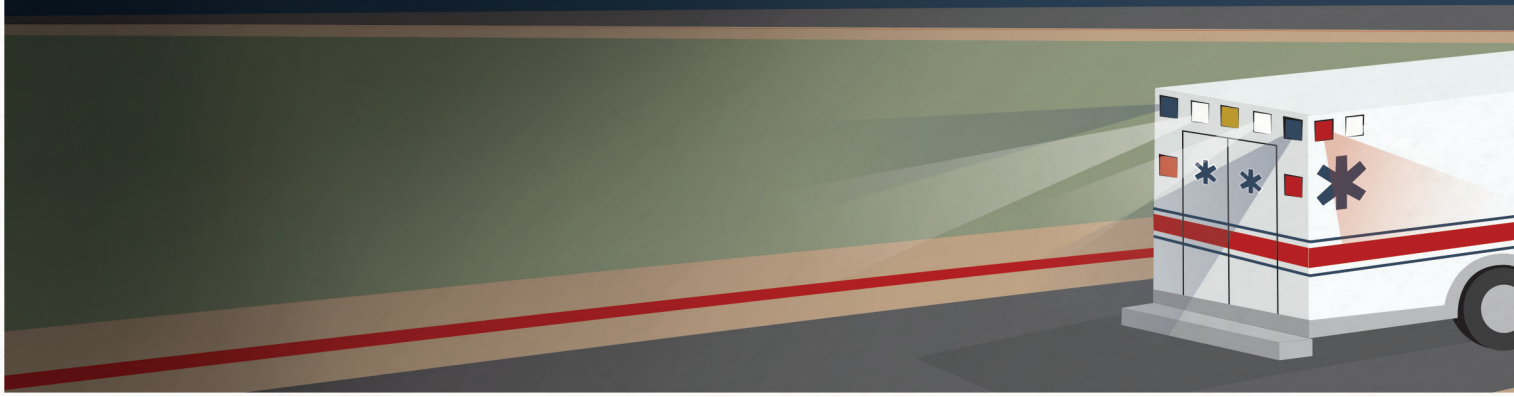
# A model to healthcare

**Dr Eva Lee** is involved in numerous projects in the areas of clinical and translational science, healthcare delivery, emergency response and defence. To establish connections between these divergent fields, she talks of the current policy landscape and the mathematics and computational tools that have helped support reform



**In an interview with International Innovation in 2012, you discussed optimising decision support tools for emergency response. Has the project progressed since that time?**

Yes, we have incorporated biological information related to pandemic characteristics, such as the virus type, infectivity rate and transmission potential, to help prioritise the vaccine portion. For example, if you don't have enough vaccines for a pandemic, how do you strategically dispense available resources to the affected population? The goal is to minimise infections and total mortality by targeting high-risk people (women, children, elderly and the sick) strategically to achieve the best result. We were the first group to create a system that enables this, whereby we can determine the best timing to switch from high-risk vaccination to general dispensing.

**You are now looking at how to improve emergency departments (EDs) across the country. Why is there a need to streamline processes?**

The American College of Emergency Physicians recently ranked the performance of the EDs across the US and showed that the state of policy and deliverance of care was inefficient. The entire nation was given a D+. Hence, it is extremely timely that we continue to push for change and work with more EDs to improve performance and showcase what can be achieved through our approach.

Improving quality, from patient care through to services, is very important. We see the science directly influencing day-to-day life, and that is the ultimate goal of most researchers. My first project in medicine involved cancer patients, and I saw the need to take this patient-centred approach.

There are many researchers working hard to improve quality of care, but there is always more that needs to be done. It is always challenging, at least in the US, because the costs are so high.

**You apply your research to real-world situations and have assisted in the aftermath of emergencies outside the US. Do you train others to implement your tools in other countries?**

Yes, we work with investigators and practitioners in other countries, disseminate our tools and train users, if necessary. Most importantly, it is a hands-on process; everyone works together and we all learn how to apply the technology under different scenarios.

Our tools also include self-learning guides. We try to develop tools with interfaces conducive to practitioners whose expertise lies outside our own. For example, emergency planners and directors are experts in dealing with public service and operations, but may not be familiar with the mathematics or software. As it can be difficult for them to use, we incorporate cognitive analytics within our solutions so the user interface is visualised and easy to understand and follow. We also rely on transitive training; that is, we train a small group of users and have these individuals train another group, and so forth. By doing so, it helps to rapidly spread the technology and its usage. Our systems have been used by the Red Cross, Qatar Red Crescent Society, Israeli Health Ministry, as well as the Japanese emergency response teams, following Fukushima, and the Haiti response operations teams.

