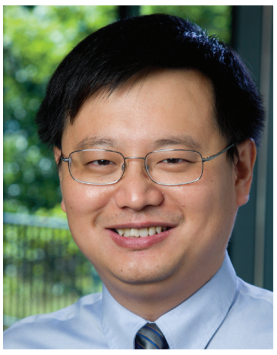
RESEARCH

Inside IISE Journals

This month we highlight two articles scheduled to appear in the August 2023 issue of *IISE Transactions* (Volume 55, No. 8). The first article recalls a decade-old incident at one of the Foxconn factories in southwestern China, the aftermath of which motivated Apple to build a sustainable supply chain. The authors ask whether other companies should follow suit. Using a bi-objective integer programming formulation, the authors provide a tool for generating a series of Pareto-optimal solutions, considering both sustainability and operations performance at different stages of a supply chain. The authors further advise that a firm should set up its global sourcing network with a limited number of carefully selected suppliers and continually nourish them in sustainability performance. The second article looks at a machine learning problem, the piecewise linear regression, a semi-parametric learning method that captures nonlinearity of an overall response surface even though a linear function is fit for each of the subregions. The authors specifically enhance existing piecewise linear regression methods with an inbuilt outlier detection for achieving better robustness in learning outcomes. Their solution approach is built upon a combinatorial Benders decomposition. The authors show their proposed approach is fast and efficient, and more effective at finding optimal solutions in the presence of outliers than existing software for any time budget.

Apple learned to build a sustainable supply chain; how about your company?



Gang Li

Yu Amy Xia

In 2012, after a seemingly minor incident in a Foxconn factory in southwestern China, Apple's stock value dropped $30 billion in one day. That factory, as a part of Apple's global supply chain, was reported as having demoralizing and dangerous working conditions. Apple's case was not alone; many multinational companies such as Nike, Adidas, Microsoft, Walmart, Ford, Toyota, and General Motors Corp. have experienced similar crises in recent years. Their experiences demonstrate a rising bar of sustainability-performance requirements in our time and sometimes conflicting objectives on sustainability and operational efficiency.

In their work, "A Supply Chain Sourcing Model at the Interface of Operations and Sustainability," professors Gang Li from Bentley University and Yu Amy Xia from the College of William and Mary propose a supply chain sourcing model that incorporates both sustainability and operational performance measures. They formulate the problem as a nonlinear bi-objective integer-programming model and develop an effective solution algorithm utilizing the problem's key features.

Numerical tests with large scale instances confirm the computational efficiency of their algorithm, and the simulation results on Apple's path to continually improve its supply chain sustainability match with the company's subsequent business practices.

Li's and Xia's study generate important insights for practitioners. Specifically, as sustainability becomes a progressively important goal in supply chain management, suppliers with high sustainability performance are increasingly preferable. Offshoring and reshoring decisions can both be justifiable based on specific cost structures of the potential suppliers in various regions and a company's sustainability investment budget.

Moreover, while increasing the number of suppliers may cause additional sustainability risk in supply chain management, decreasing the supply base will decrease the production capacity and increase the risk of delivery delay. Therefore, a firm should set up its global sourcing network with a limited number of carefully selected suppliers and continually nourish them in sustainability performance. This is particularly true when the focus of sourcing planning gradually moves away from cost-based decisions to those seeking excellence in both sustainability and operations.

For such a transition, Li's and Xia's model and algorithm provide a valuable tool for generating a series of Pareto-optimal solutions at different stages.

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When linear regression is insufficient, use (fast) piecewise linear regression

It is often the case that linear regression is insufficient to model the output of data due to nonlinearities in the relationship between the inputs and outputs. Hence, regression functions are sought that can capture the intricacies of more complex relationships.

Piecewise linear (PWL) regression is a machine learning approach commonly used to approximate nonlinear functions or to model data when standard linear regression models are insufficient. This allows the efficient solving of complicated nonlinear optimization problems with high degrees of complexity. Common approaches to finding PWL functions typically rely on highly involved models, with long runtimes due to the complexity of modeling continuity and a lack of robustness against outlier data points.

In their paper, "Generating Optimal Robust Continuous Piecewise Linear Regression with Outliers Through Combinatorial Benders Decomposition," postdoctoral researcher John Warwicker, Ph.D., and chair of the stochastic optimization group professor Steffen Rebennack, Ph.D., from Karlsruhe Institute of Technology present an efficient solution approach for PWL regression which takes advantage of the structure of the problem.

