RESEARCH
Inside IISE Journals

This month we highlight two articles from a special issue of *IISE Transactions*. The seven invited papers focus on the high-level visions and perspectives, supported by historical review and exciting examples. This issue aims at accomplishing two objectives: to showcase how ISE/operations research contributes to addressing applications of national importance and shaping the national research landscape; and to lay out a vision for research opportunities for next-generation researchers in the decades to come. The papers cover a broad range of topics of interest to the industrial and systems engineering field and will be made open access for 2023. The first article discusses the issue of supply chain resilience. The second article talks about the futuristic autonomous manufacturing driven by artificial intelligence. The authors of both share their visions for how ISE/OR researchers contribute to the timely research needs that address the supply chain crisis or make autonomous manufacturing a reality. These articles will appear in the January 2023 issue (Volume 55, No. 1).

Rethinking supply chain management in the wake of major disasters

The number and magnitude of natural disasters and health emergencies, and their societal and economic impact, have been growing. Recent examples include hurricanes Harvey, Irma, Maria, Fiona and Ian, and the COVID-19 pandemic, all of which have severely disrupted supply chains. Shortages of basic food products (e.g., infant formula), tech components (e.g., semiconductor chips), medical supplies (e.g., saline and personal protective equipment), and many other vital products have highlighted the dangers of supply chain failures on disrupting daily lives, economies and population health and safety.

In response, supply chain researchers and practitioners have shifted attention from a just-in-time focus on efficiency to a just-in-case focus on resilience. The focus on resilience ignited rethinking procurement and shipping practices in industry, new programs and regulations in government and a flurry of research in academia.

Ozlem Ergun

Several recent studies by the National Academies of Science, Engineering and Medicine (NASEM) focused on improving supply chain resiliency to ensure timely and continuous access to lifeline services, medical supplies or seasonal and pandemic vaccines during extreme events such as hurricanes or pandemics.

The authors of the *IISE Transactions* paper, "A Structured Overview of Insights and Opportunities for Enhancing Supply Chain Resilience," Ozlem Ergun, Wally Hopp and Pinar Keskinocak, participated in some of these NASEM studies, which utilized a basic model of supply chain mechanics and created a framework for classifying potential causes of supply chain disruptions and various approaches for improving resiliency. The studies highlighted a set of insights from the literature organized around this framework and proposed policies for improving supply chain resiliency to enable continuity of access to products and services during and after emergencies.

Wally Hopp

Pinar Keskinocak

Some of the main takeaways from the NASEM studies, as well as from the growing body of literature on supply chain resilience, are that the resilience of essential product supply chains can be improved via a combination of awareness, mitigation, preparedness and response measures, and that further research is needed to address gaps in our understanding of the vulnerabilities of supply chains and to leverage the vast sources of (not always public) data potentially available to design, manage and secure our key supply chains.

In this paper, the authors describe the basic framework for enhancing supply chain resilience and use it to summarize practical insights and research opportunities for creating supply chains that will better serve us in the inevitable next round of disruptive events.

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Tired of the buzz on autonomous cars? Here is some hype and hope on autonomous factories, manufacturing systems

Autonomous systems such as driverless cars, smart homes and humanoid robots have caught the attention of the modern society. In the past five years, there has been a growing effort to bring autonomy to industrial and manufacturing operations.

The nascent thrusts in this realm are focused on planning and execution of a sequence of iterative experiments to cleverly search and discover a material that is best tailored for a given application. These efforts have been mostly undertaken by materials science researchers. Discovering the process plans or the recipes to make these materials and products – which is at the heart of an autonomous manufacturing system and is more pertinent to the industrial and systems engineering and operations research community – has not received much attention.

The *IISE Transactions* paper "Autonomous Materials Discovery and Manufacturing (AMDM): A Review and Perspectives," presents an overview of the growing volume of work toward addressing the major challenges that arise in autonomous manufacturing systems. It also discusses the emerging challenges in both the brain and the body aspects, such as in fusing different kinds of models, searching and discovering the suitable manufacturing recipes, and enabling effective machines and testing setups. These challenges are quite interdisciplinary, as they lie at the nexus of manufacturing, artificial intelligence, data and decision sciences.

Addressing these challenges can potentially revolutionize the way things are manufactured. For example, it would help precisely control not just the geometric quality but tailor the material from which a part is made, including its chemical composition. It opens possibilities for the new generation of products and their manufacturing process plans that can significantly surpass the performance, environmental sustainability and socio-economic envelopes. These could profoundly impact the emerging global competitive landscape, such as ensuring the structures of the hypersonic planes can function under high temperatures, find more economical substitutes for highly scarce critical materials such as lithium employed for batteries, and minimize material and carbon footprint in a manufacturing process.

Satish T.S. Bukkapatnam

Let us seize this exciting opportunity. Also, stand by for a call on a special issue of *IISE Transactions* that would focus on this and various other aspects of the future of manufacturing.

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This month, we highlight two articles from Volume 10, No. 3, of *IISE Transactions on Occupational Ergonomics and Human Factors*. In the first, Gabriel Diamond-Oullette and colleagues provide results that suggest the need for a sufficient period of familiarization to obtain the potential benefits of a passive load-bearing exoskeleton. Hamed Asadi, et al., in the second paper, used wearable sensors to identify several important physical risk factors for injuries among veterinary surgeons and surgical assistants.

How learning to use exoskeletons leads to better results in easing military personnel's heavy loads

Military personnel often need to carry heavy loads. Existing evidence has shown that load carriage can affect gait efficiencies, which in turn may increase energy expenditure during walking and the risk of injury. Passive biomimetic exoskeletons represent an emerging technology that could reduce energy expenditure, fatigue and injury risk by redirecting the load away from the soldier.