**The Obamacare bill, also known as the Patient Protection and Affordable Care Act (PPACA), was enacted by the House of Representatives on 21 March 2010. What is your opinion on its effectiveness?**

The bill consists of over 1,000 pages, so it is understandable that politicians and citizens alike may focus on some paragraphs and formulate their opinion based on limited information, rather than read the entire bill, which consists of many intricate components. There are major challenges over the system's design; it is extraordinarily hard to establish


these programmes because you have to pull together all the information on state-wide healthcare and all the records of individuals to make the system work.

The federal level is a lot harder. It is setting up a network that has to be useful to more than 30 states that do not offer their own health insurance exchange. The roll out was to be expected, but the initial system testing should have been done earlier and more thoroughly. I was surprised by the response to its effectiveness. The federal site has turned out to be very critical, with some states now turning to the federal site for sign-up. It will take at least five years to become a well-oiled machine; just like any new system, there are flaws that need to be ironed out.

**How important is collaboration to your research endeavours? With whom do you collaborate?**

Collaboration is key to my research. I love mathematics; I love the theory and its application. It is beautiful to prove a theorem, but it is even more rewarding when I can apply it to a real problem and make it work. I enjoy finding practical solutions, and I want to be able to advance the scientific field by developing mathematical and computational techniques and implementing impactful tools. They make a difference to humankind and the world.

I value collaboration because I need domain-expert collaborators to educate me about the challenges they face; I need them to test and implement my tools and disseminate findings to solve the real problems that impact people's lives, the environment and affect the world. I work with different types of investigators, basic and translational scientists, executives, chief information officers, financial and operations managers, policy makers and volunteers; I look for interesting and challenging problems among them that I can help address. I am not confining myself to healthcare research alone; rather, I choose projects I consider important and capable of making a difference to the society.

**How do you manage your time in order to carry out these studies while balancing other appointments?**

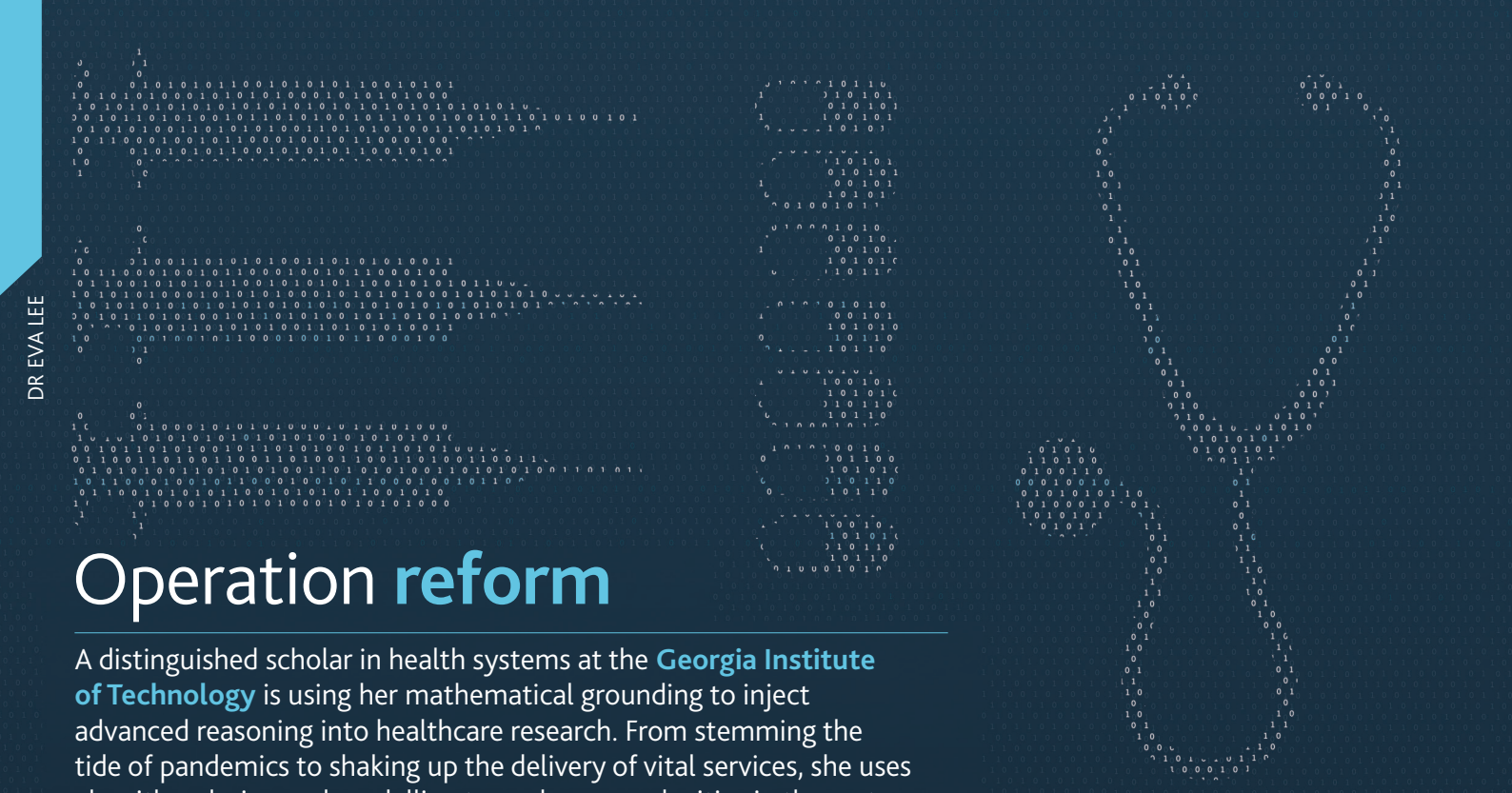
It is not easy to quantify! I enjoy scientific investigation immensely, and I strive to bring the theoretical and technological advances into practice. I spend a lot of time with practitioners to ensure our advances are being implemented and tested, so they work and benefit patients and providers. I also spend time educating the younger generation. It is important to instil in them the love of scientific discovery.

