Research

EXECUTIVE SUMMARIES : BY RONALD ASKIN AND THOMAS O. BOUCHER

This month we highlight two diverse articles that focus on using resources efficiently. The first article addresses achieving energy efficiency in large data centers. The second article details building nurse staffing schedules for hospitals that ensure quality care at affordable cost and nurse satisfaction. These articles will appear in the October issue of IIE Transactions (*Volume 45, No. 10*).

Engineers help nurses care for patients

Nurses play a key role in hospitals. In addition to being the closest person to patients, more than 50 percent of hospital expenditures are nurse staffing costs. One of the most critical problems in the healthcare industry is that many hospitals worldwide deal with high turnover rates and shortages of nursing personnel. High workloads and undesirable schedules are two major reasons nurses report job dissatisfaction. Nurses who work long hours to care for patients generally burn out and tend to leave their jobs.

A nurse manager is responsible for revising a nurse schedule, called nurse staffing, and assigning nurses to patients at the beginning of every shift. At present, nurse staffing and patient assignment often are done manually. A poor decision could lead to an undesirable schedule for a nurse and thereby impact the quality of patient care. Some nurses may feel personal bias from their manager.

To alleviate this problem, assistant professor Prattana Punnakitikashem, program chair of Healthcare and Wellness Management from the College of Management, Mahidol University (CMMU) in Thailand – together with Jay Rosenberger and Deborah Buckley-Behan – developed

Prattana Punnakitikashem's work "Stochastic Programming Approach for Integrated Nurse Staffing and Assignment" helps balance the workload for every nurse, leading to a better quality of patient care for an appropriate cost at hospitals.

Deborah Buckley-Behan (left) and Jay Rosenberger (far right) demonstrate the model that could be embedded in computer software to help nurse managers create better schedules for their nurses.

"an integrated nurse staffing and assignment model" that helps nurse managers make suitable decisions for nurse staffing and assigning patients with appropriate workloads. Rosenberger is an associate professor and the director of the Center on Stochastic Modeling, Optimization, and Statistics (COSMOS) at the University of Texas at Arlington (UTA), and Buckley-Behan is a clinical associate professor at the UTA College of Nursing.

The model carefully considers: the condition of patients – what condition diagnosis-related group patients have; the location of the patients' rooms – distance and flow of work; and time – the duration that nurses spent with each patient. The model used real historical data collected by radio-frequency identification (RFID) recorders indicating the time nurses spent with patients to balance nurse workload and ensure patient quality

The decision support model helps the managers staff their nurses by providing a list of many superior nurse schedules for a shift along with the cost of each schedule. This list allows nurse administration to consider trade-offs between the number of personnel and finance. Then, personal judgments can be made to provide the best care to patients.

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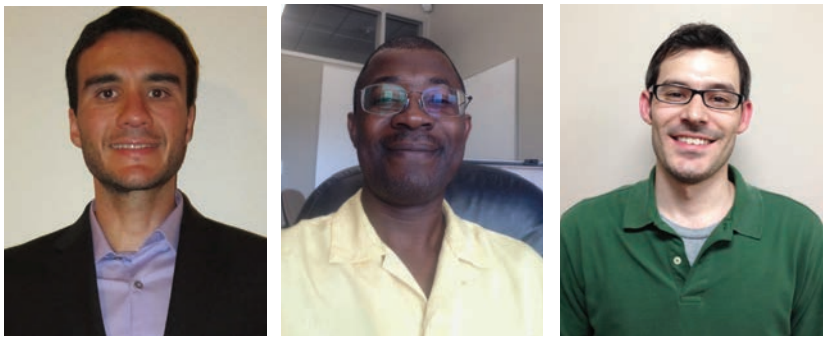
Saving energy in data centers

Data centers needed to support our growing reliance on electronic devices like smartphones and services like cloud computing already account for about 1.5 percent of the energy consumed in the United States.

Computer scientists and electrical engineers are working hard to make these



Julian A. Gallego Arrubla (from left), Lewis Ntaimo, Ronny J. Polansky and their colleagues devised an optimization model that can shave 40 percent off energy use in large data centers.

Carlo Alberto Magni ~~and his co-author~~ demonstrated an economic performance measure that is superior to the much-used internal rate of return.

huge data centers more energy efficient by developing new technologies such as virtualization, clock speed scaling and better cooling. But technology is only part of the solution, as saving energy also depends on how the centers are planned and operated. As we continue to build more servers and data centers with advanced technologies to keep our world in sync, it is important to understand that the average utilization of the servers in these data centers remains quite low. This raises many strategic and operational questions. For instance, is it a good idea to cluster servers? Should we combine positively or negatively correlated applications into one server? Is the same clock speed across servers optimal? Do we really need dynamic clock speed changes?