However, as with all assistive devices, familiarization periods are necessary to facilitate adaptive behavioral and muscle use strategies. Otherwise, suboptimal strategies could be adopted that could limit the intended benefits of the device.

Researchers and a Ph.D. student at the Université Laval in Quebec, Canada – Gabriel Diamond-Ouellette, Krista Best, Laurent Bouyer and Jean Leblond – in partnership with Thomas Karakolis of the Defence Research and Development Canada, and Allesandro Telonio of Mawashi Science and Technology, evaluated the influence of the Mawashi exoskeleton on energy expenditure.

As reported in their paper, "Exploring the Change in Metabolic Cost of Walking Before and After Familiarization With a Passive Load-Bearing Exoskeleton: A Case Series," three male soldiers walked on a treadmill with a 38-kilogram payload at eight speeds until steady-state was attained. Measurements were taken during three conditions: 1) no exoskeleton; 2) with exoskeleton before familiarization; and 3) with exoskeleton after familiarization. The familiarization period consisted of nine,

Krista Best

Laurent Bouyer

Gabriel Diamond-Ouellette

three-hour sessions completing functional and military related tasks. Soldiers were retested during a follow-up session three months later, both with and without the passive exoskeleton.

Compared to the control condition (no exoskeleton), there was a significant increase in energy expenditure while walking with the exoskeleton before familiarization. After familiarization, energy expenditure during walking with the exoskeleton returned to the same level as the control condition. After a three-month retention period, energy expenditure while wearing the exoskeleton was less than the control condition.

These preliminary results suggest that adequate familiarization is likely needed to optimize the use of an exoskeleton by reducing energy expenditure during walking. The authors recommend including sufficient familiarization to evaluate the physiological effects of exoskeleton technology, and they note that future studies are required to determine how to optimize familiarization periods.

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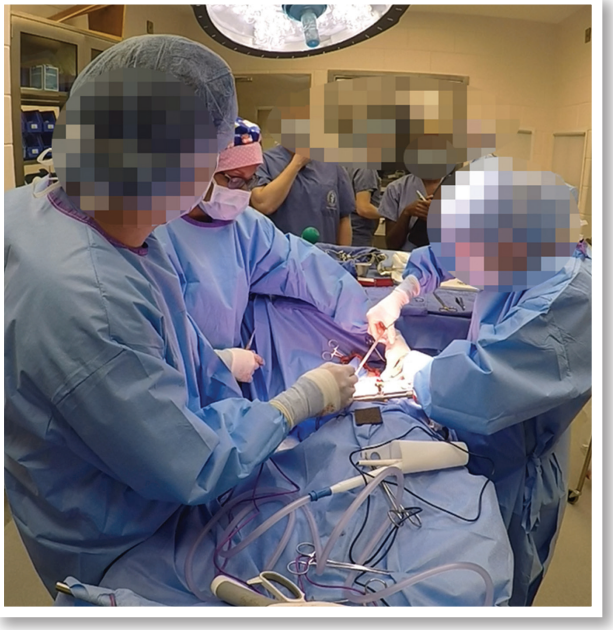
Addressing ergonomic risks faced by veterinary surgeons

Veterinary surgeons provide essential and life-saving health services for animals, yet veterinary professionals experience one of the highest incidence rates for nonfatal occupational injuries and illnesses. With the recent increase in pet ownership during the COVID-19 pandemic, these occupational health concerns will likely increase. Studies conducted in human medical-surgical disciplines have identified several workplace contributors to occupational and safety hazards, yet the physical risk factors for veterinary surgeons and surgical teams have not been characterized.

A multidisciplinary team of veterinary and human factors engineering experts from Purdue University, including Hamed Asadi, Micha Simons, Gert Breur and Denny Yu, identified potential ergonomic risk factors using continuous, objective motion and muscle activity sensors among veterinary surgeons and surgical assistants during 26 live veterinary surgeries.

Their findings reported in their paper, "Characterizing Exposure to Physical Risk Factors During Veterinary Surgery with Wearable Sensors: A Pilot Study," include both self-report



Veterinary surgeons can undergo ergonomic risks, including neck strains and other musculoskeletal injuries.

Hamed Asadi

Gert Breur

Micha Simons

Denny Yu

and sensor-based metrics of workplace physical risk factors. Neck and back stiffness were frequently self-reported. Regardless of surgical role or surgical specialty, participants reported that their neck stiffness increased in over 25% of the observed procedures. The sensor-based metrics identified potential physical factors to explain reported musculoskeletal symptoms.

For example, neck postures were often observed in flexion and remained static for most of a procedure. They also found that physical risk factors varied by job roles and specialty. Surgeons performing orthopedic procedures generally had higher levels of muscle activation than soft tissue surgeons.

This work is first to provide in-the-field measurements of posture and muscle activity for veterinary surgical teams. Their work highlights the value of a sensor-based approach for measuring workplace physical risk factors in the veterinary operating room, and these results help bring awareness to occupational risks often overlooked in veterinary medicine.

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About the journals

IISE Transactions (*link.iise.org/iisetransactions*) 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 Occupational Ergonomics and Human Factors (*link.iise.org/iisetransactions_ergonomics*) is devoted to compiling and disseminating knowledge on occupational ergonomics and human factors theory, technology, application and practice across diverse areas. You can follow on Twitter at *twitter.com/iisetoehf* or @iisetoehf.

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