I work on many projects, many on a voluntary basis, because I care a great deal about people, especially the poor. I don't worry about time because I have lots of energy. But to know that I can make a difference to people's lives, even if I don't know them, makes me very happy. In the US, we are very fortunate but often take things for granted; we have running water, food, municipal sewage systems – essentials in life that we should all expect the right to have. Many people in other parts of the world don't have them, but they still live happily. I am acutely aware of it, and it motivates me to work hard to contribute to projects that touch people's lives in positive ways.

In the US, a percentage of the poor live in dangerous neighbourhoods. They are lucky to survive and not be killed by gunfire, so having access to a good education doesn't come 'free' to them. Good education is hard to come by. That's why I mentor public school children, where the majority live under poverty line. I want them to know if they work hard and excel in their studies they will have a bright future.

**Ultimately, what impact do you hope your ongoing research will have on patients and healthcare?**

I would like to see patients receiving timely and high-quality care that is delivered safely, efficiently and cost-effectively. Quality assurance, no matter where patients receive the care, should be guaranteed. This is true for the US and for other countries. Healthcare is global. An infectious outbreak from one country can travel rapidly to another; therefore, emergency response is also global. Hence, our technology has to be generalisable and applicable to many scenarios.



# Operation **reform**

A distinguished scholar in health systems at the **Georgia Institute of Technology** is using her mathematical grounding to inject advanced reasoning into healthcare research. From stemming the tide of pandemics to shaking up the delivery of vital services, she uses algorithm design and modelling to explore complexities in the system

SCIENTIFIC MODELS SEEK to systematically describe a phenomenon or object by creating conceptual, operational, graphical or mathematical tools using real-world variables as inputs. The latter tool is particularly useful as it affixes value to different components of a system and tries to predict behaviour, saving time and resources, and often in the case of healthcare, lives.

In the US, healthcare expenditures are on target to reach $4 trillion in 2015, or 20 per cent of total GDP, posing a significant burden to public spending, private financing and global competitiveness. Radical restructuring has been suggested, but the answer is a lot simpler in practice. Aligning rapid and accurate diagnostics with diseases that cost the most – both financially and in term of lives lost – will not only help to balance the wants of patients and taxpayers, but also ensure that every dollar is allocated wisely. This objective is the main mission of the Patient Protection and Affordable Care Act (PPACA), or Obamacare.