Firstly, the authors enhance existing models with inbuilt outlier detection, improving their robustness. Then, so-called combinatorial Benders decomposition is used as a solution tool. Precisely, the models are decomposed into two, where the first submodel fixes a temporary solution and the second performs an analysis and provides information to the first on how to improve it. This back-and-forth information sharing leads to much more efficient problem-solving, removing many poor solutions much quicker.

The model is then further enhanced with tailored solution approaches that take advantage of the structure of the problem. The authors show the enhancements provided by smart initialization, strong cut formulation and a tailored branching approach can lead to speedups over 12,000 times faster than standard solution software. In fact, the approach from the paper is more effective at finding optimal solutions in the presence of outliers than the software for any time budget, showcasing its superiority.

John Warwicker

Steffen Rebennack

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This month we highlight two articles from *The Engineering Economist* (Volume 68, Nos. 1 and 2). In the first, the authors develop a data-driven framework to quantify the economic risks of flooding along inland U.S. waterways used to transport freight. They used their model to evaluate the industries' production losses and the sectors most impacted along the upper Mississippi River. Their methodology can apply to other hazards and sections of the inland waterways and to other modes of transportation. In the second article, the authors sought to measure the accuracy of stock market index trends based on data from the first 10 minutes of trading. They used machine learning to analyze the frequency of data that produced the highest prediction accuracy and determined the 10-minute trading span produces accurate predictions close to that found in longer intervals.

Evaluating the risk of flood disruptions to inland waterway supply chains

The U.S. inland waterways are an extensive collection of navigable rivers, ports, locks and dams that are crucial to the domestic economy. However, extreme weather events, especially floods, perennially threaten to disrupt their operations.

When the waterways are closed due to high-water conditions, freight scheduled to ship through an inland port may be rerouted via different modes of transport (e.g., rail) or remain at a port until the waterways are safe to navigate. These routing decisions are case-specific regarding the costs, preferences and constraints of each company making them, but they have far-reaching consequences for other businesses and regions.

In the article, "An Integrated Approach to Evaluating Inland Waterway Disruptions Using Economic Interdependence, Agent-based and Bayesian Models," authors Paul Johnson, Hiba Baroud, Craig Philip and Mark Abkowitz from Vanderbilt University develop a data-driven framework for quantifying the economic risks of disruptions due to floods along the inland waterways. Their work intuitively combines river gage data, guidelines for safely navigating the waterways, routing simulations and input-output models.

The authors demonstrate their approach by evaluating impacts to industries affected by various flood scenarios along the

Paul Johnson

Hiba Baroud

Craig Philip

Mark Abkowitz

upper Mississippi River (UMR). Additionally, they feature a case study where a publicly operated, flood-resilient port located near the mouth of the UMR can help reroute shipments and mitigate production losses for the region.

The authors find that Illinois, Louisiana, Minnesota and Missouri are the states that suffer the most production losses from flood disruptions along the UMR and that agriculture and chemical manufacturing are the most impacted sectors. Furthermore, their results show that the flood-resilient port becomes cost-effective for mitigating losses during floods that have a return period exceeding 30 years (i.e., "30-year" floods).

The methodology developed in this article can be extended to other hazards and sections of the inland waterways and to other modes of transportation to help evaluate investments in climate-resilient infrastructure.

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Can first 10 minutes of trading after the morning bell accurately predict daily stock trends?

Could we predict the daily trend of the index based on stock exchange data from the first 10 minutes of the morning? Is China's stock market an efficient market?

Professor Pan Tang, Xin Tang and Wentao Yu from Southeast University studied these issues in their article, "Intraday Trend Prediction of Stock Indices with Machine Learning Approaches."

This article discusses three issues: 1. whether it is possible to predict the changes in the stock index on that day based on the 10-minute stock price change data in the morning; 2. determining the frequency data with the highest prediction accuracy; and 3. establishing trading strategies that can achieve excess returns based on the prediction results.

Their results indicate that support vector machines perform better than other support vector machines at the same time frequency. The prediction accuracy of the 10-minute frequency is close to that of longer intervals, indicating that the intraday trend can be determined by morning fluctuations.

In addition, trading relies on daily and weekly Shanghai Stock Exchange (SSE) 50 price changes predictions, achieving higher absolute returns compared to basic buy and hold trades. These results demonstrate the feasibility of technical analysis in the Chinese stock market.

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