic and objective way to explore and evaluate alternative care delivery scenarios. It enables clinic managers to make informed and evidence-based planning and scheduling decisions before putting them into practice. Managers can determine capacity requirements, identify current bottlenecks and quantitatively evaluate options to overcome challenges. The research team also developed 3D animation of the simulation model to help users visualize and understand how different decisions impact the evaluation metrics under different scenarios.

Although focused on a specific chemotherapy clinic, the proposed methodology can be applied to other problems that involve delivering a medical treatment in multiple sessions and according to strict protocols. It can be used in a range of healthcare areas to evaluate the simultaneous impact of capacity and scheduling changes when intersecting systems are too complex to evaluate through analytical methods alone.

This research was partially supported by the Canadian Institutes of Health Research and by the Michael Smith Foundation for Health Research.

CONTACT: Antoine Sauré; asaure@uottawa.ca; (613) 562-5800 (8838); Telfer School of Management, 55 Laurier Avenue East, Ottawa, Ontario K1N 6N5, Canada

Jianjun (Jan) Shi is the Carolyn J. Stewart Chair and professor in the H. Milton Stewart School of Industrial and Systems Engineering at the Georgia Institute of Technology. He is editor-in-chief of IISE Transactions, *an academician of the International Academy for Quality and a fellow of IISE, ASME and INFORMS.*

Teresa Wu is an industrial engineering professor in Arizona State University's School of Computing, Informatics and Decision Systems Engineering. She is editor-in-chief of IISE Transactions on Healthcare Systems Engineering.

About the journals

IISE Transactions is IISE's flagship research journal and is published monthly. It aims to foster exchange among researchers and practitioners in the industrial engineering community by publishing papers that are grounded in science and mathematics and motivated by engineering applications.

IISE Transactions on Healthcare Systems Engineering is a quarterly, refereed journal that publishes papers about the application of industrial engineering tools and techniques to healthcare systems.

To subscribe, call (800) 494-0460.