Dr Eva Lee is Director of the Center for Operations Research in Medicine and Healthcare (CORMH) at the Georgia Institute of Technology (Georgia Tech), and co-Director of the National Science Foundation (NSF) Industry and University Cooperative Research Centers (I/UCRC) Center for Health Organization Transformation (CHOT). She has enjoyed an exciting and varied academic career, heading to the US after her undergraduate degree in Hong Kong to study applied mathematics, and later Berlin to undertake postdoctoral research on scientific computing and parallel computation. Real-world solutions have always been at the forefront of her mind, and as such Lee has used her skills to generate models for every level of the healthcare system and worked closely at the policy level to help transform the culture and organisation of public health services and practice.

> As Lee is steadfast in improving the experience of the extremely poor and underserved she rightfully deserves recognition

## FROM BENCH TO BEDSIDE

Starting at the clinical and translational research level, Lee was the first Operations Research and Industrial Engineering (OR/IE) recipient of the Whitaker Foundation Biomedical Grant for Young Investigators for her novel approach to combining biological imaging and optimal treatment design for prostate cancer in 2004. She and her team now work on machine learning and analytics to predict and detect health risks and diseases, taking into account omics data along with individual health information, behaviour, family history, environment and other factors. Vaccine immunogenicity is being explored to improve medical countermeasures and drug design, enable target delivery, and reduce adverse reaction; and in terms of treatment, models developed by her team are helping to improve the efficacy of brachytherapy's potential (see Lab research). "We strive to advance personalised treatment to improve outcome," explains Lee. "We are working to uncover treatment evidence and enable this knowledge to be incorporated into routine providers' decision process, thus empowering them with informed decision capabilities."

Scaling up the impact of her work, Lee also looks at the bigger picture. She wants to understand the whole healthcare system, break it down into its constituent parts and rebuild for a smoother operation. Specifically, her team at the CHOT engages with service providers and healthcare managers to improve delivery of care for greater efficiency and effectiveness. More broadly, as a I/UCRC, CHOT pushes for disruptive innovation and progressive breakthroughs with healthcare organisations, educational institutions and businesses to resolve challenges in the access, delivery, cost and quality of healthcare at the policy level.

## ER: A MEDICAL DRAMA

Emergency departments (EDs) are a prime example of where the work of CHOT is being felt. The Grady Health System, in the state of Georgia, is one of the largest public health systems in the US, but in 2008, it faced imminent closure. Cutbacks made as a result of the financial crisis threatened every local- or state-owned public safety-net hospital as they are based on a not-for-profit model, serving low-income, uninsured and vulnerable populations. "At Grady, the high volume of ED patients seen combined with the low return on payment charges resulted in a shortage of over $100 million," emphasises Lee.

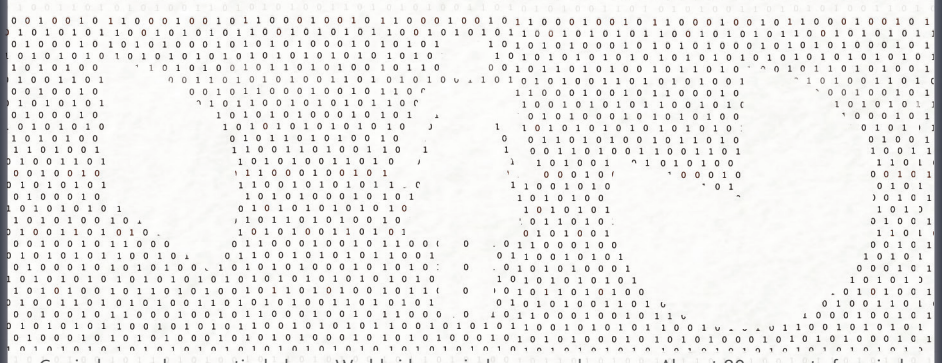
It was an unplanned meeting with the hospital Senior Vice President Calvin Thomas IV (currently Vice President for Health Division at Ivy Tech Community College in Indiana), which set the wheels in motion for her team to apply their technical skills to assist in placing the hospital on a more sound financial footing by streamlining processes through decision

## Lab research

Lee divides her time equally among a wide array of transformative projects, of which translational research remains a key component. Using her mathematical background, in her latest endeavour she devises optimal treatment and drug delivery for improved outcomes

Radiation therapy can be delivered as external beam, or through internal therapy known as brachytherapy. The procedure uses a radioactive substance sealed in needles, seeds, wires or catheters that are placed directly (permanently or temporarily) into or near the cancer, thus allowing full tumouricidal effect to eradicate the growth from within the cancer site while ensuring minimal radiation to surrounding healthy tissues. For high-dose rate (HDR) brachytherapy, patients receive treatment through catheters from five days to two weeks. Brachytherapy is organ-preserving, usually with no loss of functionality, and is thus fast-becoming the choice of treatment among prostate, breast, cervix and uterus cancer patients.