To answer these and other questions, Texas A&M University Ph.D. candidate Julian A. Gallego Arrubla, Pohang University of Science and Technology assistant professor Young Myoung Ko, Texas State University assistant professors Ronny J. Polansky and Eduardo Pérez, and Texas A&M associate professors Lewis Ntaimo and Natarajan Gautam authored "Integrating Virtualization, Speed Scaling and Powering On/Off Servers in Data Centers for Energy Efficiency." Their paper introduces a unified optimization model that combines the state-of-the-art technologies such as virtualization, dynamic voltage frequency scaling, and powering on/off of servers.

The unified model is a large-scale mixed-integer program. Since only small to medium-sized problems can be solved using commercial optimization software, the authors develop a heuristic algorithm and test it with an extensive set of numerical experiments. The result is that the unified framework can produce energy savings of up to 40 percent compared with the traditional approach, which separately applies the required technologies. This impressive energy saving is accomplished without any hardware changes.

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The most recent issue of The Engineering Economist *(Volume 58, Number 2) contains four articles, two of which are highlighted here. The first article shows the superiority of a new measure of a project's rate-of-return over the popular internal rate of return used by industrial practitioners. The second article introduces a computationally efficient way of generating a complete cumulative probability distribution of a project payback period using stochastic annual cash flows.*

Improving economic performance measures

Economic profitability is a matter of central importance in engineering economy and a rate of return is the most natural choice for assessing such things. In real life applications, the internal rate of return (IRR) is the rate of return metric of choice, by far, among industrial practitioners. Such popularity notwithstanding, IRR is quite imperfect.

Fortunately, there is a more-than-viable alternative to IRR, the average internal rate of return (AIRR), a metric first introduced in a 2010 theoretical paper published in *The Engineering Economist*.

Now, in "The Internal Rate of Return Approach and the AIRR Paradigm: A Refutation and a Corroboration," Carlo Alberto Magni of the University of Modena and Reggio Emilia elucidate the flaws of IRR and demonstrate the superiority of AIRR. In the first part of the paper, a compendium of 18 conceptual, mathematical and economic flaws of the IRR approach is presented. Chief among them are mathematical problems of inexistence and multiplicity as well as several ambiguities and inconsistencies of various kinds. Most notably, it is shown that the "internal" rate of return is associated with a particular notion of capital that is fictitious in the sense that capital is "internally" determined as a byproduct of the process of calculating the return measure itself and does not correspond to the capital actually invested in the project.



Byung-Cheol Kim (from left), Euysup Shim and Kenneth F. Reinschmidt have devised an alternative to Monte Carlo simulations when trying to compute cash flow probabilities.

In the second part of the paper, the AIRR approach is developed, utilizing the simple notion that the rate of return of a project should be an amount of return per unit of capital invested. In addition to AIRR being simpler, e.g., not requiring a polynomial equation, the AIRR is devoid of each of the 18 flaws that plague the IRR. Further, an elegant, yet simple, computational shortcut for AIRR exists and is provided. This research reveals that the AIRR approach is more friendly to users and a better alternative than the flawed IRR metric. It provides industrial practitioners with an improved method for measuring the economic performance of capital investments.

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Dealing with uncertainty

One challenge in making capital investment decisions is to account for the inherent uncertainty in cash flow estimates over the future analysis period; another is to compare cash flows for different projects. When uncertainty exists, the best approach is to make the uncertainty explicit and quantitative so that decisions can be made with a higher degree of transparency. Although it has theoretical limitations, project payback period (or breakeven time) frequently is used in practice to compare alternate cash flow scenarios.

In "Probability Distribution of the Project Payback Period using the Equivalent Cash Flow Decomposition," Byung-Cheol Kim of Ohio University, Euysup Shim of Illinois State University, and Kenneth F. Reinschmidt of Texas A&M University introduce a computationally efficient way of generating a complete cumulative probability distribution of the payback period using stochastic annual cash flows. The research was motivated by the observation that when a complete probability distribution of the payback period is desired, the only viable solution is Monte Carlo simulation.

The authors present a numerical technique named "the equivalent cash flow decomposition (ECFD)" to bridge the gap between a technique using the net present value distribution for probabilistic payback analysis and the need for a complete probability distribution of the payback period in order to make properly informed decisions. The ECFD consists of a set of formulas that convert the means and covariances of a stochastic annual cash flow to an economically and statistically equivalent subannual cash flow at any desired level (i.e., quarterly, monthly, or weekly). In the article, it has been shown that the proposed method is robust with accuracy comparable to Monte Carlo simulation.

Computationally efficient solutions to replace simulation are needed, especially for practitioners and students. The authors show that the proposed technique can be programmed easily as an add-in for Microsoft Excel or even in handheld engineering calculators. A smartphone app would be another option for practical application.

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About the journals

IIE Transactions is IIE'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.

The Engineering Economist is a quarterly refereed journal devoted to issues of capital investment. Topics include economic decision analysis, capital investment analysis, research and development decisions, cost estimating and accounting, and public policy analysis.

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