HDR brachytherapy holds great promise to expediting tumour eradication, but first the best seed type, spatial configuration and dwelling time need to be determined for successful treatment. "Our team developed an advanced planning model to simultaneously address both of these issues," explains Lee. "To take advantage of the best available information, our model works with inputs from positron emission tomography (PET) to capture the biological activities of the cancer cells for target escalated dose delivery." Multiple objectives were assessed by the model so that optimisation algorithms could be produced to resolve challenges. "The result has been accurate solutions, which are obtained rapidly," Lee adds. Using the facilities afforded by Rush University Medical Center, USA, clinical trials later demonstrated superior medical outcomes that improved tumour control probability from 60 to 90 per cent.



Cervical cancer has a particularly high mortality rate (approximately 35 per cent) in the US and is difficult to treat successfully

Worldwide, cervical cancer ranks as the second most common cancer in women, with about 500,000 new cases and 250,000 deaths annually

Almost 80 per cent of cervical cancer cases are in less-developed countries

optimisation theory analysis. The Grady Health System signed up to CORMH and CHOT's health transformation leadership programme, and Lee and the Grady team swiftly began developing system models and machine learning tools to reduce wait time, improve workflow and overall effectiveness of care delivery based on patient risk factors, demand characteristics, treatment evidence, hospital resources and providers' knowledge. The model was so successful that the team won second place in the 2013 Daniel H Wagner Prize for Excellence in Operations Research Practice and was selected as a finalist for the 2014 Franz Edelman Prize. The Edelman Prize recognises outstanding examples of analytics and operations research that transform companies, industry or people's lives, and as Lee is steadfast in improving the experience of the extremely poor and underserved, she rightfully deserves recognition.

### OBAMA CARES

President Barack Obama's healthcare bill is designed to promote significant advances in healthcare delivery by addressing quality and affordability and reforming health insurance, as well as developing new patient care models; all of which are deeply engrained in Lee's ethos. "About 50 million Americans did not have health insurance before Obamacare so many are choosing to enrol, which is good for the health of our nation," notes Lee. "But some of these individuals may not fully understand health insurance and how it works." This results in unnecessary visits to the ED (in some places equating to almost 40 per cent of patients) at times when patients have a non-urgent problem. Lee is keen to add: "If the public thinks they can use ED resources for trivial health problems then they will collapse the system".

The solution lies in education. Digesting the lengthy healthcare bill is no easy feat, and some of the US population do not understand the complexity involved. By informing the public of the services available, and the need to use primary care providers for non-urgent care, they can make informed decisions about where to go. With greater access (to care) comes greater responsibility (to educate).

## ADVANCED MODELLING IN PERSONALISED MEDICINE AND HEALTHCARE DELIVERY

### OBJECTIVES

To advance clinical translational research; health systems transformation; systems modelling, big data computation, decision and predictive analytics.

### KEY COLLABORATORS

**Hany Y Atallah, MD**, Fellow of the American College of Emergency Physicians, Chief of Emergency Medicine Grady Health System • **James C H Chu, PhD**, FAAPM, FACR, Professor and Chair of Department of Medical Physics, Rush University Medical Center • **Allan Levey, MD, PhD**, Professor and Chair of Department of Neurology, Director of Emory Alzheimer's Disease Research Center • **William Mahle, MD**, Professor of Pediatrics, Medical Director of Heart Transplant and Clinical Research, Sibley Heart Center, Children's Hospital of Atlanta • **Ferdinand H Pietz, MPH**, Senior staff in Planning, Policy, and Analysis, Strategic National Stockpile, Centers for Disease Control and Prevention • **Bali Pulendran, PhD**, Professor of Pathology and Laboratory Medicine, Director of Innate Immunity Program, Emory Vaccine Center

### FUNDING

National Science Foundation

National Institutes of Health

Centers for Disease Control and Prevention

### CONTACT

**Professor Eva Lee**
Principal Investigator

School of Industrial and Systems Engineering
Georgia Institute of Technology
755 Ferst Drive North West
Atlanta, Georgia 30332-0205
USA

**T** +1 404 894 4962
**E** eva.lee@gatech.edu

**EVA LEE** is Professor at the School of Industrial and Systems Engineering at the Georgia Institute of Technology and Director for the Center for Operations Research in Medicine and Healthcare. Her research focuses on mathematical programming and algorithmic design for risk assessment, decision making, predictive analytics and systems optimisation. She has made major contributions in advances to medical procedures, emergency response and medical preparedness, healthcare operations and business operations transformation.

**Reflecting on this years' nominations, Lee's colleagues explain why work to improve health services is so important:**

"We are deeply honoured to have been finalists for such prestigious awards. The hard work that has resulted from the collaboration with Dr Lee at Georgia Tech and our programmes at Grady has benefited patients and directly saved lives. We are testament to the fact that even in the current economic and healthcare climate, improvements can be made that benefit patients, the institution and lead to improved patient outcomes. The true winners are our patients"

**Dr Hany Y Atallah** and **CEO John Haupert**, Grady Health System

"These awards are indicative of the efforts of Dr Lee and her students in the multi-university Industry and University Cooperative Research Center (I/UCRC) Center for Health Organization Transformation (CHOT). As lead of the Georgia Tech Site of CHOT, her lab continues to make important contributions that are of value to CHOT industry members and the public at large"

**Larry Hornak, PhD**, Program Director, Fundamental Research Program for I/UCRCs, Division of Industrial Innovation and Partnerships in the Directorate of Engineering, National Science Foundation

Three years have elapsed, but it is still too soon to quantify the overall impact of Obamacare. "However, I do hear from some individuals who have had no prior health insurance and they are very eager to sign up to an insurance plan," reflects Lee. "For safety-net hospitals, providers welcome insured individuals as this could reduce overall treatment expense." Lee wants to continue to monitor progress and fine-tune tools to ensure they are user-friendly and effective. Such an ambitious programme will require some time before functionality can be perfected, but reasonable coverage and regular visits to primary care facilities to prevent emergencies could one day become the norm. Greater access is seen as a positive step if used wisely, although this is just one piece of the puzzle: "As for the health of our nation and globally, personal lifestyle including healthy diet remains critical. Being able to access healthy food at affordable price is critical," warns Lee.

### INTERNATIONAL AFFAIRS

Outside of her country of residence, Lee uses her skills to look at wider issues of access to healthcare, crucially in the event of pandemics, which require immediate access and careful resource allocation.

Working alongside Center for Disease Control and Prevention (CDC) public health experts, Lee designed a system that has been exposed to numerous datasets that must be considered in times of crisis – socioeconomic, demographic, healthcare and infectious disease information. Infectious pathogen outbreaks can then be tracked and abated. Health officials in the affected country are trained in its use so they can input geographic information and known resources, such as vaccine availability, along with information gleaned from social media so physicians can build the clinical layout that represents their healthcare setting. Knowledge might be far from complete, so the system accounts for uncertainties and then optimises the processes. The result? An easy-to-use tool called RealOpt that mitigates the spread of disease by optimising decision making during a crisis. Dr Bernard Benecke, Deputy Director for Global Disease Detection and Emergency Response at CDC is keen to comment on the tools success: "RealOpt, is flexible, adaptable, easy-to-use and produces meaningful results to the user, allowing them to optimise staffing and deal with shifting demands during a crisis event. No other modelling software that I am aware of is able to do this".

This outreach work is completely pro bono as Lee is more concerned about the health of people than the health of her bank balance. "Even without emergencies, there is still a need for broad training and dissemination. For example, I offered our RealOpt system to Tanzania health ministry for free to optimise resource allocation across their healthcare network," Lee admits.

### A CLOSED LOOP

The final component of Lee's holistic approach to healthcare optimisation and transformation is dissemination. She is a proponent for sharing knowledge and building capacity, and takes every opportunity she can to discuss her findings at conferences, like the American Association for the Advancement of Science (AAAS) Annual Meeting, which was held in February.

Mathematics is often seen as an impenetrable field, with complex formulae and data lacking real-world application. Lee proves this is not the case. Her vision for a better world, achieved through systematic change, is creating widely applicable tools that get to the true cause of a problem, improve medical care, advance care delivery, optimise scarce resources usage, strategise rapid response, prevent undue strain on the emergency room and limit loss of life for all.